

# Prediction of Infant Mortality Rate in Rwanda Using the Multilayer Perceptron Neural Network

<sup>1</sup>Dr. Smartson. P. NYONI, <sup>2</sup>Thabani NYONI

<sup>1</sup>ZICHIRE Project, University of Zimbabwe, Harare, Zimbabwe

<sup>2</sup>SAGIT Innovation Centre, Harare, Zimbabwe

**Abstract** - In this research article, the ANN approach was applied to analyze infant mortality rate in Rwanda. The employed annual 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 Rwanda. The ANN (12, 12, 1) model projections suggest that infant mortality will be around 23/1000 live births per annum over the next 10 years in Rwanda. The government is encouraged to intensify maternal and child health surveillance and control programs amongst other measures in order to curb infant mortality in Rwanda. This might be specifically executed by adopting the suggested 7-fold policy recommendations.

**Keywords:** ANN, Forecasting, Infant mortality.

## I. INTRODUCTION

Infant mortality refers to the death of a child during the first year of life (Hanmer & White, 2003). The majority of infant deaths happen in low and middle income countries (NISR, 2017). Several studies have shown that 10-20% of infants die before their first birthday and black infants are at a higher risk of dying when compared with the white infants (UNICEF, 2009). The majority of infant deaths are as a result of cultural, maternal, infant, proximity and delivery factors ( Lamichhane et al, 2017; Sarkar & Dhar, 2017; Stevens et al, 2017; Issaka et al, 2016; Rezaei, 2015; Greenaway, 2012; Carlo, 2011; Bajanowski, 2007; NAP, 2007; Hunt & Hauck, 2006; Patel, 2000; It has been noted that the epidemiology of HIV, malaria, TB, war and civil conflict aggravate the situation (UN, 2007). Rwanda has an estimated population of about 11.4 million people (Gupta et al, 2018). The country has made significant progress in improving child survival. The country recorded 37 neonatal and 152 under 5 deaths per 1000 live births in 2005 and then 20 and 50 deaths per 1000 live births respectively in 2015 (NISR, 2015). This positive trend was a result of the national introduction of community health insurance program, high vaccination coverage, Vitamin A supplementation, integrated management of childhood illnesses, and prevention from mother to child transmission of HIV, increase in institutional deliveries and improved communication between the community and healthcare facilities in cases of emergency (Musafili et al, 2015; Mugeni et al, 2014; Farmer et al, 2013). Infant mortality ratio modeling and forecasting is vital in evaluating progress towards achieving the sustainable development goal number 3. In this paper we apply the multilayer perceptron to model and forecast infant mortality ratio in Rwanda. The applied model is composed of three layers of neurons which are the input, hidden and output layers. The layers are connected by acyclic links called connection weights (Nyoni et al, 2020; Zhao et al, 2020; Kaushiki & Sahi, 2018; Yan et al, 2018, Fojnica et al, 2016; Zhang, 2003). The findings of this study will reveal the future trends of infant mortality ratio in Rwanda and will guide decision makers in implementing preventive and corrective measures to significantly reduce infant mortality.

## II. LITERATURE REVIEW

Biracyaza & Habimana (2019) developed a model of infant mortality and its associated risk factors in Rwanda from 2011 to 2015. A cross-sectional survey was conducted using data from 2014/2015 Rwanda Demographic and Health Survey. Target population was women aged 15-49 years from sampled households. All 492 of the clusters selected were surveyed for 2014/2015 RDHS. STATA version 13 was used to analyze the statistical data. The study concluded that factors associated with IM were grouped into community, ecological, socio-economic and proximate factors and identified that each group consists of multifactor that influence the infant mortality rate. Khurmi et al (2017) reviewed evidence-based interventions and coverage levels already implemented in the country; identified key issues and bottlenecks in service delivery and uptake of services by community/beneficiaries, and provided key recommendations aimed at faster reduction in newborn mortality rate. This study utilized mixed method research including qualitative and quantitative analyses of various maternal and newborn health programs implemented in the country. This included interviewing key stakeholders at each level, field visits and also interviewing beneficiaries for assessment of uptake of services. Monitoring systems such as Health Management Information Systems (HMIS),

maternal and newborn death audits were reviewed and data analyzed to aid these analyses. The study revealed that Policies, protocols, various guidelines and tools for monitoring are already in place however, implementation of these remains a challenge e.g. infection control practices to reduce deaths due to sepsis. Although existing staff are quite knowledgeable and are highly motivated, however, shortage of health personnel especially doctors in an issue. New facilities are being operationalized e.g. at Gisenyi, however, the existing facilities needs expansion. In another study, Musafili et al (2015) analyzed trends and social differentials in mortality before the age of 5 years in Rwanda from 1990 to 2010. They performed secondary analyses of data from three Demographic and Health Surveys conducted in 2000, 2005 and 2010 in Rwanda. These surveys included 34 790 children born between 1990 and 2010 to women aged 15–49 years. The main outcome measures were neonatal mortality rates (NMR) and under-5 mortality rates (U5MR) over time, and in relation to mother’s educational level, urban or rural residence and household wealth. Generalized linear mixed effects models and a mixed effects Cox model (frailty model) were used, with adjustments for confounders and cluster sampling method. The study revealed that reductions in child mortality in Rwanda have concurred with improved social equity in child survival. Current challenges include the prevention of newborn deaths.

