



Research Article

A Box-Jenkins ARIMA Modeling Approach for Infant Mortality Rate in Maiduguri, Borno State

¹Hamidu Aliyu Chamalwa and ²Faisal Mohammed Kumshe

¹Department of Statistics, Faculty of Physical Sciences, University of Maiduguri-Borno State

²Department of Mathematics and Computer Science, Faculty of Science, Borno State University, Maiduguri-Borno State

*Corresponding author's Email: chamalwa@unimaid.edu.ng, doi.org/10.55639/607.232221

ARTICLE INFO:

ABSTRACT

Keywords:

Assess,
Child,
Death,
Fitted,
Order

The research utilizes the ARIMA model to conduct a comprehensive time series analysis on infant mortality rates in Maiduguri, revealing trends and seasonality. For both genders, there's a recent fluctuation in trends. Autocorrelation and partial autocorrelation functions are employed to determine the model's order. The data were transformed into stationary by differencing once after which ADF and KPSS were used to confirm the stationary status; several tentative models were fitted and assessed for best fit; using the AIC, BIC and HQIC criteria. The chosen models are ARIMA (0,1,2) for male and ARIMA (0,1,1) for female was validated through diagnostics and employed for forecasting. Forecasts for 2024 indicate an unstable trend for males and stability for females. Recommendations include: enhancing delivery channels and community-based services, particularly in high-mortality areas, emphasizing girl-child education through religious and traditional leader advocacy campaigns.

Corresponding author: Hamidu Aliyu Chamalwa, Email: chamalwa@unimaid.edu.ng

Department of Statistics, Faculty of Physical Sciences, University of Maiduguri-Borno State, Nigeria

INTRODUCTION

Curbing infant mortality has been of concern to government and stakeholders in developing nations, successive governments at both state and national levels in Nigeria and Borno state in particular have come up with policies and programmes targeted at improving maternal and infant healthcare services; this is achieved through education and information on the

importance and availability of antenatal, neonatal and postnatal healthcare services in state-owned healthcare centres and Non-Governmental Organizations provided. Expansion and construction of new healthcare centres in the state; accessibility and affordability; among others. Infant mortality assessment and understanding highlights its essence and role as an essential part of all healthcare indicators in

Nigeria due to the fact that infancy is one of the most delicate stages of life. It equally points to the overall well-being of the infant and pregnant women, quality and accessibility of healthcare services and other socioeconomic factors.

Infant mortality rate is affected by GDP per capita as a proxy for income, public health expenditure as a percentage of GDP, Prevalence of HIV and the participation of adult female in the labour force (Osawe, 2014). Adedini (2013) further explained that newborn deaths encompass the chances of infants not reaching their first birthday. This issue is of significant National and international concern, requiring a proper and more concerted efforts for an effective mitigation. The study by Ouma, Bashar, and Tuno (2014) presented neonatal mortality as deaths occurring within the first 28 days of life, categories into early neonatal (0-6 days) and late neonatal (7-28 days) deaths. WHO (2006) attributed neonatal deaths and stillbirths to factors such as: poor maternal health, inadequate pregnancy care, complications during pregnancy and delivery, hygiene issues during delivery, and lack of newborn care. Additionally, some deaths result from severe malformations, premature birth, obstetric complications, difficulty adapting to post-birth life, or harmful post-birth practices leading to infections. Modeling makes it possible to predict future values of infant mortality using historical data, outlining and estimating possible scenarios of the health event and its magnitude.

Aigbe *et al.* (2012) in a study spatial analysis of infant and child mortality rates among the geopolitical zones of Nigeria and reported that spatial differences in infant mortality rates and under-five mortality rates among the country's geo-political regions in 1999 and 2008 and by rural urban residence were significant. Northeast has clusters of highest under-five mortality rates and southwest had the lowest under-five mortality rate clusters.

Ugoh *et al.* (2022) modelled Infant Mortality Rate (IMR) by gender for Nigeria and showed that on Male and Female attained stationarity after the second differencing. ARIMA (2,2,0) and ARIMA (1,2,0) were the best fit for male and female infant mortality rate respectively. They concluded that there will be a decline in male infant mortality rate in the nearest future

Etionwu *et al.* (2020) used logistic regression and linear discriminant analysis approach to model using the data from Enugu State University Teaching Hospital (ESUTH), revealed that infants' weights have significant effect on the birth outcome classification

ARIMA (1, 2, 5) model was the best for fitting and forecasting in infant deaths in Zimbabwe and that infant deaths per year for out-of-sample forecast *exhibit a downward trend* (Nyoni, 2020)

Khan *et al.* (2019) reported a strong negative correlation between infant mortality rate and GDP (PPP) for developed and developing nations and found out that AR (1) model was the best for most of the countries while AR (1, 1, 1) model was the most appropriate for Nepal and Japan respectively.

