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China's TB Program Success: Evidence from Artificial Neural Networks

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***Abstract* - The Republic of China has done tremendously in the control of TB in the country as the TB incidence has been significantly declining over the period 2000-2018.It has become imperative at this point to model and forecast TB incidence in order to understand the future evolution of the epidemic in China and to assess the impact of TB control measures. In this research article, the ANN approach was applied to analyze TB incidence in China. 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 China. The results of the study indicate that TB incidence will continue to decline but at a very slow rate from 60.3 in 2019 to 59.2 cases per 100 000/year in 2023. The Chinese government is encouraged to continue intensification of TB surveillance and control programs in order to maintain this desirable downward trajectory.**

Keywords: ANN, Forecasting, TB incidence.

I. INTRODUCTION

China is one of the countries in the World which has been devasted by the TB epidemic (WHO, 2016).TB is an ancient scourge and the causative agent is mycobacterium Tuberculosis (MTB). The bacilli primarily affect the lungs .The Global TB report 2018 indicated that there were about 10 million new TB cases and 1.57 million deaths due to TB in 2017. World-wide, TB is the 10th leading cause of mortality and the leading cause of mortality from a single infectious agent (WHO, 2018). The global TB incidence is declining at a rate of about 2% per year ,however there is still a long way to reach the first milestones of the "END TB '' strategy as a result of a myriad of challenges which include the emergence of multi-drug resistant TB (MDR-TB),TB/HIV co-infection and high TB incidence in the floating population (Sgaragli &Frosini, 2016; Wang, 2018; Lv, 2018; Wangdi et al, 2010).In order to achieve the goal of the "END TB" strategy accurate forecasting of TB disease trends and related factors is critical (Heesterbeck et al, 2015; Arora et al, 2017).

One of the widely used predictive models is the Autoregressive integrated moving average (ARIMA) model which was proposed by Box and Jenkins in the 1970s (Lin. Y et al, 2015). The artificial neural network has been developed and is now widely applied in forecasting in many fields including human medicine. The model is self-adaptive and does not require prior knowledge (Wang, 2008; Baxt, 1995; Khan, 2019). In 1986, the back propagation neural network (BPNN) was proposed by Rumelhant and Mc Clelland as one of the commonly used ANNs (Wang et al, 2016). The prediction of TB incidence serves as a form of early surveillance and detection and can stimulate prevention and control of TB. Epidemic forecasting techniques are considered an important aspect in predicting the occurrence of infectious diseases. In this paper the researchers chose to apply the artificial neural network ANN (9,12,1) to model and forecast the incidence of TB in China in order to stimulate an evidence based national response to the TB epidemic.

II. LITERATURE REVIEW

Author(s)/year	Study period	Method	Major Findings
Liu et al (2019)	January 2005-December 2015	-ARIMA -BPNN	The BPNN model outperforms the ARIMA model in predicting the seasonality and trend of TB in the Chinese population.
Qiang et al (2018)	January 2004-	SARIMA model	The incidence of TB from January to June 2016 was predicted to be

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	December 2015		6.63 ,4.72 ,5.82 ,5.55 and 4.92 per 100 000 population.
Wang et al (2018)	2013-2016	Artificial Intelligence Algorithm-Cuckoo search used to forecast TB prevalence rates.	The model is simple and can satisfactorily approximate the actual TB prevalence rate and can be applied extensively in the medical field.
Cao. S et al (2013)	January 2005-December 2011	SARIMA model Hybrid model (SARIMA plus GRNN).	The hybrid model showed better TB incidence forecasting than the SARIMA model
Wang. Y et al (2019)	January 1997-March 2018	SARIMA-NARNNA hybrid model	The model predicted that over the period 2018-2025 TB incidence will continue to drop by 3.002 % annually but will remain high.
Wang K.W et al (2017)	January 2007-March 2016	ARIMA-NAR hybrid model	The hybrid model is an effective method to fit the linear and nonlinear patterns of time series.
Li et al (2019).	January 2007-June 2016	ARIMA-GRNN ARIMA	The hybrid model was superior to the single ARIMA model in predicting short term TB incidence in China
Wang et al (2020)	January 1997-August 2019	SARIMA ETS	The ETS model provided a pronounced improvement for long term seasonality and trend forecasting in TB incidence rate over the SARIMA model
Wang et al (2020)	January 2004-December 2016	SARIMA NNNAR Hybrid SARIMA-NNNAR	The hybrid model showed superiority in both mimic and predictive parts.
Zhang et al (2013)	January 2004-December 2011	-GRNN-ARIMA -SARIMA	The hybrid model out performs the traditional ARIMA model
Zheng et al (2020)	January 2012-June 2019	SARIMA model	The SARIMA model has a high prediction accuracy. The model predicted a slight decrease in TB incidence in Guangxi in China.

