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Forecasting Infant Mortality Rate in Senegal Using the Multilayer Perceptron Neural Network

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***Abstract* - In this research paper, the ANN approach was applied to analyze infant mortality rate in Senegal. The employed annual data covers the period 1960-2020 and the out-of-sample period ranges over the period 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 Senegal. The ANN (12, 12, 1) model predicted that IMR will be around 33/1000 live births per year in the next 10 years. Therefore the government is encouraged to increase coverage for child immunizations, Vitamin A supplementation, exclusive breastfeeding for at least 6months and intensify maternal and child surveillance programs.**

Keywords: ANN, Forecasting, infant mortality rate.

I. INTRODUCTION

Artificial neural networks (ANNs) have gained popularity in the field of public health where they are used for time series prediction. ANNs are electronic models based on the structure and function of the human brain. They provide an accurate approach to problems and they have the advantage of not requiring clear understanding of the underlying mathematical relationships between input and output values (Buitrago & Asfour, 2017). They have gained popularity in time series forecasting problems because they were seen to be more accurate than the traditional statistical methods (Zhao et al, 2020; Adhiswara et al, 2019; Zhang et al, 2014). ANNs have been applied in medicine to predict the incidence of diseases such as TB, HIV, Malaria, schistomiasis and typhoid. They have also been applied in forecasting health related events (Weng et al, 2017). The Multilayer Perceptron is the most widely used ANN framework which is feed forward and back propagation network (Yu et al, 2008; Jin-ming & Xin-heng, 2009). The model is made up of 3 layers of neurons which are the input, hidden and output layers. The layers are connected by connection weights (Zhao et al, 2020; Kaushik & Sahi, 2018; Yan et al, 2018; Zhang, 2003).The choice of the number of nodes for each layer depends on the problem under investigation (Zhang et al, 2008). There are two programs in the learning process on the back propagation neural network algorithms, the first one is input information transmitted in the forward direction where input information goes to the hidden layer and then output layer. Secondly, errors are transmitted in backward direction which will create weights in each layer of neurons to be modified to reduce the percentage error. The difference between the actual response and the target will produce an error signal which is sent backwards through the hidden layer to the input layer (Adhiswara et al, 2019, Reddy & Momoh, 2014). In this paper we applied the ANN (12, 12, 1) model to predict infant mortality in Senegal. The findings of this study are envisioned to assist in detecting future trends of infant mortality rate, assess progress towards achieving sustainable development goals and evaluating maternal and child health programs in the country.

II. LITERATURE REVIEW

Nyoni & Nyoni (2020) modelled and forecasted infant deaths in Zimbabwe using ARIMA model. The study utilized annual time series data on total infant deaths in Zimbabwe from 1960 to 2018. The best model based on AIC was the ARIMA (1, 2, 5) model. The ARIMA (1, 2, 5) model predictions suggested that the number of infant deaths per year, over the out-of-sample period, would follow a downward trend. Nyoni & Nyoni (2020) used monthly time series data on neonatal deaths cases at Chitungwiza Central Hospital (CCH) from January 2013 to December 2018; to forecast neonatal deaths over the period January 2019 to December 2020 using the Box-Jenkins SARIMA approach. The parsimonious model was found to be the SARIMA (0, 0, 3) (2, 0, 0)12 model and its predictions indicate slow but steady decrease in neonatal deaths at CCH. Gayawan (2016) examined the residual geographical variations in infant and child mortality and how the different categories of the risk factors account for the spatial inequality in West African countries. The researchers pooled data for 10 of the countries extracted from Demographic and Health Surveys and used the spatial extension of discrete-time survival model to examine how the variables exert influence on infant and child mortality across space. Inference was Bayesian based on the computational efficient MCMC technique. They found different geographical patterns for infant and child mortality. In the case of children under five, demographic factors inherent to the mother and child as well as maternal status variables when accounted for explain away a good part of the huge

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variations observed in the crude rates. There was no evidence of significant variations, however, in infant mortality except for three neighboring regions of Liberia and Sierra Leone. Weldearegawi et al (2015) measured infant mortality rate, investigated risk factors for infant deaths and identified causes of death in a rural population of northern Ethiopia. Live births to a cohort of mothers under the Kilite Awlaelo Health and Demographic Surveillance System were followed up to their first birthday or death, between September 11, 2009 and September 10, 2013. Maternal and infant characteristics were collected at baseline and during the regular follow-up visit. Multiple-Cox regression was used to investigate risk factors for infant death. Causes of infant death were identified using physician review verbal autopsy method. The authors concluded that the IMR for the four-year period was lower than the national and regional estimates. Our findings suggest the need to improve the newborn care, and empower teenagers to delay teenage pregnancy and attain higher levels of education.

III. 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 Senegal.

Data Issues

This study is based on annual infant mortality rates in Senegal 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.

IV. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	E
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	0.016346
MSE	0.760009
MAE	0.692431

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Residual Analysis for the Applied Model