Due to the persistence of infant mortality as a public health problem, the applicability of this method (modeling) will be useful in the timely and systematic management of child health indicators, in addition to being a method with least cost of operation, which in the contexts of cost reduction in public healthcare services, becomes a robust management tool (Silva, 2021) This study is to assess the infant mortality rate for both gender in Maiduguri based on historical data, fit an appropriate model, make forecast and recommend.

MATERIALS AND METHODS

The study utilized a time series modeling approach to examine the cases of infant mortality spanning from the year (2008-2022) data were sourced from the medical records unit of Umaru Shehu Ultra-Modern Hospital. ARIMA models were developed to forecast infant mortality data.

The data set was split into male and female data (Jan 2008-Dec 2022). The data are monthly recorded cases of infant mortality amounting to One Hundred and Twenty (120) observations.

Ethical clearance

This study relies on secondary data obtained from Umaru Shehu Ultra-Modern Hospital Maiduguri. As indicated in the section above, we sought and received permission from the hospital. Copies of the aim, purpose, and data requirements were submitted for clearance and approval. We are

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \dots - \theta_q e_{t-q} \quad (1)$$

We say that $\{Y_t\}$ is a mixed **Autoregressive Moving Average** process of orders p and q , respectively; ARMA(p, q).

Using the lag operator $L^d Y_t = Y_{t-j}$ for all j . It becomes

$$\text{Or } \phi(L)Y_t = \theta(L)e_t \quad (2)$$

$$\text{Where, } \phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \dots - \phi_p L^p \quad (3)$$

$$\theta(L) = 1 - \theta_1 L - \theta_2 L^2 - \dots - \theta_q L^q$$

Autoregressive (AR) process and Moving Average (MA) process are special cases of ARMA

Autoregressive: AR(p) model

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + e_t \quad (4)$$

Moving Average: MA(q)

$$Y_t = e_t + \theta_1 e_{t-1} + \theta_2 e_{t-2} + \dots + \theta_q e_{t-q} \quad (5)$$

Autoregressive Integrated Moving Average (ARIMA) model

A time series $\{Y_t\}$ is said to follow an **Integrated Autoregressive Moving Average** model if the

$$W_t = Y_t - Y_{t-1} \text{ we have}$$

$$W_t = \phi_1 W_{t-1} + \phi_2 W_{t-2} + \dots + \phi_p W_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \dots - \theta_q e_{t-q} \quad (6)$$

Where $e_t \sim WN(0, \sigma^2)$

Autoregressive (AR) Process: A stationary AR(p) process satisfies the following

$$e_t = Y_t - \theta_1 Y_{t-1} - \theta_2 Y_{t-2} - \dots - \theta_q Y_{t-q} \quad \text{Where } e_t \sim WN(0, \sigma^2) \quad (7)$$

Moving Average (MA) Process: A Moving Average MA(q) process satisfies the following

$$Y_t = e_t + \theta_1 e_{t-1} + \theta_2 e_{t-2} + \dots + \theta_q e_{t-q} \quad \text{Where } e_t \sim WN(0, \sigma^2) \quad (8)$$

Modeling fitting

Box-Jenkins ARIMA methodology is a two-way three step approach: identification, estimation and diagnostics/forecasting

confident in stating that the datasets utilized in this study have been ethically cleared and approved by the hospital's ethical clearance committee.

Autoregressive Moving Average (ARMA) model

This is a model that is employed when the data displays a decaying Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). Its represented mathematically as

d th difference $W_t = \nabla^d Y_t$ is a stationary ARMA process. If $\{W_t\}$ follows an ARMA(p, q) model, we say that $\{Y_t\}$ is an ARIMA(p, d, q) process.

1. **Identification:** the identification is accomplished through examination of the time series plot, the ACF, PACF and unit root test to assess the trend, possible

order of the tentative model and stationarity

2. **Estimation:** this the act of finding best estimate for the unknown parametres of

$$AIC(p, q) = \log[(\hat{\sigma}^2_{p,q}) + \frac{(p+q)^2}{T}] \tag{9}$$

Schwarz Information Criteria (SIC), Schwarz, 1978)

$$SIC(p, q) = \log[(\hat{\sigma}^2_{p,q}) + \frac{(p+q)\log(T)}{T}] \tag{10}$$

Hannan-Quinn Information Criteria (HQIC), Hannan-Quinn, 1979), are used to determine the best fit

3. **Diagnostics:** the fitted models are assessed for any inadequacies by making sure all the assumptions were well satisfied. If they are reasonably satisfied, then the model is used for forecasting.

the tentative model through maximum likelihood methods. Akaike information criteria ((AIC), Akaike, 1969)

RESULTS AND DISCUSSION

A total of one-hundred and seventy nine (179) observations for both male and female data. The data were subjected to trend analysis and stationarity test. The results were presented and discussion were mad on each

