Bahrain's TB Program Success: Message from Artificial Neural Networks

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Abstract - **The Kingdom of Bahrain's TB program is one of the successful Health programs in the Middle East. In this research article, the ANN approach was applied to analyze TB incidence in Bahrain. The employed annual data covers the period 2000-2018 and the out-of-sample period ranges over the period 2019-2023. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting TB incidence in the Kingdom of Bahrain. The model predictions suggest that TB incidence will remain low in the country over the period 2019-2023. The Health Authorities are encouraged to strengthen TB/HIV collaboration in order to maintain this desirable outcome.**

Keywords: ANN, Forecasting, TB Incidence.

I. INTRODUCTION

Bahrain is a Middle East country which has done well in the national response to TB (WHO, 2016), however; Tuberculosis remains a public health problem in the country (Basem et al, 2015; Jawad et al, 2014; Alkhawaja et al, 2012; Alkhawaja et al, 2018). The TB burden in Bahrain is largely driven by foreign nationals (migrant workers) contributing around 80 % of the TB cases (Alkhawaja et al, 2018). The bulk of the foreigners originate from high TB burden countries such as the Sub Saharan Africa and India (Gilbert et al, 2009; Maguire et al, 2002; French et al, 2007). The annual incidence of TB has significantly declined in Bahrain from 34/100 000 in 2007 to 11 /100 000 in 2016 (Alkhawaja et al, 2017). Over the period 2005-2016, 43 % of all TB cases were from young adults aged 25-34years and this young age group is largely composed of foreigners. For Bahrain the group which was largely affected by TB was the 45-54 year age group (Alkhawaja et al, 2017; Jawad et al, 2014; Alkhawaja et al, 2012; Al Ubaida et al, 2015). The goal of the National TB program in Bahrain is to screen all migrant workers who seek employment in the country. The program also aims to detect and treat TB in the local people group who are contacts of sputum positive TB cases in order to reduce morbidity and mortality and curb community transmission of TB. The kingdom of Bahrain is committed to the global goal to "End TB "by 2035 .This target is achievable for Bahrain as the country has recorded a significant decline in the annual incidence of TB. There is high political will and the private sector engagement is bearing fruits in the provision of high quality TB services. The TB program continues to face challenges which include continued influx of migrant workers from high TB burden countries and the emergence of multidrug resistant TB (WH0, 2018).

This paper aims to develop an Artificial neural network model to predict the annual incidence of TB in the Kingdom of Bahrain. The results of the study are expected to provide an insight of the future trends of the TB incidence in the country and the model can be used as a tool to assess the impact of TB prevention and control measures which are implemented by the government. The model predictions will guide in decision making, planning and in the execution of the national response to the TB epidemic.

II. LITERATURE REVIEW

Globally there are many empirical studies that have been done to model and predict the incidence of TB. Wang et al (2017) applied a hybrid SARIMA-NAR model to predict the monthly TB incidence in China using monthly TB incidence data from January 2007 to March 2016. The study concluded that the hybrid model was an effective method to fit the linear and nonlinear patterns of the time series data. Ribeiro et al (2019) applied simple exponential smoothing (SES), ARIMA and Holt-Winters' exponential smoothing (HWES) model to model and forecast monthly TB incidence in Brazil. The research utilized monthly TB data covering the period January 2001 to June 2018. The study findings indicated that the best model is the HWES (0.2,0.1,0.1). Nyoni & Nyoni (2019a) developed a SARIMA model to predict TB notifications at Zengeza clinic in Zimbabwe. The study utilized monthly TB notifications data covering the period January 2013 to December 2018. The optimal model based on AIC, the

SARIMA (2,0,2) (1,0,1)$_{12}$ predicted a downward trend in monthly TB notifications over the out of sample period at Zengeza clinic. In a related study, Nyoni & Nyoni (2019b) constructed a SARIMA model to project monthly TB notifications at Silobela District Hospital. Monthly TB notification data covering the period January 2014 to December 2018 was utilized. The best model based on AIC was the SARIMA (1,0,1) (0,1,1)$_{12}$ model. The results of the study suggested that monthly TB notifications were expected to decline over the out of sample period.