III. METHOD

The Artificial Neural Network (ANN) 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 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 purpose. It consists of basically three layers i.e., input layer, hidden layer, and output layer, the present work includes the number of years as input layer and the annual TB incidence in China as output data for the network. In this endeavor, our ANN is based on the hyperbolic tangent function.

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Data Issues

This study is based on TB incidences (cases per 100 000 population/year) [referred to as A 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
81.105	81.000	61.000	107.00
Std. Dev.	C.V.	Skewness	Ex. Kurtosis
14.794	0.18241	0.23521	-1.1787
5% Perc.	95% Perc.	IQ range	Missing obs.
Undefined	107.00	27.000	0

ANN MODEL SUMMARY FOR ANNUAL TB INCIDENCE (new cases per 100 000 population) IN CHINA

Table 2: ANN model summary

Variable	A
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	0.028964
MSE	0.547877
MAE	0.554558

Residual Analysis for the ANN model

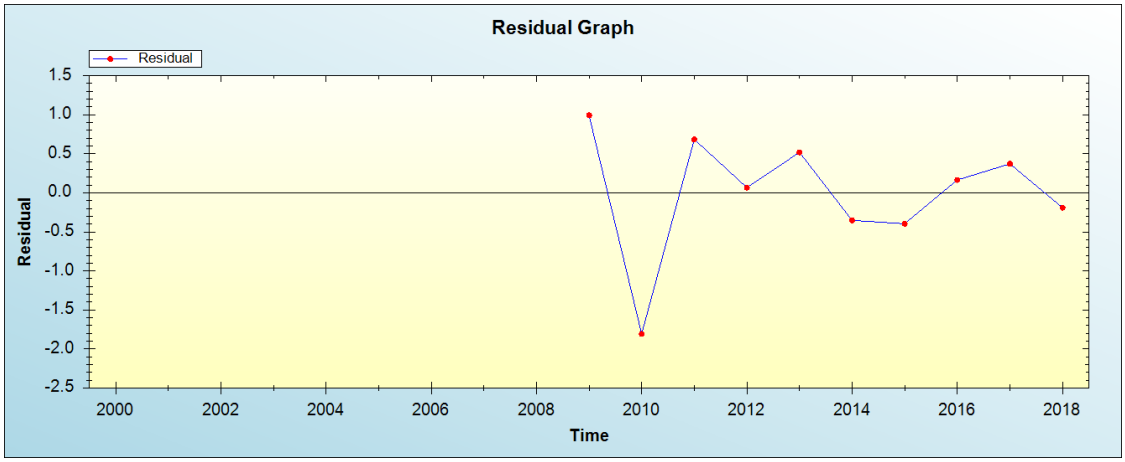

Figure 1: Residual analysis

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In-sample Forecast for A

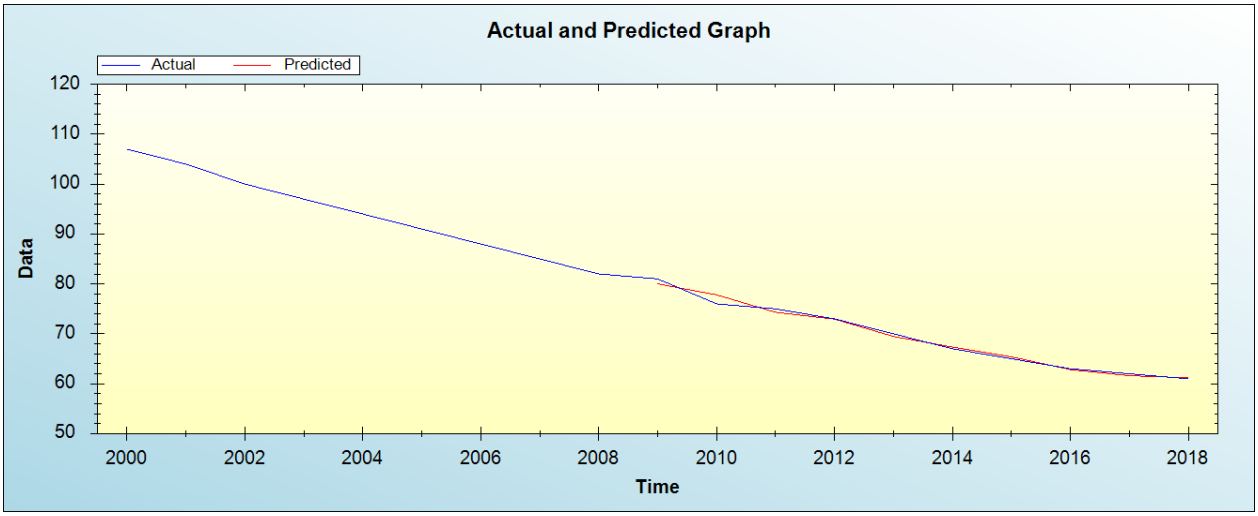

Figure 2 shows the in-sample forecast for A series

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

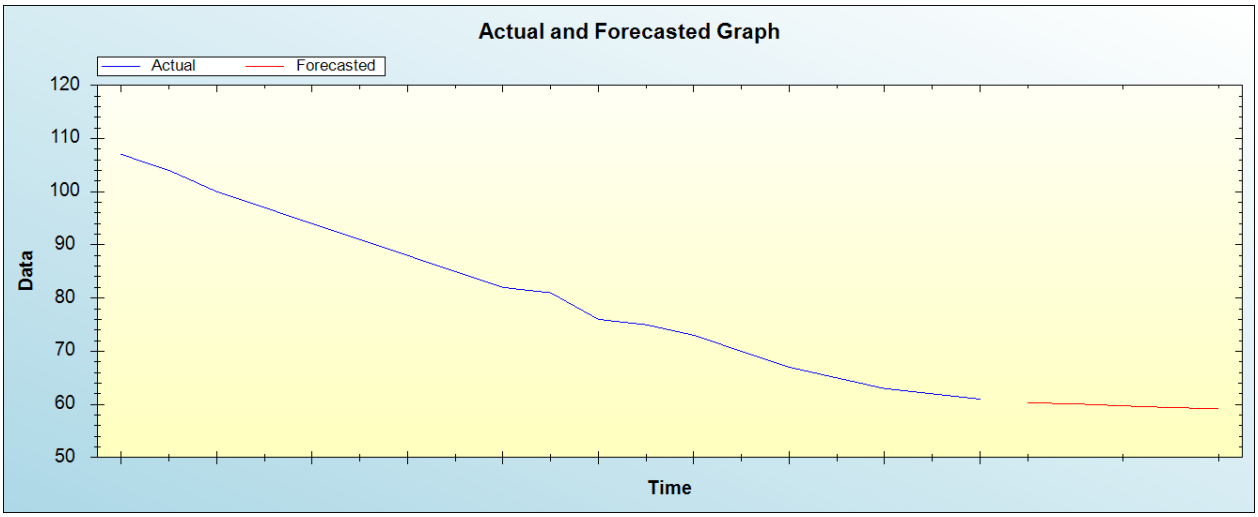

Figure 3: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2019	60.3348
2020	60.1142
2021	59.7330
2022	59.4114
2023	59.2197

Over the study period 2000-2018, the TB incidence has been gradually decreasing. Table 1 shows that the average TB incidence was 81 cases per 100 000 population/year. The minimum and maximum incidence was 61 and 107 cases per 100 000 population /year respectively. The applied data is positively skewed and platykurtic. The model evaluation criteria and the residual graph indicate that the applied ANN (9,12,1) stable and suitable for forecasting TB incidence in China. The model simulates the observed values very well as shown in Figure 2. The model predicts that over the period 2019-2023 the incidence of TB will continue to decline though at slower rate from 60.3 in 2019 to 59.2 cases per 100 000 /year in 2023 and will remain high. Our

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study results are consistent with the findings by Wang et al (2019) who applied the SARIMA-NARNNA hybrid model and the model predicted that the annual TB incidence would drop annually by 3.002 % over the period 2018-2025.

V. CONCLUSION & RECOMMENDATIONS

China has done very well in preventing and controlling TB in the country as indicated by Figure 3. This is as result of robust measures which have been put in place by government. In order to continue on this commendable path, the Ministry Health should not relax but should rather strengthen HIV/TB collaboration and intensify TB surveillance and control programs despite the presence of the COVID-19 pandemic.

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