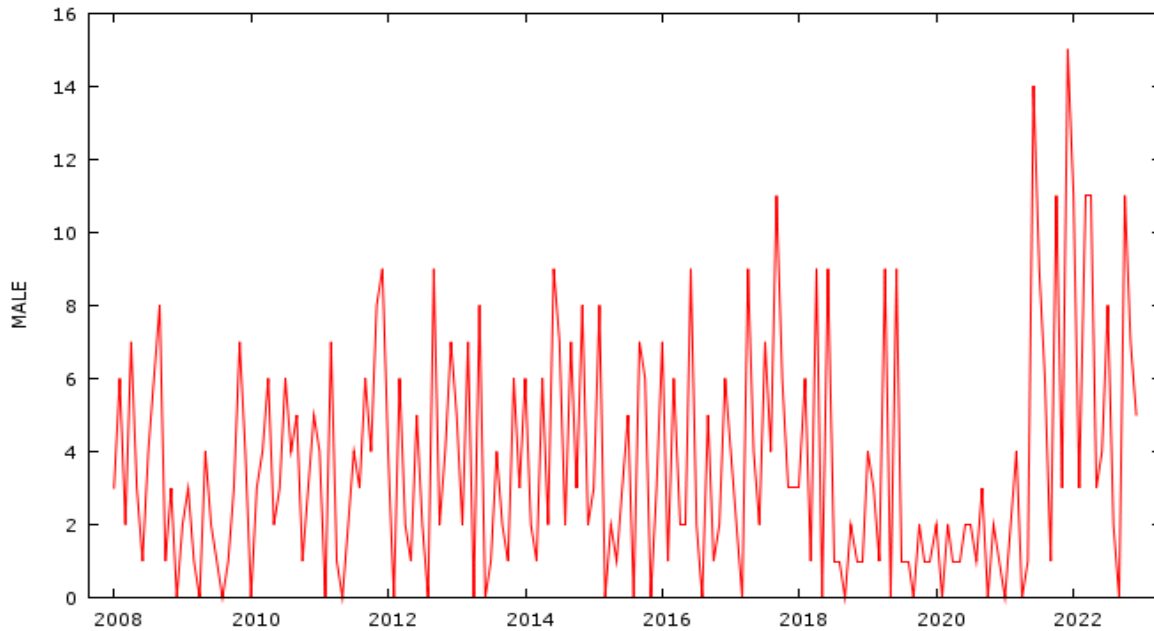


Figure 1: Time Series for Male Infant Mortality

The figure above shows the time plot for the male infant mortality rate for the period of 2008-2022. The graph revealed a slight increase towards the

end, this means there is no evidence of constant variance. The series is non-stationary and hence need to be differenced to achieve stationarity.

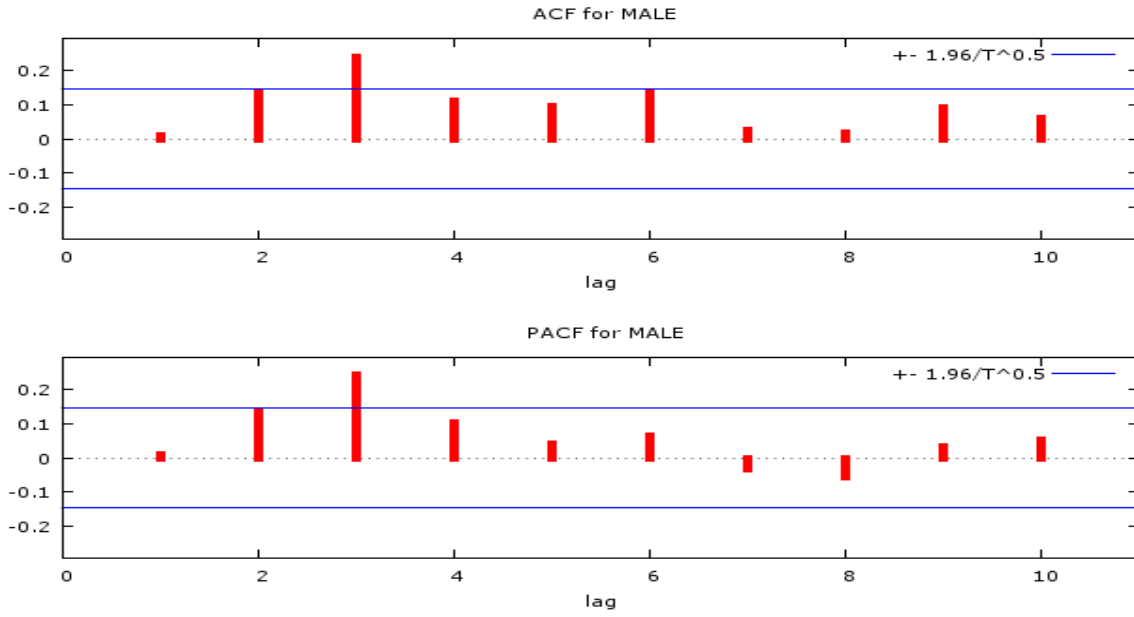


Figure 2: ACF and PACF plot for male.