III. METHOD

The Artificial Neural Network (ANN), which we intend to apply in this research paper; is a data processing system consisting of a large number of simple and highly interconnected processing elements resembling a biological neural system. It has the capability of learning from an experimental or real data set to mathematically describe the nonlinear and interaction effects with great accuracy. ANN-based curve fitting technique is one of the extensively applied artificial intelligence methods that are used for forecasting and prediction purposes. It consists of basically three layers i.e., input layer, hidden layer, and output layer, the present paper includes the number of years as input layer and the annual TB incidence in Bahrain as output data for the network. In this paper, our ANN is based on the hyperbolic tangent function.

Data Issues

This study is based on TB incidences (new cases per 100 000 population per year) [referred to as H series in this study]. The annual data covers the period 2000-2018 while the out-of-sample forecast covers the period 2019-2023. All the data employed in this research paper was gathered from the World Bank online database.

IV. FINDINGS OF THE STUDY

Descriptive Statistics

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
25.368	30.000	11.000	39.000
Std. Dev.	C.V.	Skewness	Ex. Kurtosis
9.4529	0.37262	-0.21540	-1.4781
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	39.000	17.000	0

ANN MODEL SUMMARY FOR TB INCIDENCE (new cases per 100 000 population/year) IN BAHRAIN

Table 2: ANN model summary

Variable	H
Observations	10 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	9
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	0.019162
MSE	0.088852
MAE	0.243346

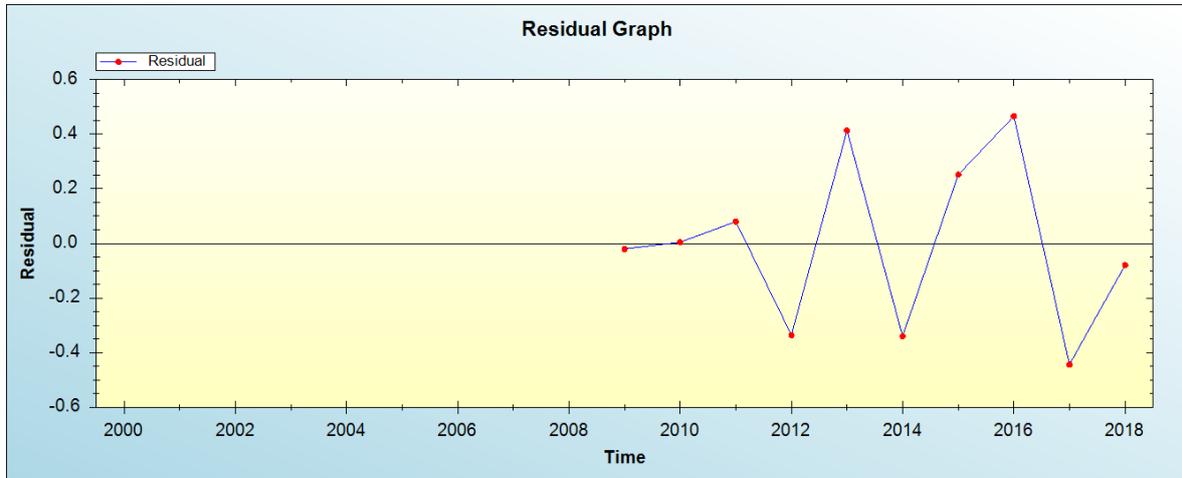*Residual Analysis for the ANN model*

Figure 1: Residual analysis
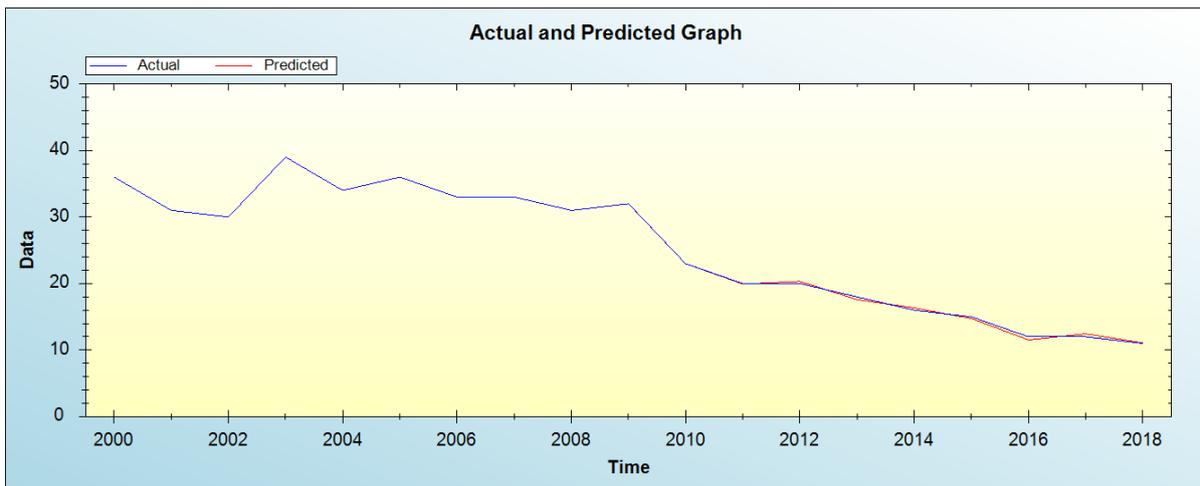
In-sample Forecast for H

