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USING ARTIFICIAL NEURAL NETWORKS FOR PREDICTING NEW PNEUMONIA CASES IN CHILDREN UNDER 5 YEARS OF AGE AT GWERU DISTRICT HOSPITAL IN ZIMBABWE

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ABSTRACT
In this paper, the Artificial Neural Network model has been employed to project pneumonia cases in children under 5 at Gweru District Hospital (GDH) in Zimbabwe. The study covers the period January 2010 to December 2019. The out-of-sample forecasts range over the period January 2020 to December 2021. The residual analysis of the model indicates that the model applied in this research article is stable and suitable for forecasting under 5 pneumonia cases at GDH. The forecasts show a generally downwards trajectory of pneumonia cases at GDH over the period January 2020 – December 2021. The paper offers a 5-fold policy recommendation for use by the GDH health executive as well as other relevant government authorities.

INTRODUCTION
Pneumonia can be defined as an infection of lung parenchyma (alveoli) by microbial agents (Kabra et al., 2010). Community Acquired Pneumonia (CAP) is clinically defined as the presence of signs and symptoms of pneumonia in a previously healthy child caused by an infection acquired outside a hospital (Harris et al., 2011). A myriad of pathogens can cause pneumonia (including bacteria, virus, fungi and parasite) and the extent of pulmonary involvement, the onset, pattern and duration of symptoms; as well as the mortality rate depend on both the causative agent and precipitating factors. In most cases the lower respiratory tract is sterile. Organisms that enter the lungs are prevented from colonizing the airways distal to the glottis by mechanical means, such as coughing, or by immune mechanisms (Duffin, 1993). However, if any of these defense mechanisms are compromised, and when exposed to a highly virulent strain of organism or a high aerosol dose, infection and the resultant inflammation of pneumonia can occur in healthy individuals. Endogenous sources of the microorganisms causing pneumonia are colonization of the sinusitis, pharynx, trachea, gastric tract and hematogenous spread (Alcon et al., 2005).
The etiology of pneumonia in high-income countries is not similar to that in low-income countries, including more viral and atypical organisms (Kabra et al., 2010). In developed countries, viruses cause 30 – 67% of CAP and are more frequently identified in children aged less than 1 year than in those aged above 2 years. Bacteria are more frequently identified with increasing age, resulting in mixed infections being less common with age (Harris et al., 2011). Streptococcus pneumonia is the leading cause of bacterial pneumonia among children in developing countries, responsible for 30 – 50% of pneumonia cases. The second most common is Haemophilus influenza type b (Hib; 10 – 30%), followed by Staphylococcus aureus and Klebsiella pneumonia. Other bacteria are Mycoplasma pneumonia and Chlamydia pneumonia, causing atypical pneumonia (Simoes et al., 2006); non-typable H. influenza (NTHI) and non-typhoid Salmonella. Furthermore, Mycobacterium tuberculosis is also an important cause of pneumonia (Rudan et al., 2008). In 40 – 50% of infants and children hospitalized in developing countries, viruses are the causing agent (Simoes et al., 2006).
Diagnosis of pneumonia largely depends on setting. In a hospital setting, there are many investigations available, including radiography and microbiological methods, whereas in the community setting, one has to rely mainly on the clinical features of the ill child. The symptoms vary widely between individuals with pneumonia. A child may present with cough, fever and difficult breathing; they may also present with abdominal pain, headache and vomiting (Harris et al., 2011). The HIV pandemic has contributed substantially to increase the incidence, severity, and mortality of childhood pneumonia in the developing world, especially in Sub-Saharan Africa (Zar, 2004). Mortality due to childhood pneumonia is also strongly linked to malnutrition, poverty and inadequate access to health care (WHO, 2009). Treatment of pneumonia depends on the child, the severity of illness, the likely causative agents and their resistance patterns (Forsberg, 2012). For management of non-severe pneumonia in children, it is recommended to treat the child

as an outpatient, giving oral co-trimoxazole or amoxicillin. Children with severe pneumonia should be admitted to hospital and treated with benzylpenicillin, switching to oral amoxicillin when the child improves. Oxygen therapy may be used in children with signs of hypoxia (WHO, 2005).

1.1 OBJECTIVES OF THE STUDY

i. To assess new pneumonia cases in children under 5 years of age at Gweru District Hospital (GDH) over the period January 2010 to December 2019.
ii. To predict pneumonia cases for GDH over the period January 2020 to December 2022.
iii. To determine whether pneumonia cases are increasing or decreasing for GDH over the out of sample period.

