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PREDICTION OF TB NOTIFICATIONS AT GWERU PROVINCIAL HOSPITAL USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT
In this research article, the ANN approach was applied to analyze TB notifications at Gweru District Hospital (GDH). The employed data covers the period January 2010 to December 2019 and the out-of-sample period ranges over the period January 2020 to December 2021. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting TB notifications at GPH. The results of the study indicate that TB case notifications are likely to increase over the period January 2020 to December 2021. In order to contribute meaningfully to the national control strategy of a TB-free Zimbabwe, GPH should, among other things, intensify TB surveillance and control programmes in its catchment area.

KEYWORD: ANN, Forecasting, TB Notifications

INTRODUCTION
Despite the fact that the global Tuberculosis (TB) incidence has declined by 1-2% per year (Raviglione et al., 2012), TB is still a major health problem in many developing countries (Sgaragli & Frosini, 2016) such as Zimbabwe (National TB Guidelines, 2010; Dube, 2015; Nyoni & Nyoni, 2019a & b) and has a vast health burden due to high medical expenses, drug resistance and co-infections (WHO, 2016). In fact, TB is the most common airborne infectious cause of death, inducing nearly 3 million deaths each year, principally among young adults in the globally poorest nations (Neville et al., 1994; Yew & Chau, 1995; WHO, 1997; Farmer & Kim, 1998; Dye et al., 2006; Bhunu et al., 2012). TB is an infectious bacterial disease caused by Mycobacterium tuberculosis, and typically exerts adverse effects not only on the lungs, but also on other bodily organs (Wang et al., 2018). TB is transmitted from one person to another via small droplets of sputum and saliva expelled when an infectious patient coughs or sneezes (Guernier et al., 2006). Previous studies have forecasted TB notifications at primary level (Nyoni & Nyoni, 2019a) and secondary level (Nyoni & Nyoni, 2019b) of the health referral system in Zimbabwe. No study has forecasted TB notifications at tertiary level of the referral system in Zimbabwe. In this study, we focus on TB notifications recorded and managed at Gweru Provincial Hospital (GPH). The objectives of this study are basically two-fold, that is, to analyze the trend of TB notifications at GPH over the period Janaury 2010 – December 2019 and to determine the predicted number of TB notifications over the period January 2020 – December 2021.

LITERATURE REVIEW
Alba et al. (2018) developed and validated a predictive ecological model for TB prevalence in 63 low and middle income countries across Africa and Asia and finally concluded that predictive ecological modeling is a useful complementary approach to indirectly estimating TB burden. Wang et al. (2018) analyzed TB prevalence rates in China using a novel combination model, and concluded that their developed combination model is not only simple, but is also able to satisfactorily approximate the actual TB prevalence rate, and can be an effective tool in mining and analyzing big data in the medical field. In another Chinese study, Wang (2019) developed a predictive model of TB transmission among household contacts, using the LASSO regression technique and concluded that a predictive model that incorporates features of both the index patients and the contacts is of great value for the individualized prediction of TB transmission among household contacts. Nyoni & Nyoni (2019a) forecasted TB notifications at Zengeza clinic in Chitungwiza, Zimbabwe, based on a data set covering the period January 2013 to December 2018, using SARIMA models and revealed that the TB notifications will decline in the Zengeza clinic catchment area over the out-of-

sample period. In another Zimbabwean study, Nyoni & Nyoni (2019b) forecasted TB notifications at Silobela District Hospital (SDH), based on a data set covering the period January 2014 – December 2018, using SARIMA models and revealed that TB notifications will generally decline in Silobela community over the out-of-sample period. While this study is not new in Zimbabwe, it will contribute to literature differently as we apply Artificial Neural Networks (ANNs) in forecasting TB notifications at GPH.

METHOD

This paper applies the multi-layer perceptron neural network type of the ANN approach in order to predict TB notifications at GPH. The particulary applies the ANN (12, 12, 1) model and chooses the more efficient hyperbolic tangent function as the activation function.

Data Issues

This study is based on newly diagnosed monthly TB infections [case notifications] (reffered to as NTB series in this study) in all age groups at GPH. The data covers the period January 2010 to December 2019 while the out-of-sample forecast covers the period January 2020 to December 2021. All the data employed in this research paper was gathered from GPH Health Information Department.

FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

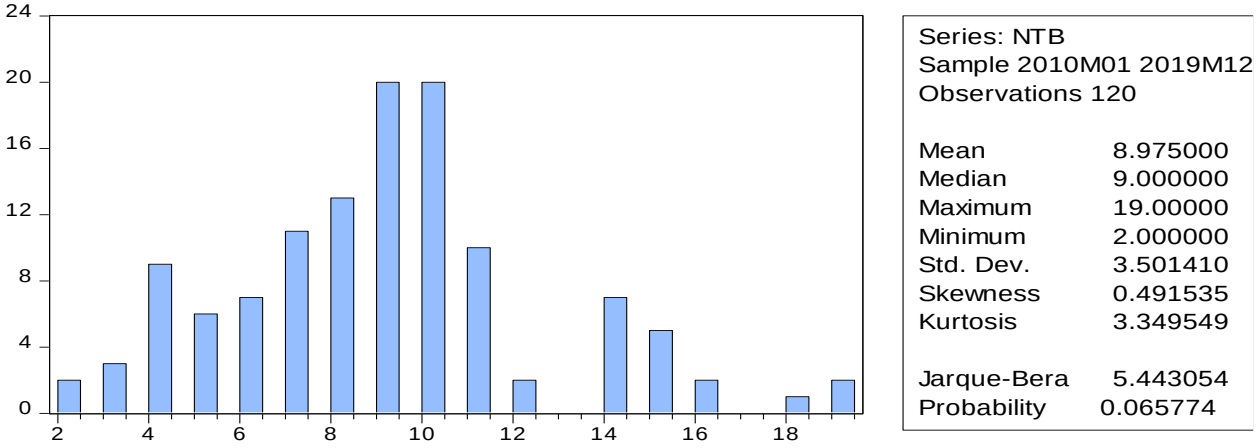

Figure 1: Descriptive statistics

The average number of TB notifications over the study period is 9 cases per month. The minimum number of TB notifications is 2 cases while the maximum is 19 cases. This clearly indicates that TB is slowly becoming the new scourge in Zimbabwe, especially in the GPH catchment area.

ANN MODEL SUMMARY FOR DYSENTRY CASES IN CHITUNGWIZA URBAN DISTRICT

Table 1: ANN model summary

Variable	NTB
Observations	108 (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	0.079809
MSE	0.568142
MAE	0.639540

The table above displays the estimated ANN (12, 12, 1) model.

Residual Analysis for the ANN model

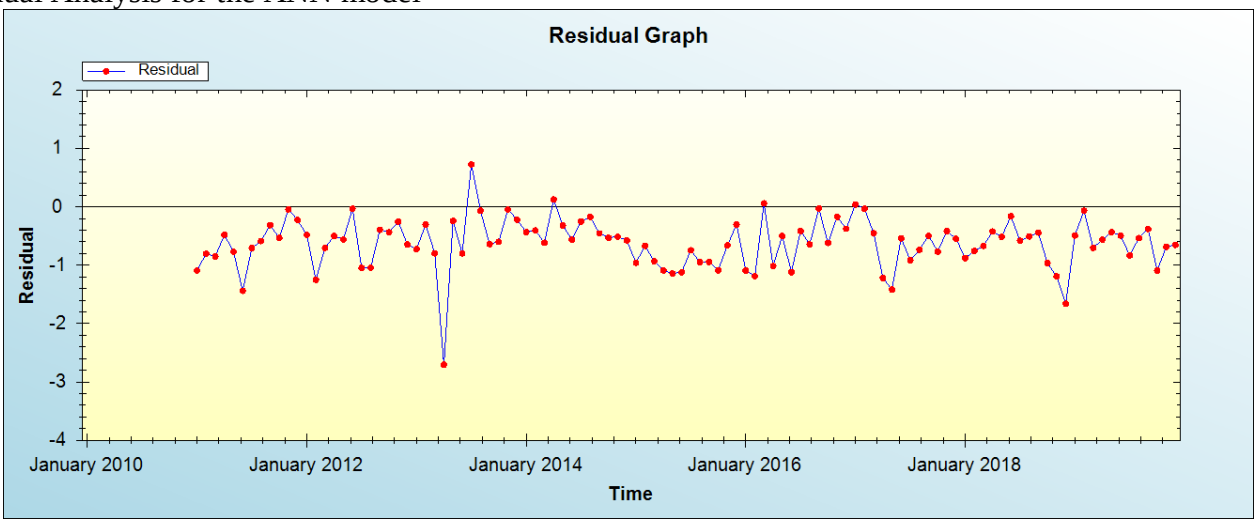

Figure 2: Residual analysis

Figure shows the plot of the residuals of the ANN (12, 12, 1) model. From mere observation of the graph, it clear that the predictive model is stable since the residuals are so close to zero.