### 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 Rwanda.

#### Data Issues

This study is based on annual infant mortality rates in Rwanda 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	F
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	0.030426
MSE	4.322804
MAE	1.429397

*Residual Analysis for the Applied Model*

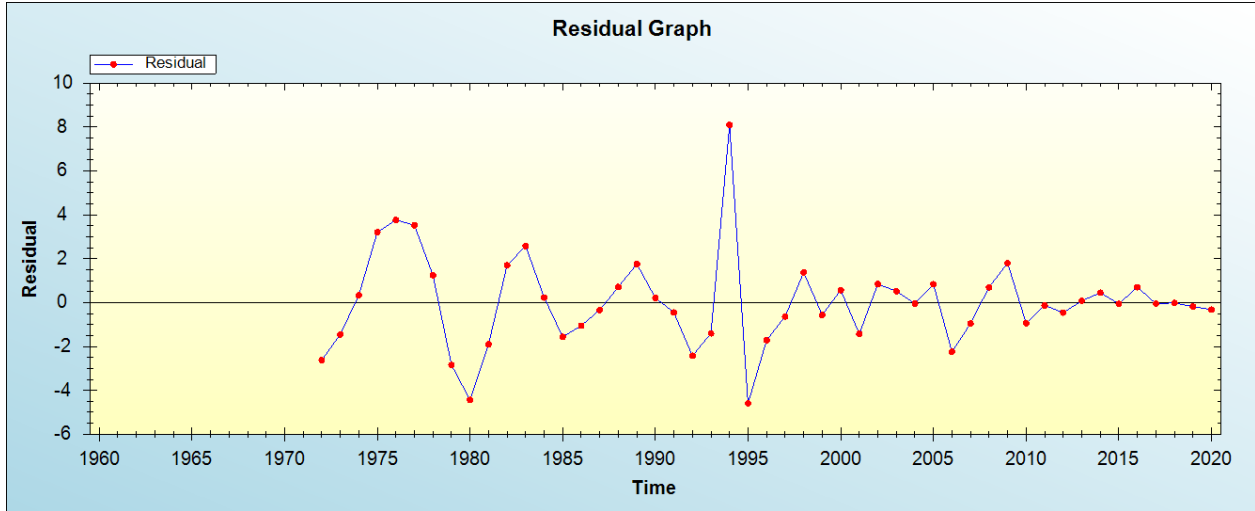


Figure 1: Residual analysis

*In-sample Forecast for F*

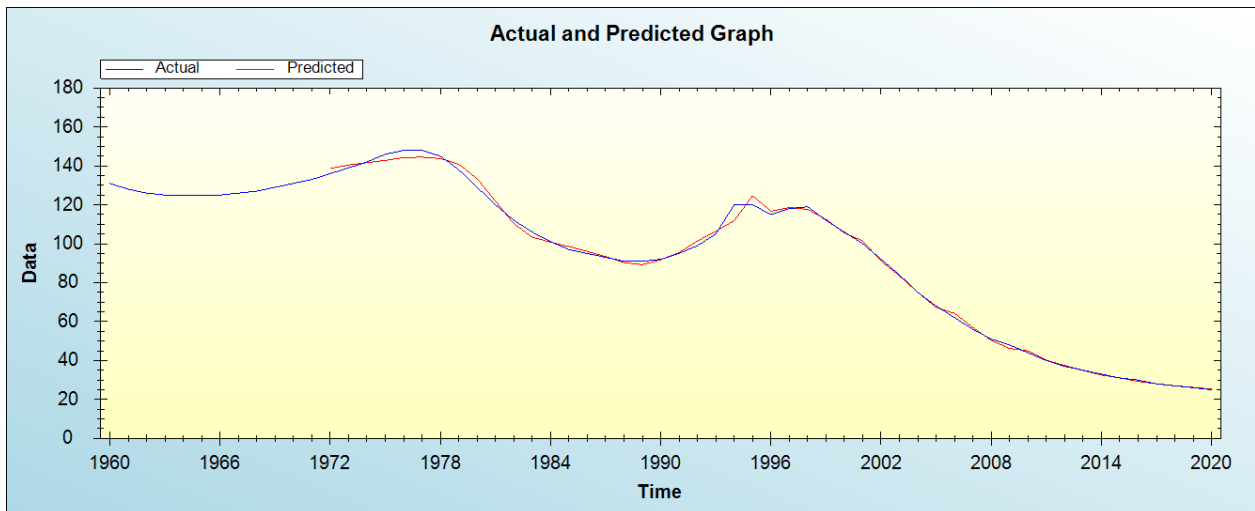


Figure 2: In-sample forecast for the F series

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

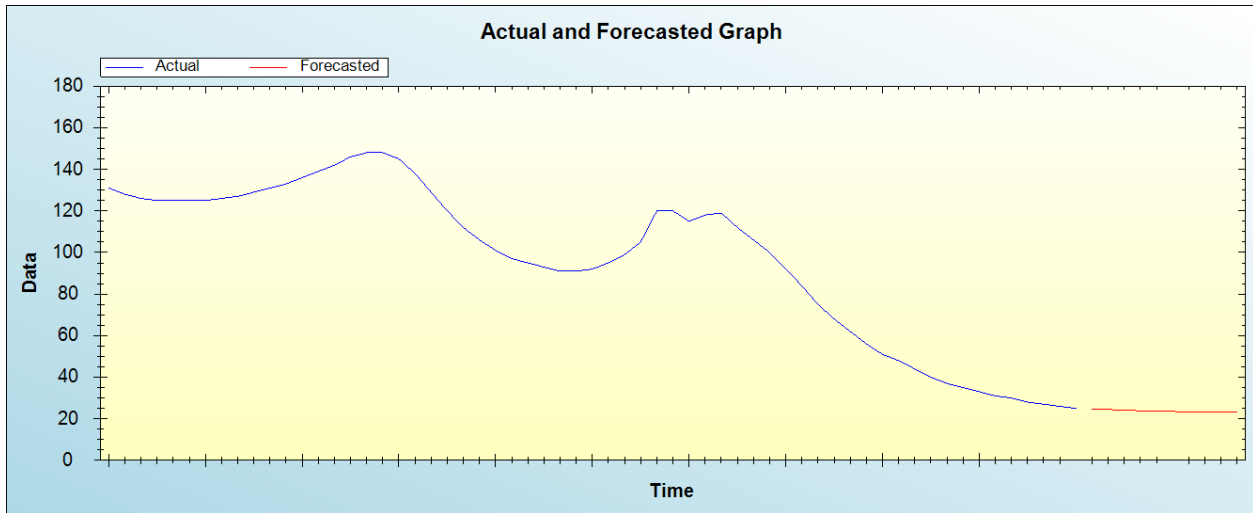


Figure 3: Out-of-sample forecast for F: actual and forecasted graph

Out-of-Sample Forecast for F: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2021	24.8186
2022	24.4848
2023	24.0859
2024	23.8814
2025	23.7100
2026	23.5235
2027	23.3706
2028	23.2630
2029	23.1328
2030	23.0864

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 Rwanda is likely to remain around 23/1000 live births per annum over the next decade.

### V. CONCLUSION AND POLICY RECOMMENDATIONS

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

- i. The Rwandan government should continue to encourage mothers to breast-feed their babies adequately.
- ii. There is need for all Rwandan child-bearing women to be vaccinated against common illnesses.
- iii. There is need to prevent birth defects in Rwanda.
- iv. The government of Rwanda should address preterm birth, low birth-weight and their outcomes.
- v. The government of Rwanda 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 Rwanda.