1.2 RELEVANCE OF THE STUDY

Pneumonia is the leading cause of mortality in children aged less than 5 years worldwide (Sazawal & Black, 2003; Black et al., 2010). It kills more children under five years of age than any other illness in every region of the world (WHO, 2009). The incidence of pneumonia in this group is approximately 156 million episodes each year, of which nearly 151 million are in developing countries and 35 million in Africa. 7 – 13% of these episodes are possibly life-threatening and require hospitalization (Rudan et al., 2008). Pneumonia is responsible for about 1.6 million deaths among children aged less than 5 years, and these occur mainly in Africa and South East Asia regions (Kabra et al., 2010). In Zimbabwe, pneumonia continues to be one of the chief causes for admissions of pediatric patients, with majority presenting with severe form (Mupfawa & Rukweza, 2020) and still is the leading cause of childhood deaths outside of the neonatal period (UNICEF, 2018). This situation must not continue (WHO, 2009). It therefore becomes necessary to forecast pneumonia cases in order to give relevant policy directions with regards to controlling and preventing the disease. This study focuses on pneumonia cases for children below 5 years of age at GDH.

RELATED STUDIES

Kisworini & Sutaryo (2010) sought to find the clinical signs, demographic factors and laboratory data that can be used as predictors of mortality from pneumonia. The historical case-control study was carried out in Sardjito Hospital between January 2004 and December 2006. Data were obtained from medical records. Differential proportion between groups was analyzed with chi square. Regression analysis was used to identify clinical factors, demographic factors and laboratory factors that associated with mortality from pneumonia. The study concluded that Tachycardia and anemia were independent predictors of mortality in children with pneumonia. Forsberg (2012) analyzed pneumonia among hospitalized children aged 1 – 9 years in Tanzania. Employing the clinical definition and severity assessment of childhood pneumonia by WHO, 140 patients were identified among the 209 children aged 1 – 9 years treated for pneumonia during the period June 2010 – July 2011. The patients admitted in June 2010 – May 2011 were included in a retrospective study solely based on information in their medical files. Patients admitted during the period June – July 2011 were included in prospective study, where information was obtained from the caregiver present regarding socio-economic status, crowding, and indoor air-pollution. No significant risk factors for pneumonia and case-fatality were identified. The results of the study also revealed that relapsing pneumonia tended to be more common in boys than girls.
Caruana et al. (2015) presented two case studies where high-performance generalized additive models with pairwise interactions were applied to real healthcare problems yielding intelligible models with state-of-the-art accuracy. In the pneumonia risk prediction case study, the intelligible model uncovers surprising patterns in that data the previously had prevented complex learned models from being fielded in this domain, but because it is intelligible and modular allows these patterns to be recognized and removed. In the 30-day hospital readmission case study, results indicate that the same methods scale to large datasets containing hundreds of thousands of patients and thousands of attributes while remaining intelligible and providing accuracy comparable to the best (unitelligible) machine learning methods. Kadam et al. (2019) used a deep learning approach based on convolutional neural networks and residual networks to predict pneumonia in India. The proposed models were found to be so useful as to help doctors better predict pneumonia in minimal time with high efficiency. Verma & Prakash (2020) proposed a Convolutional Neural Network

(CNN) model prepared without any preparation to group and identify the occurrence of pneumonia from a given assortment of chest X-ray image tests. The study concludes that CNN models are effective in diagnosing pneumonia patients more easily.

METHODOLOGY

There is a great growing interest in the domain of deep learning techniques for analyzing various pneumonia data sets (Suriya et al., 2019; Kadam et al., 2019; Verma & Prakash, 2020). This paper applies the multi-layer perceptron neural network type of the Artificial Neural Network technique in order to analyze pneumonia in children under 5 years of age at GDH.

3.1 Data Issues

This study is based on newly diagnosed monthly pneumonia cases (reffered to as P series in this study) in children under 5 years of age at GDH. The data covers the period January 2010 to December 2019 while the out-of-sample forecast covers the period January 2020 to December 2022. All the data employed in this paper was gathered from GDH Health Information Department.