The graph shows that the series is non-stationary since most the values for both the ACF and PACF are significant.

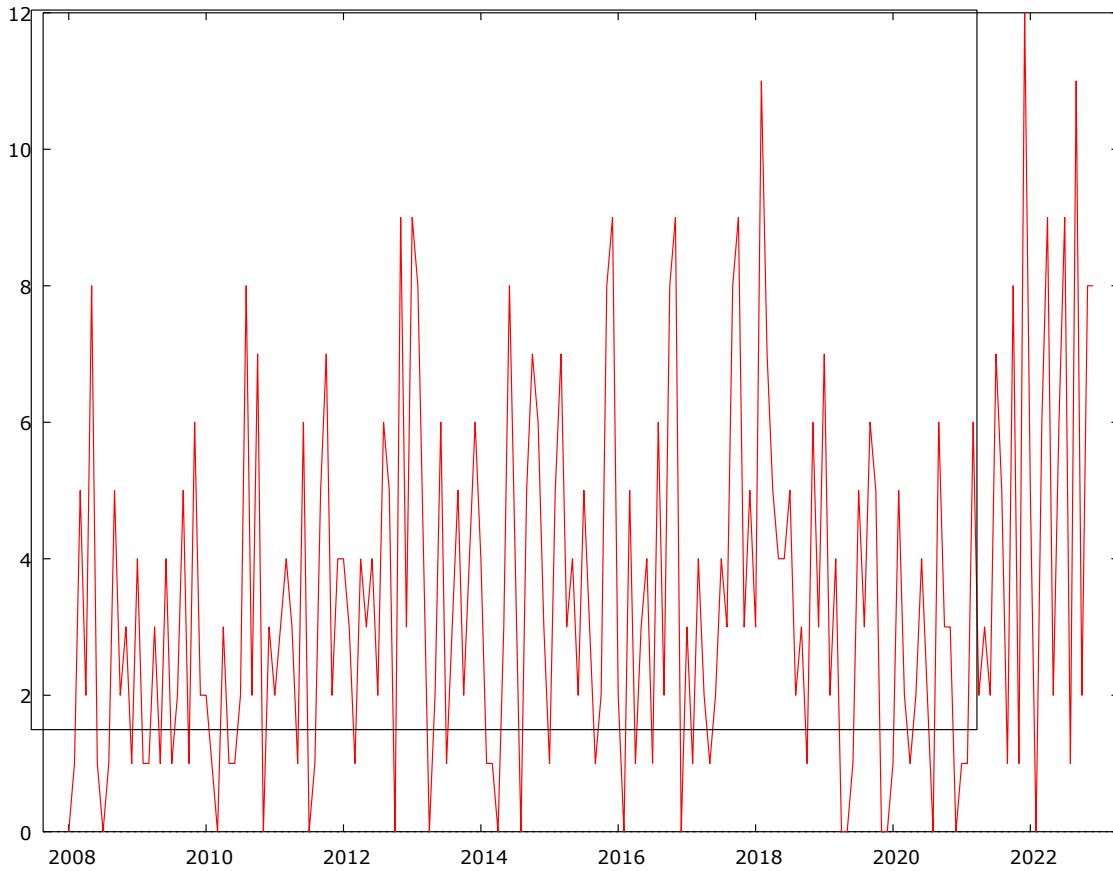


Figure 3: Time Plot for Female Infant Mortality

The graph revealed a slight increase towards the end, this means there is no evidence of constant variance for the Female Mortality Data. The

series is non-stationary and hence need to be differenced to achieve stationarity.

Table 1: Augmented Dickey-Fuller (ADF) Test

	At level		At first difference	
	Statistic	P-value	Statistic	P-value
Male	-1.69519	0.087	-10.6587	0.000
Female	-3.34976	0.076	-16.2885	0.000

The results for the ADF test shows that the series are non-stationary at level p-values 0.087 and 0.076 respectively but became stationary after the

first differencing p-values 0.000 and 0.000. i.e the mean and variance of the data (Male and Female) are now stable

Table 2: Model Selection for Male Infant Mortality

Models	AIC	SIC	HQN
ARIMA (1,1,1)	924.4981	937.2477	929.6680
ARIMA (2,1,1)	925.3970	941.3339	931.8593
ARIMA (2,1,2)	926.6966	945.82209	934.4513
ARIMA (1,1,2)	926.2233	942.1602	932.6856
ARIMA (1,1,0)	981.1035	990.6657	984.9809
ARIMA (0,1,1)	926.3376	935.8982	930.2134
ARIMA (0,1,2)	924.2517	937.0013	929.4216

A comparison of the AIC, SIC and HQC values in Table 2 for the possible models shows that ARIMA (0,1,2) has the minimum value.

Therefore, the ARIMA (0, 1, 2) produced least values and is therefore selected as the best fit model for the data and forecast.