In-sample Forecast for NTB

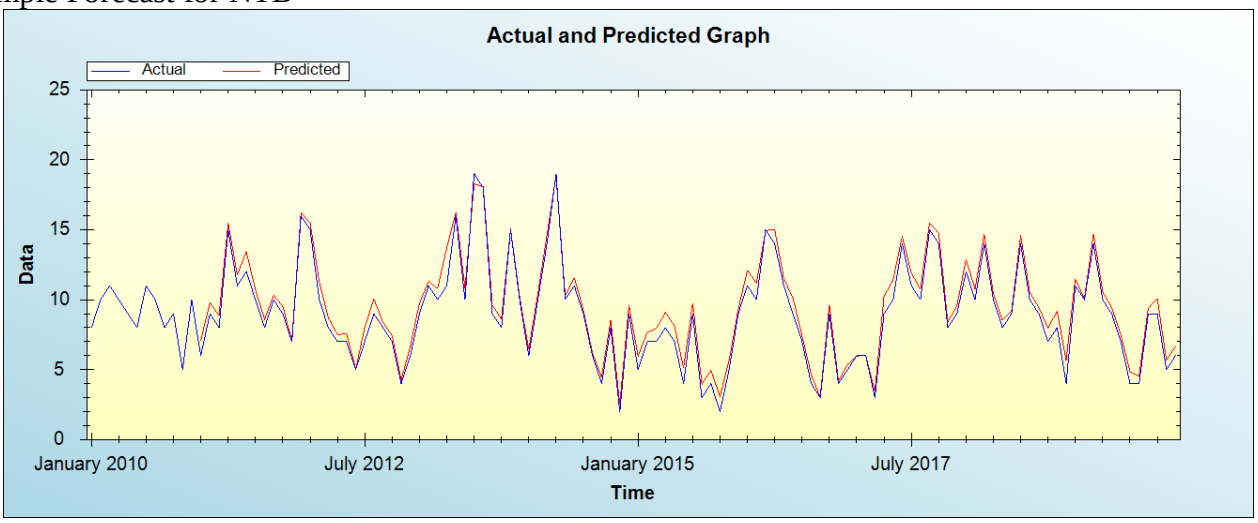

Figure 3: In-sample forecast for the NTB series

Figure 3 shows the in-sample forecast for NTB series.

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

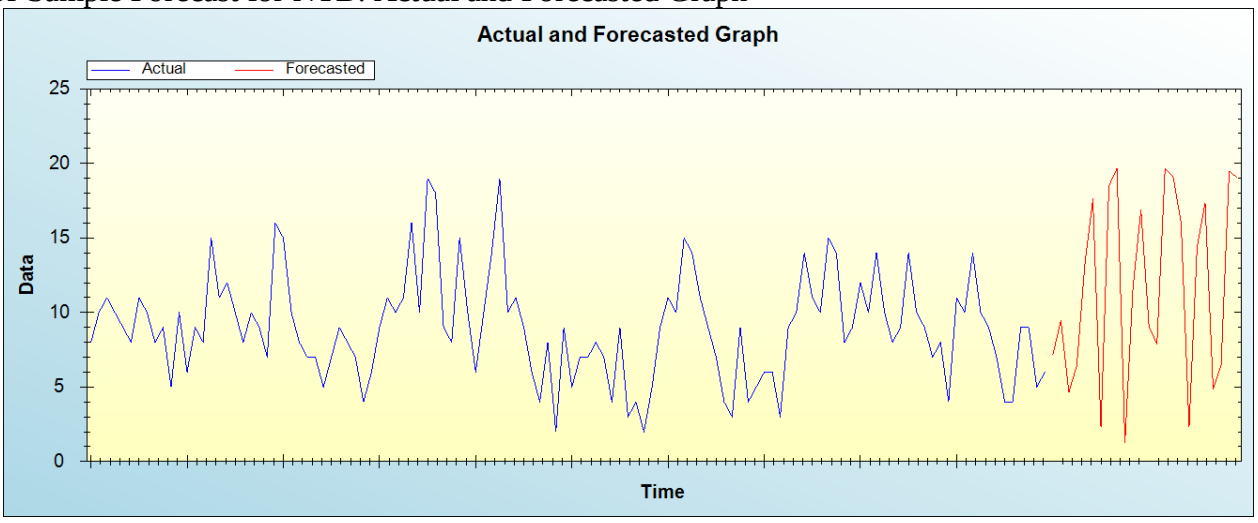

Figure 4: Out-of-sample forecast for NTB: actual and forecasted graph

Out-of-Sample Forecast for NTB: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Month/Year	Predicted NTB
January 2020	7.1436
February 2020	9.4645
March 2020	4.6365
April 2020	6.4567
May 2020	13.2339
June 2020	17.6077
July 2020	2.3529
August 2020	18.4910
September 2020	19.6526
October 2020	1.2476
November 2020	11.6829
December 2020	16.8946
January 2021	9.0532
February 2021	7.8694
March 2021	19.6569
April 2021	19.1222
May 2021	16.0111
June 2021	2.2954
July 2021	14.3784
August 2021	17.3495
September 2021	4.8709
October 2021	6.4947
November 2021	19.4694
December 2021	19.0575