FINDINGS OF THE STUDY

4.1 DESCRIPTIVE STATISTICS

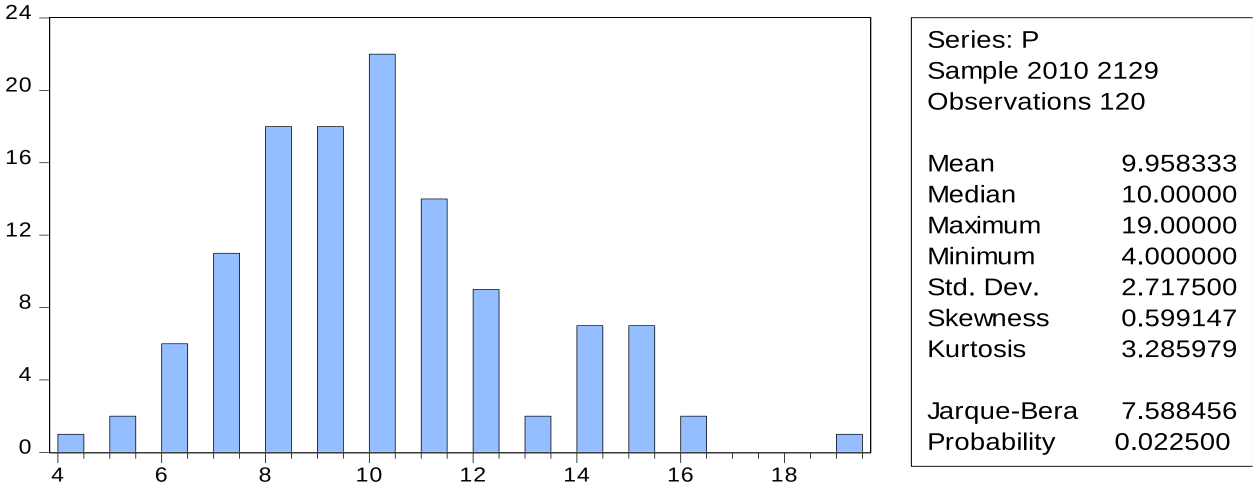

Figure 1: Descriptive statistics

As shown in figure 1 above, the average number of pneumonia cases over the study period was approximately 10 cases per month. This shows that pneumonia is a real threat to public health. The minimum number of pneumonia cases is 4 while the maximum is 19.

4.2 ANN MODEL SUMMARY FOR GDH

Table 1: ANN model summary

Variable	P
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	0.088779
MSE	0.547340
MAE	0.619413

Table 1 displays the main results of the applied predictive model. The forecast evaluation criteria support the notion that the applied model is adequate.

Residual Analysis for GDH (under 5) pneumonia cases

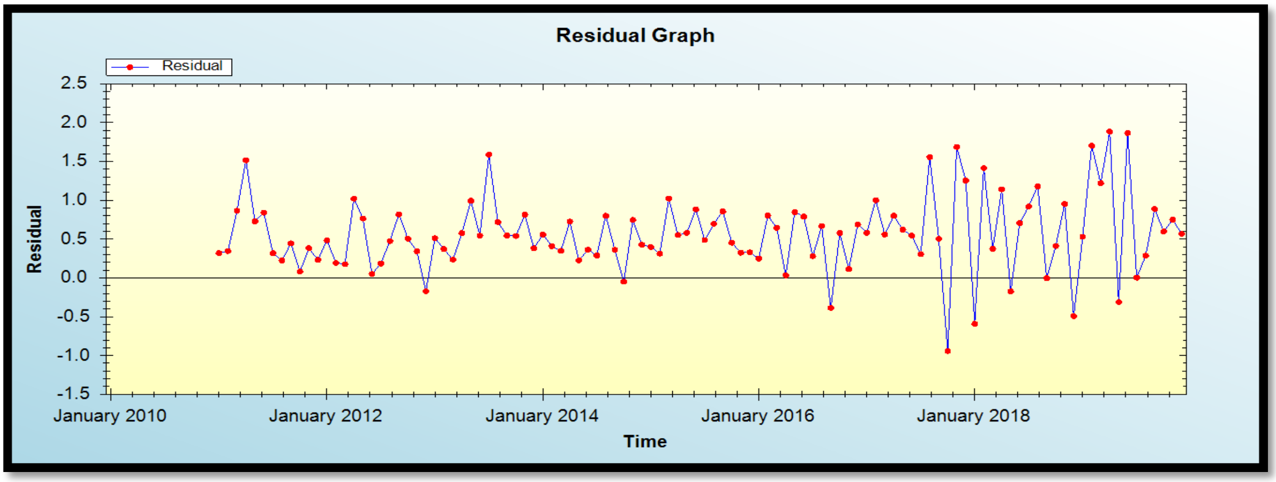

Figure 2: Residual analysis for GDH under 5 pneumonia cases

Figure 2 above shows the residual plot to of the applied model. The residual are as close to 0 as possible and this confirms the adequacy of the applied neural network.