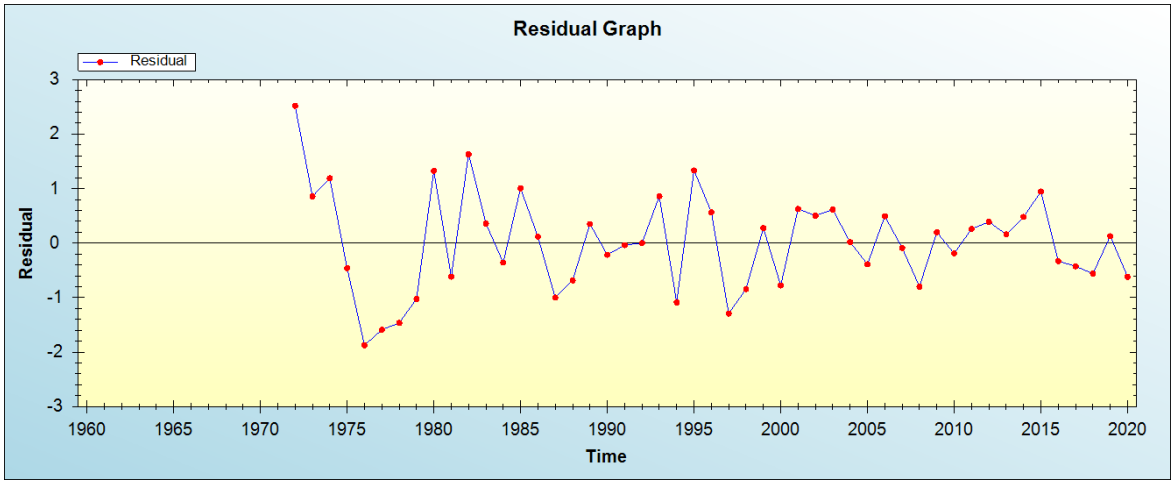

Figure 1: Residual analysis

In-sample Forecast for E

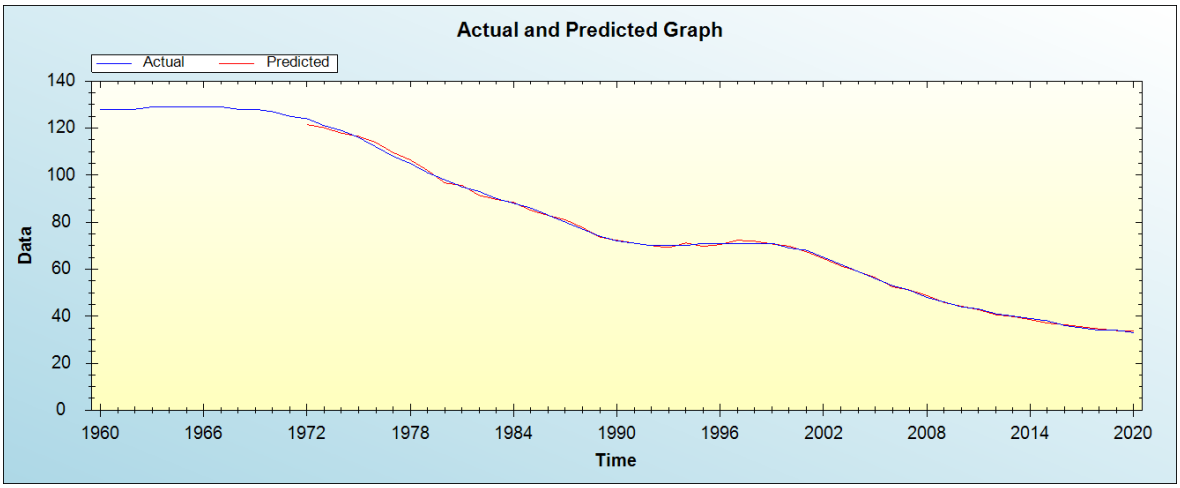

Figure 2: In-sample forecast for the E series

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

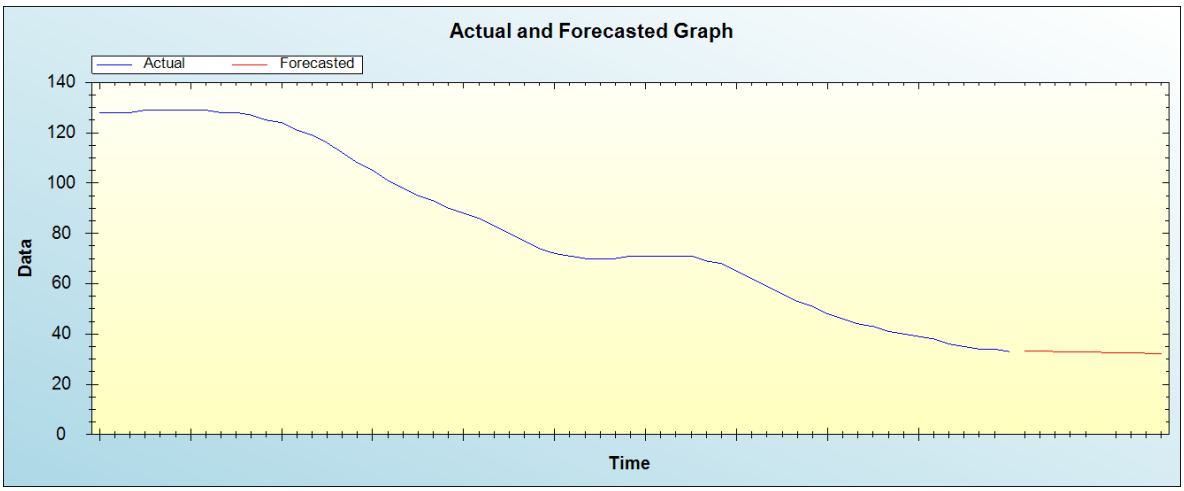

Figure 3: Out-of-sample forecast for E: actual and forecasted graph

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Out-of-Sample Forecast for E: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Predictions
2021	33.2642
2022	33.1512
2023	33.0160
2024	32.9891
2025	32.8449
2026	32.7131
2027	32.6354
2028	32.5450
2029	32.3438
2030	32.3208

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 Senegal is likely to remain around 33/1000 live births per year over the next decade.

V. CONCLUSION AND POLICY RECOMMENDATIONS

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

iv. The government of Senegal should address preterm birth, low birth-weight and their outcomes.

v. The government of Senegal 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 the country.

vii. Healthcare providers in Senegal need to use newborn screening activities in order to detect hidden conditions.

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