Figure 2: In-sample forecast for the H series

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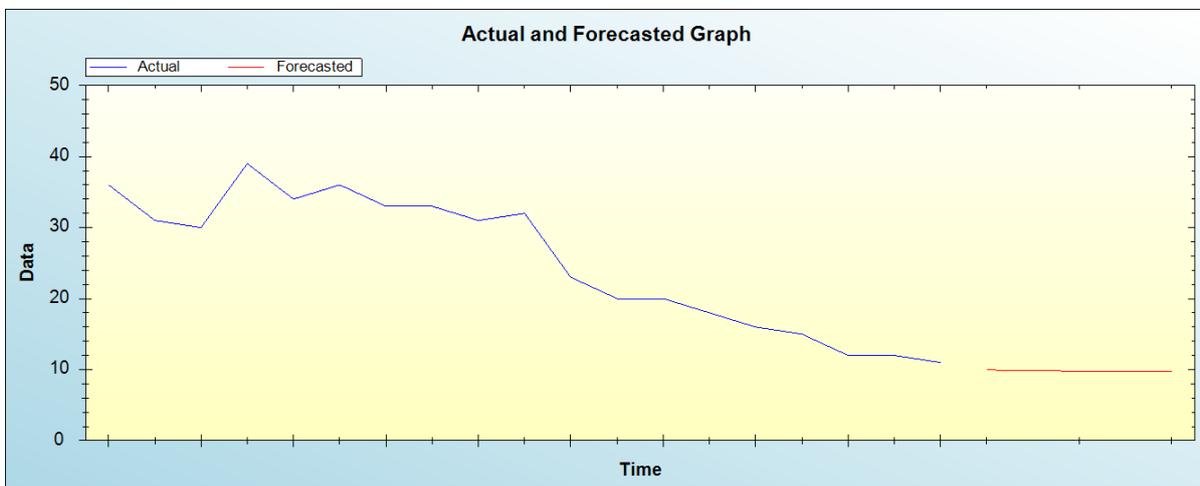

Figure 3: Out-of-sample forecast for H: actual and forecasted graph

Out-of-Sample Forecast for H: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2019	9.9649
2020	9.8386
2021	9.8020
2022	9.7202
2023	9.6992

Table 1 shows that over the study period 2000-2018, the average TB incidence was 25 cases per 100 000 population per year. The minimum and maximum TB incidence was 11 and 39 per 100 000 population per year respectively. Summary statistics show that the data is not normally distributed. It is negatively skewed with a skewness of -0.21540 and platykurtic with a kurtosis value of -1. 4781. The residual graph and model evaluation criteria indicate that the applied ANN (9,12,1) model is stable, adequate and suitable for forecasting TB incidence in Bahrain. In-sample forecasts show that the applied model simulates the observed values very well. In addition, over the period 2000-2018 the incidence of TB has been gradually declining and it is projected that over the period 2019-2023 it will be constant at a level of around 10 new cases per 100 000 population /year.

V. CONCLUSION & RECOMMENDATIONS

Bahrain is a Middle East country and has done well in its TB program over the years. Figure 2 indicates that the nation recorded a commendable decline in TB incidence over the period 2000-2018. This reflects the effective TB preventive and control measures implemented by the government. The model predicts that the incidence of TB will remain low in the country over the period 2019-2023.This is expected as the Kingdom of Bahrain has one of the best health care systems in the Middle East. We encourage the authorities in the Kingdom of Bahrain to strengthen TB/HIV collaboration in order to maintain this desirable outcome.

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