In-sample Forecast for P

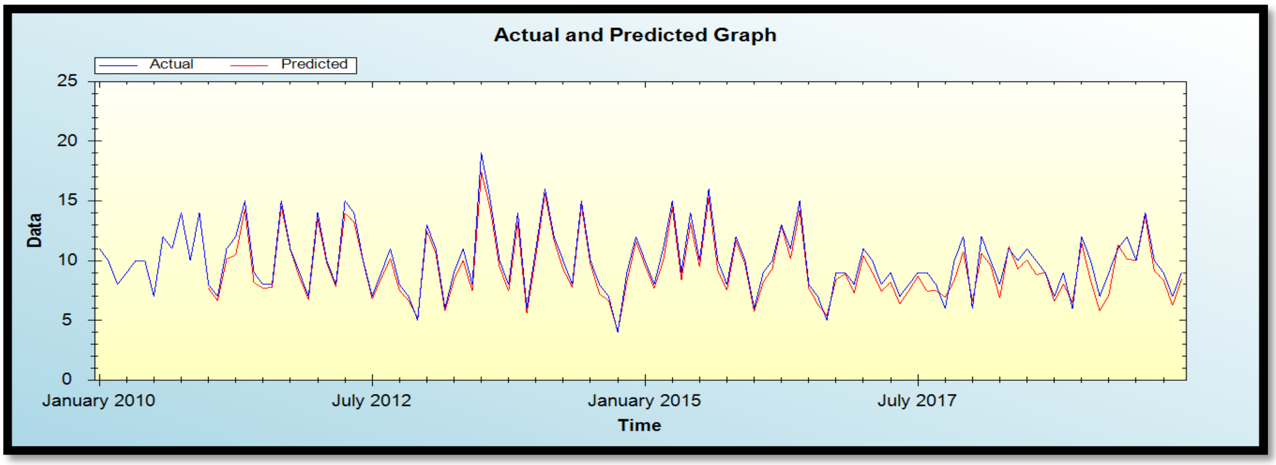

Figure 3: In-sample forecast for the P series

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

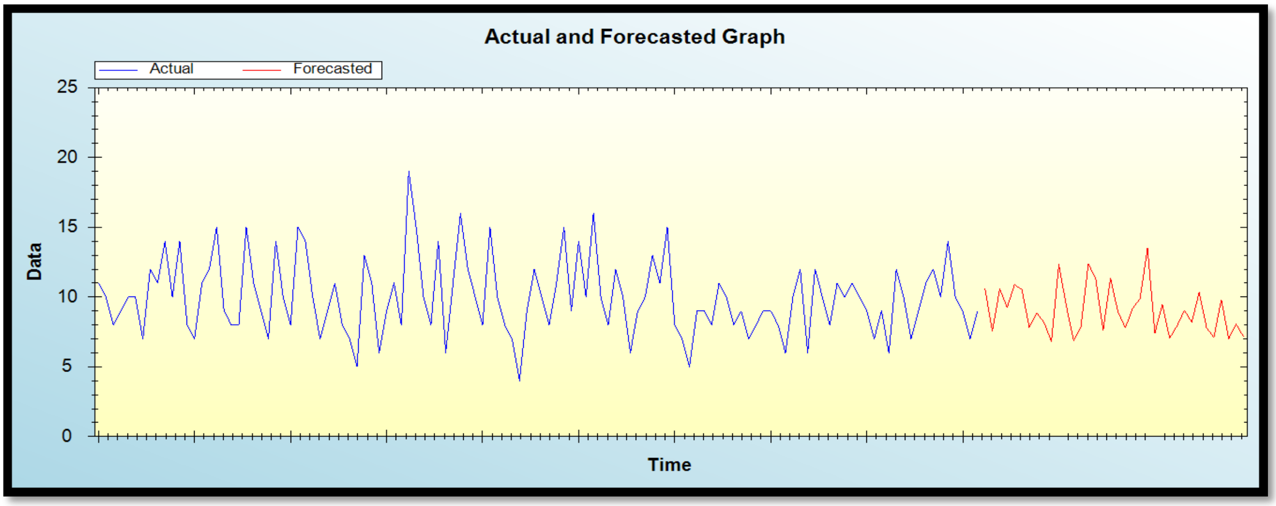

Figure 4: Out-of-sample forecast for P: actual and forecasted graph

Out-of-Sample Forecast for P: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Forecasted