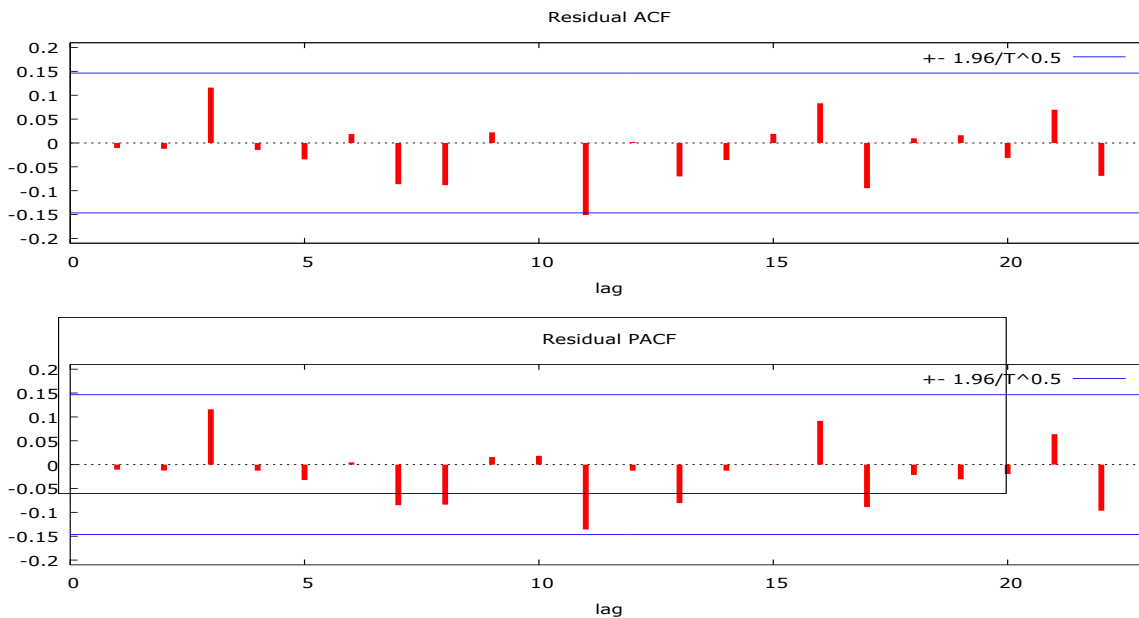


Figure 4: Graph of residual ACF and PACF for the ARIMA (0,1,2) model

The graph shows that the fitted ARIMA (0,1,2) model is best since ACF and PACF coefficients for all the lags are insignificant and within the

bands. Implying there is an evidence of non-autocorrelations in residuals of the fitted model

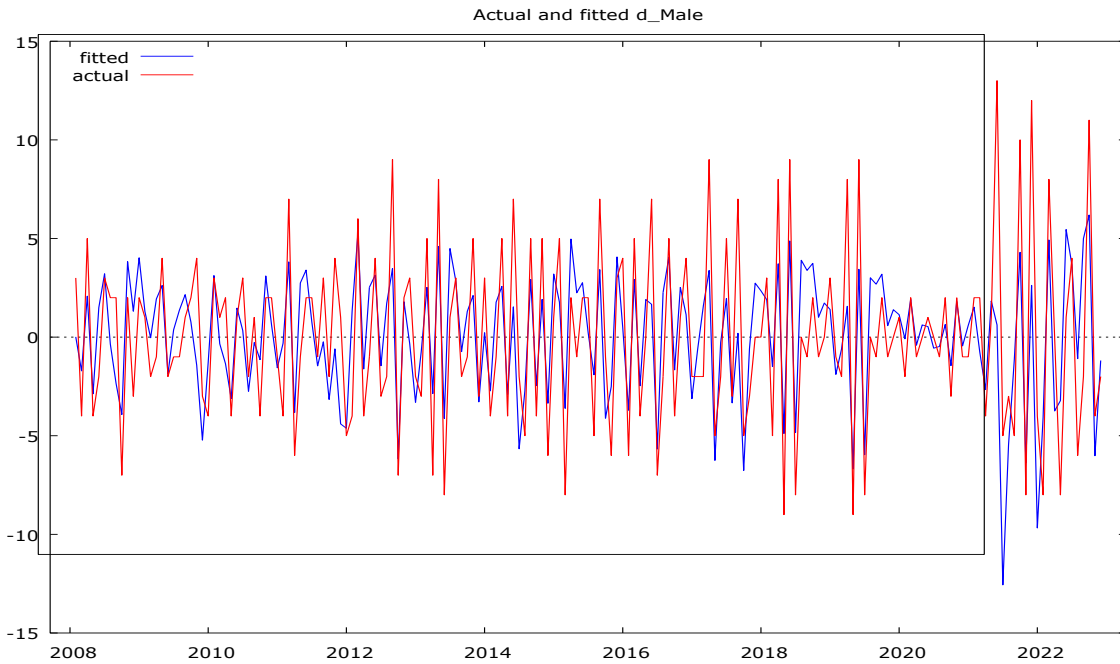


Figure 5: Graph of actual and fitted difference Male Infant data

The fitted (blue) and the actual (red) overlapped indicating that ARIMA (0,1,2) is the best fit for the male mortality data