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

## REFERENCES

- [1] Bajanowski T., Vege A., Byard R., Krous H F., Arnestad M., & Bachs L (2007). Sudden Infant Death Syndrome (SIDS)-Standardized investigations and classification: Recommendations. *Forensic Sci Int.* 165: 129-143.
- [2] Carlo WA (2011). *The High-Risk Infant* (Elsevier Inc.).
- [3] Farmer PE., Nutt CT., Wagner CM., Sekabaraga C., & Nuthulaganti T (2014) Reduced premature mortality in Rwanda: lessons from success. *BMJ.* 346:f65.
- [4] Fojnica, A., Osmanoviae & Badnjeviae A (2016). Dynamic model of tuberculosis-multiple strain prediction based on artificial neural network. In proceedings of the 2016 5<sup>th</sup> Mediterranean conference on embedded computing pp290-293.
- [5] Greenaway E S., Leon J & Baker DP (2012). Understanding the association between maternal education and use of health services in Ghana: exploring the role of health knowledge. *J Biosoc Sci.* 44: 733-747.
- [6] Hanmer L & White H (2003). Infant and child mortality in developing countries: Analyzing the data for Robust determinants. *J Dev Stud.* 40: 101-118.
- [7] Hunt CE & Hauck FR (2006). Review Sudden infant death syndrome.
- [8] Institute of Medicine (US) Committee on Understanding Premature Birth and Assuring Healthy Outcomes; Preterm Birth: Causes, Consequences, and Prevention ed ASB Richard E. Behrman (Washington (DC): National Academies Press (US)). 2007.
- [9] Issaka A I., Agho K E., & Renzaho AMN (2016). The Impact of Internal Migration on under-Five Mortality in 27 Sub-Saharan African Countries. *PLoS One.* 11: e0163179.
- [10] Kaushik AC & Sahi. S (2018). Artificial neural network-based model for orphan GPCRs. *Neural.Comput.Appl.* 29,985-992.
- [11] Lamichhane R., Zhao Y., Paudel S., & Adewuyi EO (2017). Factors associated with infant mortality in Nepal: A comparative analysis of Nepal Demographic and Health Surveys (NDHS) 2006 and 2011 *BMC Public Health.* 17: 1-18.
- [12] Mugeni C., Levine AC., Munyaneza RM., Mulindahabi E., & Cockrell HC (2014). Nationwide implementation of integrated community case management of childhood illness in Rwanda. *Glob Health Sci Pract.*2(3):328–41.
- [13] Musafili A., Essen B., Baribwira C., Binagwaho A., Persson LA & Selling KE (2015). Trends and social differentials in child mortality in Rwanda 1990-2010: results from three demographic and health surveys. *J Epidemiol Community Health.* 69(9):834–40.
- [14] 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>.
- [15] National Institute of Statistics of Rwanda (2017). Life expectancy at birth. 57: 1-18.
- [16] National Institute of Statistics of Rwanda. Rwanda Ministry of Health, and ICF international. In: Rwanda demographic and health survey 2014-15. Rockville: Final Report; 2015.
- [17] Neil Gupta1., Lisa R., Hirschhorn., Felix C., Rwabukwisi., Peter Drobac., Felix Sayinzoga., Cathy Mugeni., Fulgence Nkikabahizi., Tatien Bucyana., Hema Magge., Daniel M., Kagabo., Evrard Nahimana., Dominiqu Rouleau., Amelia VanderZanden., Megan Murray & Cheryl Amoros (2018). Causes of death and predictors of childhood mortality in Rwanda: a matched case-control study using verbal social autopsy *BMC Public Health.* 18:1378 <https://doi.org/10.1186/s12889-018-6282-z>.
- [18] Patel RM (2000). Determinants of infant mortality in Gujarat. 2000.
- [19] Rezaei S., Jamshidi K., & Moradi K (2015). Impact of Socioeconomic and Health System Factors on Infant Mortality Rate in Organization of the Petroleum Exporting Countries (OPEC): Evidence from 2004 to 2013. *Int J Pediatr.* 3: 493-499.
- [20] Sarkar SM & Dhar BK (2017). Socio-economic determinants of infant mortality in the South Asian region - A cross sectional analysis. *Int J Bus Soc.* 1: 1-6.
- [21] Smartson. P. Nyoni, Thabani Nyoni, Tatenda. A. Chihoho (2020) PREDICTION OF DAILY NEW COVID-19 CASES IN GHANA USING ARTIFICIAL NEURAL NETWORKS *IJARIII* Vol-6 Issue-6 2395-4396.
- [22] Smartson. P. Nyoni., Thabani Nyoni., Tatenda. A. Chihoho (2020) PREDICTION OF DAILY NEW COVID-19 CASES IN EGYPT USING ARTIFICIAL NEURAL NETWORKS *IJARIII*- Vol-6 Issue-6 2395-4396.

- [23] Stevens AB., Akah H., Aly R., Reat Z., Carroll B & McGee AR (2017). A new approach to reduce infant mortality and achieve equity: Policy recommendations to improve housing, transportation, education and employment Heal. Policy Inst. Ohio Health Policy Institute of Ohio for the Ohio Legis.
- [24] United Nations International Children’s Emergency Fund (2009). Tracking Progress on Child and Maternal Nutrition.
- [25] United Nations. The Millennium Development Goals Report (New York). 2007.
- [26] 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.
- [27] Zhang G P, “Time series forecasting using a hybrid ARIMA and neural network model”, *Neurocomputing* 50: 159–175.

**Citation of this Article:**

Dr. Smartson. P. NYONI, Thabani NYONI, “Prediction of Infant Mortality Rate in Rwanda Using the Multilayer Perceptron Neural Network” Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 3, pp 581-586, March 2021. Article DOI <https://doi.org/10.47001/IRJIET/2021.503099>

\*\*\*\*\*