Month/Year	Predicted P
January 2020	10.6280
February 2020	7.5349
March 2020	10.5910
April 2020	9.2565
May 2020	10.8878
June 2020	10.5310
July 2020	7.8214
August 2020	8.8689
September 2020	8.1712
October 2020	6.8064
November 2020	12.3223
December 2020	9.4162
January 2021	6.8703
February 2021	7.8742
March 2021	12.3893
April 2021	11.2991
May 2021	7.6213
June 2021	11.3584
July 2021	8.9563
August 2021	7.7898
September 2021	9.1876
October 2021	9.8879
November 2021	13.4926
December 2021	7.4153
January 2022	9.4567
February 2022	7.0572
March 2022	7.9272
April 2022	9.0452
May 2022	8.2029
June 2022	10.3470
July 2022	7.8069
August 2022	7.1120
September 2022	9.8240
October 2022	7.0179
November 2022	8.0668
December 2022	7.1762

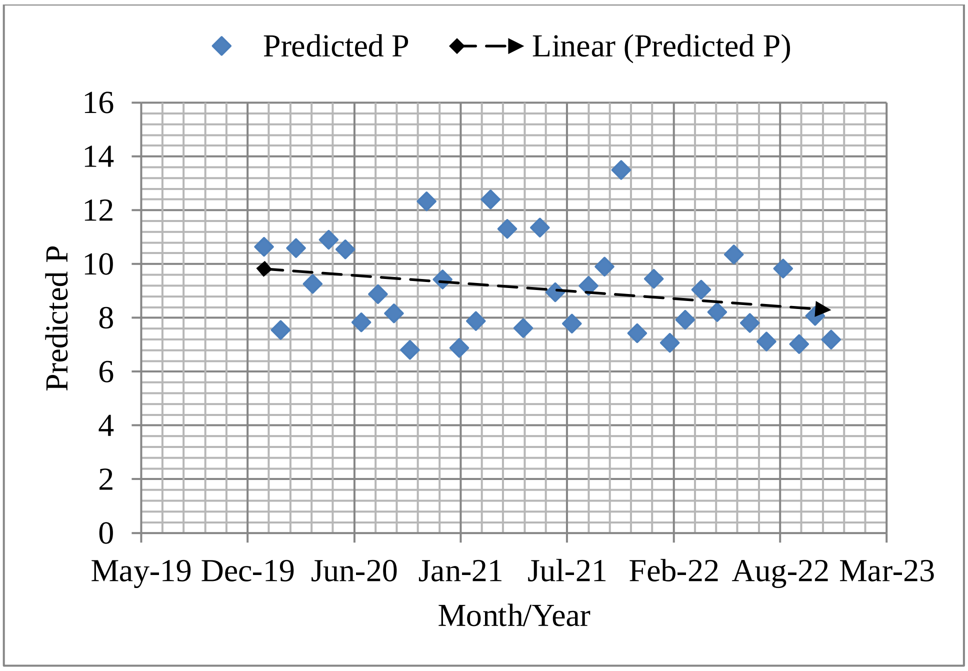

Figure 5: Graphical presentation of out-of-sample forecasts

Figure 3 – 5 as well as table 2 display out-of-sample forecasts. Pneumonia cases in children under 5 years of age at GDH are projected to decline over the out-of-sample period. This is a desirable outcome in the fight against pneumonia in the GDH catchment area and Zimbabwe at large. In order to consolidate GDH's fight against pneumonia, the study offers five main policy recommendations.

4.3 RECOMMENDATIONS

i. Increase awareness of pneumonia as a major cause of child death.
ii. Scaling up of essential interventions for pneumonia, for example, putting in place essential drugs and resuscitation equipment.
iii. Prevent children from becoming ill with pneumonia: this can be done through making sure that children have access to their recommended vaccinations such as vaccines against measles and pertussis as well as vaccines against Streptococcus pneumonia (Spn) and Haemophilus influenzae type b (Hib).
iv. Protect children by providing an environment where they are at low risk of pneumonia: that is, engaging in exclusive breastfeeding for six months, adequate nutrition, hygiene and sanitation amongst others.
v. All children who become ill with pneumonia should be treated urgently. Severe pneumonia cases should be reffered to a higher level of the referral system, that is, Gweru Provincial Hospital urgently.

CONCLUSION

Pneumonia remains the leading cause of mortality in children under 5 years of age globally (Rodrigues & Groves, 2018), but early diagnosis and intervention can effectively reduce mortality (Rambaud-Althaus et al., 2015). The current study was based on monthly observations of pneumonia cases for children under the age of five at GDH over the period January 2010 – December 2019. The study relied upon the Artificial Neural Networks in order to forecast the number of pneumonia cases in the out-of-sample period. The results of the study basically indicate that pneumonia cases in children below five years of age will decline at GDH over the period January 2020 – December 2021.

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