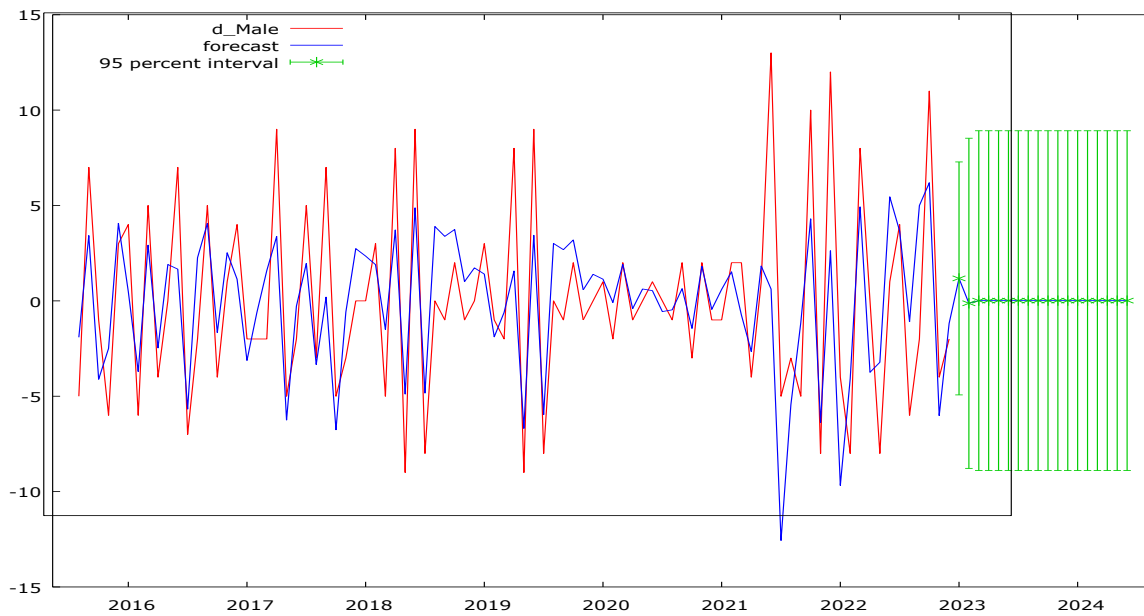


Figure 6: Graph of forecasted for year 2024

The graph above shows that there will be a significant decrease in the male infant mortality in the year 2024

Table 3: Model Selection for Female Infant Mortality

Models	AIC	SIC	HQC
ARIMA (1,1,1)	870.3022	883.0518	875.4721
ARIMA (2,1,1)	872.0548	887.9918	878.5171
ARIMA (2,1,2)	873.0335	892.1578	880.7883
ARIMA (1,1,2)	871.7778	887.7147	878.2401
ARIMA (1,1,0)	932.3707	941.9328	936.2480
ARIMA (0,1,1)	868.4232	877.9853	872.3005
ARIMA (0,1,2)	870.1002	882.8499	875.2702

From the ARIMA (0,1,1) is the one with the smallest of the three criteria of AIC, SIC and HQC. Therefore, it is the best fit for the female infant mortality rate data for the period under study.