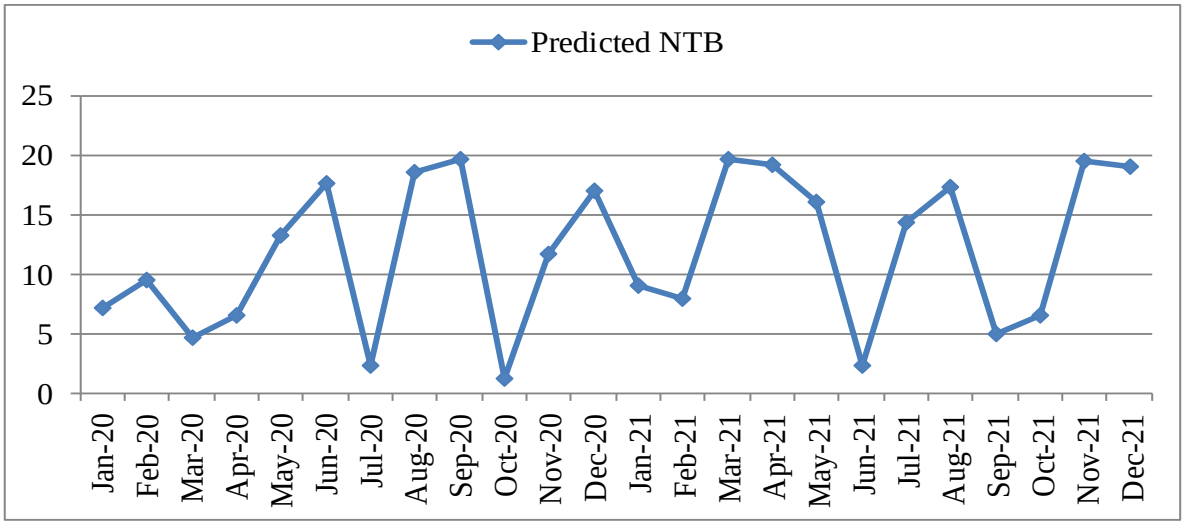

Figure 5: Graphical presentation of out-of-sample forecasts

Figure 4 and 5 as well as table 2 show the out-of-sample forecasts of the series under consideration. The forecasts show that TB cases are likely to range between 1 and 20 cases per month over the period January 2020 and December 2021. The predicted trend is basically going upwards and this not desirable, in light of the need to ensure a TB-free Zimbabwe, as enshrined in the country's National TB Control Strategy. However, this could be attributed to the fact that GPH is a referral hospital, whereby, suspected TB cases are reffered to GPH from district hospitals within its coverage. District hospitals may lack adequate resources to carry out confirmatory tests such as x-rays and scans and in such instances, the responsible clinician would refer the patient for confirmatory tests at GPH. Further studies are encouraged to model and forecast TB case notifications in each of the district hospitals and or clinics that refer patients to GPH for further TB diagnosis. This could reveal interesting results with regards to variation in trends and possible area-specific policy prescriptions.

RECOMMENDATIONS

i. There is need for intensification of TB surveillance and control programmes, particularly in the GPH catchment area.
ii. GPH should also intensify its HIV/TB initiatives.
iii. The government of Zimbabwe should also play its role in this regard, particularly in terms of availing funding for capacitation of GPH in effectively managing TB cases.

CONCLUSION

TB continues to be a serious threat to public health in Zimbabwe (Nyoni & Nyoni, 2019b). Following Nyoni & Nyoni (2019a & b), this study is the third attempt to model and forecast TB case notifications in the country. The results of the study are a warning signal to public health policy makers, especially given that the predicted trend is generally upwards; thus pointing to a possible increase in TB cases in the GPH catchment area over the period January 2020 to December 2021. These forecasts ought to be used for future planning purposes, for example, in acquiring essential medicines for TB patients and preparing enough health education programmes on TB in order to educate members of the community on the need to prevent the spread of TB.

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