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Application of Time Series Decomposition Techniques of Admission Patterns in Orphanage Homes

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Abstract

This study applies decomposition technique on the admission of orphans and vulnerable children (OVC) into orphanage homes. Present studies have dwelt more on the number of OVC, the estimation of the parents that are dead, and the socioeconomic well-being of OVC. Hence, there is need to study the pattern of OVC admittance. Monthly data were collected from Niger state orphanage home register and documented for a period of twenty years (2000-2020). A time series decomposition analysis was carried out to determine an appropriate model, investigate the trend of admission of OVC, and establish if there is a seasonal pattern in the series. Results showed that the pseudo-additive model was most appropriate for the series which showed a decreasing linear trend. The study also showed that there is a seasonal pattern that has the second and third quarters of the year with the highest incidence of admission into orphanage home.

Keywords: Orphans; Vulnerable Children; Orphanage Homes; Time Series Decomposition

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INTRODUCTION

Nigeria's Federal Ministry of Women Affairs and Social Development estimated that there are 17.5 million orphans and vulnerable children (OVC) nationwide (National Population Commission-NPC/Nigeria and ICF International, 2014). As of 2021, an estimated 14.9 million children worldwide had lost one or both parents. Three-quarters of these children (11.2 million) live in sub-Saharan Africa (United Nations Children's Fund [UNICEF], 2022).

These children face enormous challenges to their health and development and it is estimated that 95% of OVC do not receive any type of medical, emotional, social, material, or school-related assistance (National Population Commission-NPC/Nigeria and ICF International, 2014). According to UNICEF, there are roughly 153 million orphans worldwide. Every day, an estimated 5,700 more children become orphans (Jones, 2018). A maternal orphan is a child whose mother has died; a paternal orphan is a child whose father has died, and a double orphan is a child whose both parents have died. Thus, the number of maternal orphans includes double orphans as does the number of paternal orphans (Rutstein, 2008).

Vulnerable children are those whose safety, well-being, and development are, for various reasons, threatened. Lack of care and affection, adequate shelter, nutrition, education and psychological support are some of the most important factors that accentuate the vulnerability of children. Often these children are neglected, abandoned, or abused or their parents may simply lack the resources to take proper care of them. Children that have lost their primary caretakers are more vulnerable to health risks, violence, exploitation and discrimination (Mutiso & Mutie, 2018).

Evans and Murvay (2008) argued that vulnerable children merit being treated with dignity and respect as stipulated in Article 19 of the African Charter on Human and People's Rights (ACHPR). The Article says "all peoples (OVC inclusive) shall be equal; they shall enjoy the same respect and shall have the same rights". The above is enshrined in Nigeria's constitution but unfortunately, many of these children are left unattended to and live in unfavourable conditions, exposed to many problems concerning health, education, moral, and psychological development and others with varying degrees of harm to both the children and society (Ojo & Olayinka, 2019).

Tagurum *et al.,* (2015) adopted a house-to-house cross-sectional survey of OVC, employed through a multi-stage sampling technique to obtain baseline information on the needs of OVC in North-Central Nigeria as a basis for the provision of relief services. Findings showed that out of 825 OVC, with ages ranging from 0-17 years and a mean age of 9.8 ± 4.5 years, 59.8% were paternal orphans, and 12.1% of children had lost both parents. Mejia-Pailles *et al.,* (2020) estimated the levels and trends in age-specific orphan prevalence and incidence in rural KwaZulu-Natal over the period 2000–2014. The study findings showed that the proportion of children and adolescents (<20 years) for whom one or both parents had died rose from 26% to 36%. Okon *et al.,* (2020) studied the socioeconomic well-being of orphans and vulnerable children in orphanages within Cross River State, Nigeria using a descriptive research method. The study revealed that a greater number of OVC were enrolled in school, more than average maintained regular school attendance, few children obtained vocational training and many experienced educational challenges.

The idea of time series decomposition has been around for a long time and was used for the calculation of planetary orbits by seventeenth-century astronomers. Persons (1919) was the first to state explicitly the assumptions of unobserved components. As Persons saw it, time series was composed of four types of fluctuations: a long-term tendency or secular trend, cyclical movements superimposed upon the long-term trend, seasonal movement within each year, the shape of which depends on the nature of the series and residual variations due to changes impacting individual variables or other major events such as wars and national catastrophes affecting several variables. Traditionally, the trend, cyclical, seasonal and random variable (Dagum, 2010). Maskurul *et al.,* (2015) on common types of decomposition models used the logarithmic transformation to convert the multiplicative model to the additive model. The study showed that decomposition models can be used to create and present seasonally adjusted values by estimating seasonal effects. The seasonally adjusted value removes the seasonal effect from a value so that trends can be seen more clearly.

The plight of the OVC is acknowledged throughout different studies, but it has not received adequate attention from researchers on the pattern in which OVC are admitted to orphanage homes and to isolate the four components of time series.