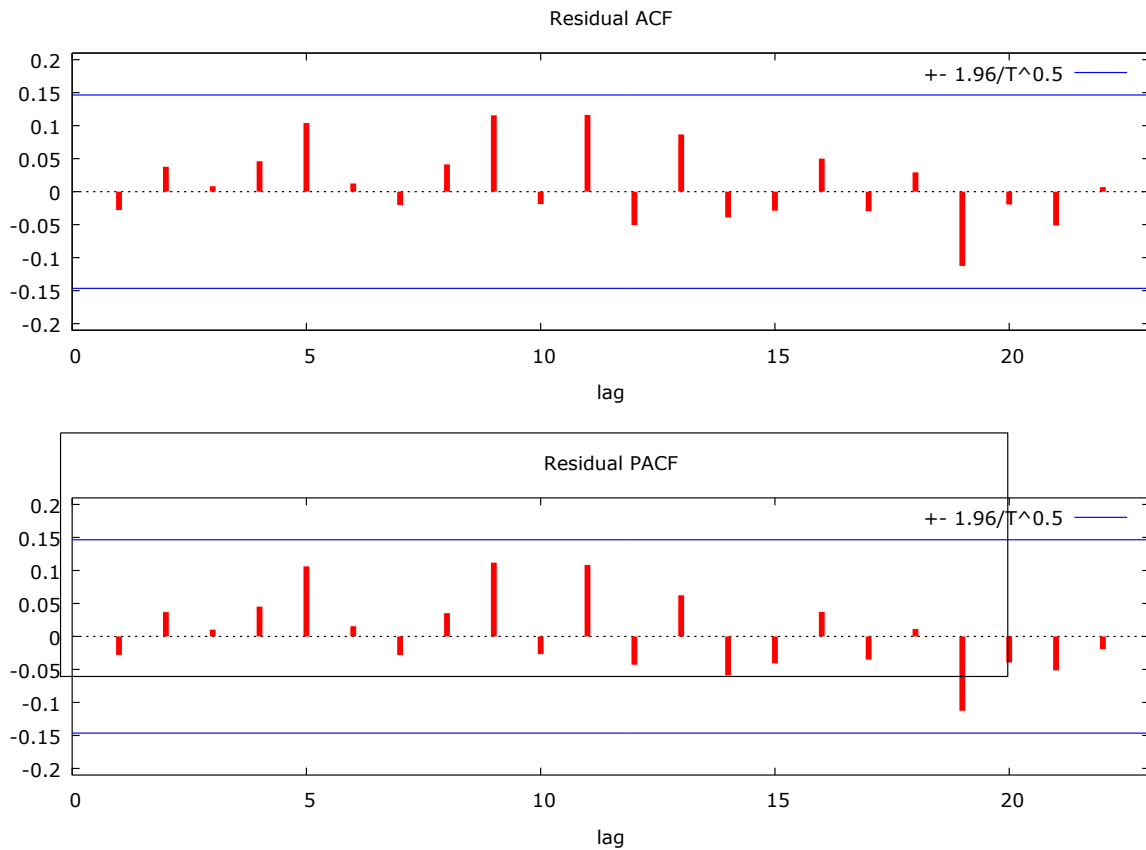


Figure 7: ACF and PACF for the ARIMA (0,1,1) model

The ACF and PACF graph shows that the fitted ARIMA (0,1,1) model is best with coefficients for all the lags insignificant and within the bands.

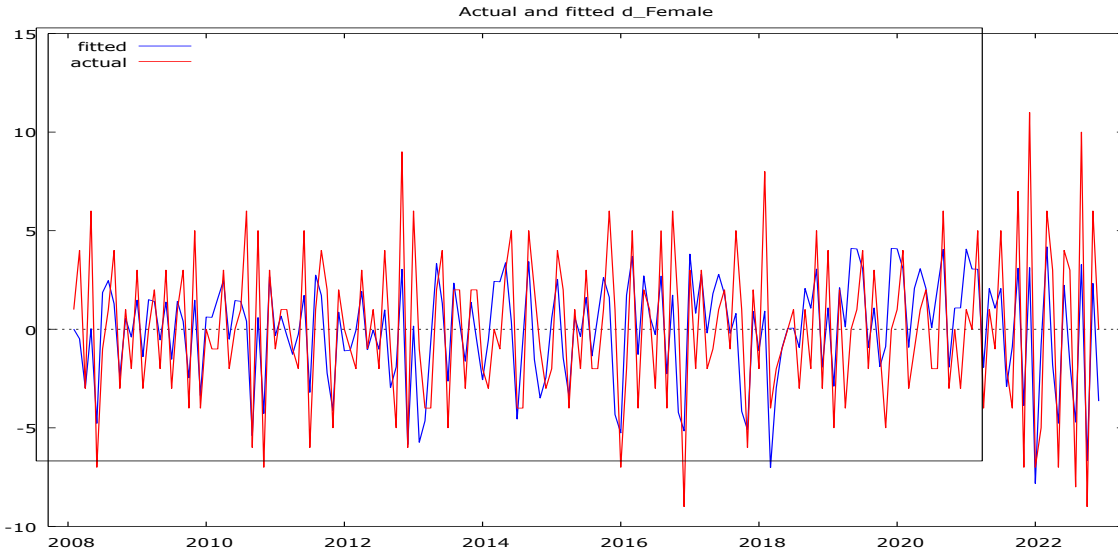


Figure 8: Graph of fitted and the actual value based on the ARIMA (0,1,1)
 The graph above confirms that the model is a good fit for data since the red and blue lines overlapped

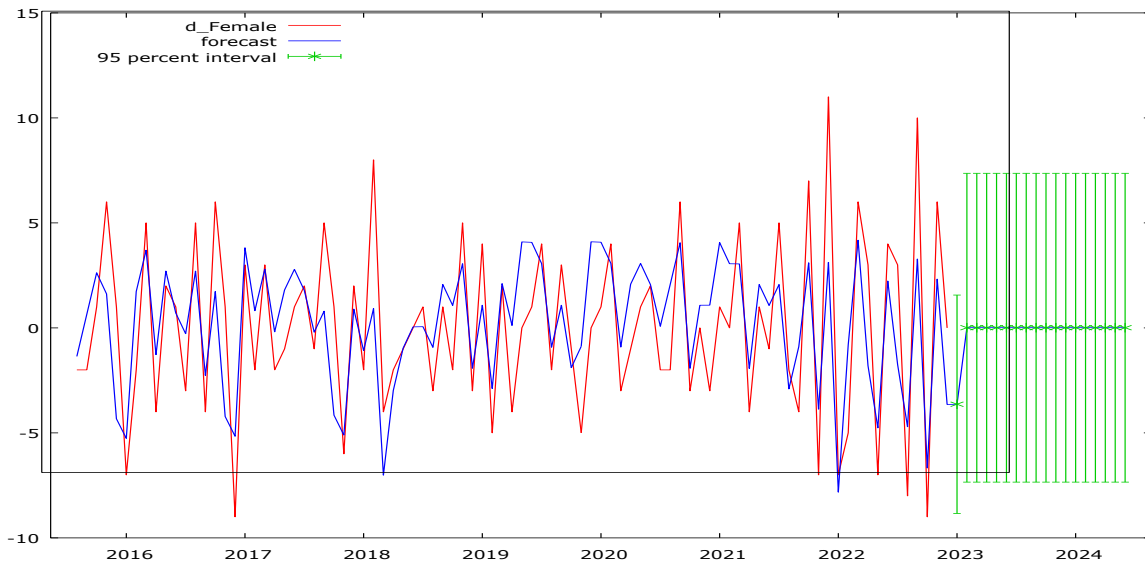


Figure 9: Graph of forecasted for the year 2024
 The graph above shows that there will be a significant decrease in the female infant mortality in the year 2024

CONCLUSION

The study analyzed Box-Jenkins ARIMA modeling approach to model and forecast Infant Mortality rates in Borno State, Nigeria. The trends analysis and examination for both male and female data shows an upward trend implying a non-stationarity. ARIMA (0,1,2) and ARIMA

(0,1,1) was selected as the best fit model for forecasting the male and female infant mortality data. The forecast indicated a decrease in the mortality values for the year 2024 and near future. In terms of recommendations, the study suggests government should intensify effort in enhancing delivery channels and community-

based services, adequate provision of healthcare facilities especially maternal and child. There is the need to localize and make healthcare accessible to vulnerable populations. Women education and empowerment should be given more priority as will reduce poverty and improve their overall healthcare status.

ACKNOWLEDGEMENT

We wish to acknowledge the management of Umaru Shehu Ultra-Modern Hospital for

approving our request and releasing the data for this study. The study was intended to bring to light the effort of government and stakeholders over the years in the healthcare sector toward mitigating and improving Maternal and Infant related mortality. Suggestions and recommendations were made for policy implication and management.

REFERENCES

- Aigbe, G. O. (2012) Differentials in Infant and Child Mortality Rates in Nigeria: Evidence from The Six Geopolitical Zones *International Journal of Humanities and Social Science* Vol. 2 No. 16.
- Akaike, H., (1976). *Canonical Correlation Analysis of Time Series and the use of an Information Criterion*. In: Mehra, R.K., Lainiotis, D.G. (Eds.), *Systems Identification: Advances and Case Studies*. Academic Press, New York
- Etionwu, A. L.1, Igwenagu, C. M., Onovo, J. O., and Ezeani, C. M. (2020) Estimation of Infant Mortality in Enugu State Teaching Hospital Park Lane, Enugu Using Logistics Regression and Linear Discriminant Analysis Approach. *Coou Journal of Physical Sciences* 3(1), 229-240
- National Bureau of Statistics (NBS) (2011). Nigeria: Monitoring the situation of children and woman. *Nigeria Multiple Indicator Cluster Survey 2011 Summary Report*. National Bureau of Statistics, Abuja Nigeria. 2011.
- Nyoni S. P. (2020) Modeling and Forecasting Infant Deaths in Zimbabwe Using ARIMA Models *Novateur Publications Journal nx- A Multidisciplinary Peer Reviewed Journal* Vol. 6, (7), 2581 – 4230
- Osawe, O. W.(2014) Determinant of Infant Mortality Rate: A Panel Data Analysis of African Countries *Developing Country Studies* www.iiste.org ISSN 2224-607X (Paper) ISSN 2225-0565 (Online) Vol.4, No.18,
- Samuel, W. S & Amoo, E.O. (2014). A Statistical Analysis of Child Mortality, *Journal of Demography and Social Statistics*, 1:110-20
- Silva A.B.S, Araújo A C M and Frias P. G. (2021) Auto-Regressive Integrated Moving Average Model (ARIMA): Conceptual and Methodological Aspects and Applicability in Infant Mortality *Rev. Bras. Saúde Mater. Infant., Recife*, 21 (2): 647-656
- Ugoh C. I. Et'al (2022) On Forecasting Infant Mortality Rate by Sex Using Arima Model: A Case of Nigeria *European Journal of Statistics and Probability* Vol.10, No.2, Pp., 29-38,
- World Health Organization, WHO (2011). Child Mortality: Millennium Development Goal (MDG) 4. The partner for Maternal and New Born Birth, World Health Organization http://www.who.int/pmch/media/press_material/fs/fs/mdg4_childmortality/e