The aim of this study is to apply the decomposition technique to the number of OVC admitted into orphanage home in Niger State. The objective was to formulate an appropriate model of admittance, obtain the trend of admission and check for seasonality.

MATERIAL AND METHODS

Data source

The data used for the study were obtained from the Niger state orphanage home in Minna, Niger State. Monthly records on the number of children admitted into the orphanage home were collected from the admission register and were documented for the period of twenty years (2000 – 2020).

Time series decomposition

Time series decomposition model are the additive, multiplicative and mixed models. The components are represented as trend (T_t), the seasonal (S_t), cyclical (C_t) and irregular (I_t). If short period of time is involved, the cyclical component is superimposed into the trend and the observed time series ($X_t, t = 1, 2, \dots, n$) can be decomposed into the trend-cycle component (M_t), seasonal component (S_t), and the irregular/residual component (I_t) (Kelechukwu *et al.,* 2020).

Additive Decomposition

Additive decomposition argues that time series data is a function of the sum of its components (Plummer, 2020). Here, given the time series, X_t, t ∈ Z, the decomposition model is given by:

$$X_t = M_t + S_t + I_t \quad (1)$$

where M_t = trend-cycle component, S_t = seasonal component, I_t = irregular/residual component.

It is always assumed that the seasonal effect, when it exists, has period *m*, that is, it repeats after *m* periods, where

$$S_{t+m} = S_t \text{ for all t}$$

And it is assumed that the sum of the seasonal components over a complete period is zero (Iwueze *et al.*, 2011).

$$\sum_{j=1}^{m} S_{t+j} = 0 \quad (2)$$

Multiplicative Decomposition

Rather than a sum, the multiplicative decomposition argues that time series data is a function of the product of its components (Plummer, 2020). Here, given the time series, X_t, t ∈ Z the decomposition model is given by:

$$X_t = M_t \times S_t \times I_t \quad (3)$$

where

$S_{t+m} = S_t$ for all t

And it is assumed that the sum of the seasonal components over a complete period is m (Kelechukwu *et al.,*2020).

$$\sum_{j=1}^{m} S_{t+j} = m \quad (4)$$

Pseudo-Additive Model

A pseudo-additive model is the combination of the elements of both the additive and multiplicative models. This model assumes that seasonal and irregular variations are both dependent on the level of the trend but independent of each other (Australian bureau of statistics, 2020).

Here, given the time series, $X_t, t \in Z$ the decomposition model is given by:

$$X_t = M_t \times S_t + I_t \quad (5)$$

where

$S_{t+m} = S_t$ for all t

it is assumed that the sum of the seasonal components over a complete period is m (Kelechukwu *et al.,*2020).

$$\sum_{j=1}^{m} S_{t+j} = m \quad (6)$$

Measuring the accuracy of the model

The traditional error measures, such as mean square error, do not provide a reliable basis for the comparison of methods. There are numerous ways in which the accuracy of a

forecasting method is assessed. Hyndman divided forecast error metrics as the mean absolute error (MAE or MAD), mean absolute percentage error (MAPE), relative error and scale-free error metrics (Tirkeş *et al.*, 2017). However, MAPE has several desirable properties including reliability; ease of use and interpretation. It also incorporates all of the information in its calculation (Swanson, 2015).

Mean Absolute Percentage Error (MAPE)

MAPE is a measure in which positive and negative values do not offset each other; it measures the precision of the forecasts by showing the average per cent difference between forecasts and actual activities regardless of whether the individual forecasts were too high or too low (Swanson, 2015). MAPE is calculated using the absolute error in each period divided by the observed values that are evident for that period. Then, averaging those fixed percentages (Khair *et al.*, 2017). This measure will be used to select the most appropriate model. Selection will be based on the model with the least MAPE value.

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left(\frac{|y-\hat{y}|}{y}\right) \times 100 \quad \text{(Khair } et\ al.\text{, 2017)} \qquad (7)$$

Where y is the actual value, $\hat{y}$ is the fitted value, and n equals the number of observations.

RESULTS AND DISCUSSION

Summary Statistics

Table 1: Summary Statistics showing the number of orphans and vulnerable children admitted into orphanage homes in Niger State (2000:1 - 2020:4) (84 valid observations)

Mean	Median	Minimum	Maximum	Standard Deviation	Skewness
3.2024	3.0000	0.0000	10.0000	2.0522	0.8611

Table 1 presents the summary statistics of the orphans and vulnerable children (OVC) that were admitted from the first quarter of the year 2000 to the fourth quarter of the year 2020. From the table, we observed that the average number of OVC admitted each quarter was 3.2024 with a maximum number of 10.000 and a minimum of 0.000. The observation has a skewness of 0.8611 which lies between 0.5 and 1. This shows that the observation is moderately skewed to the right.

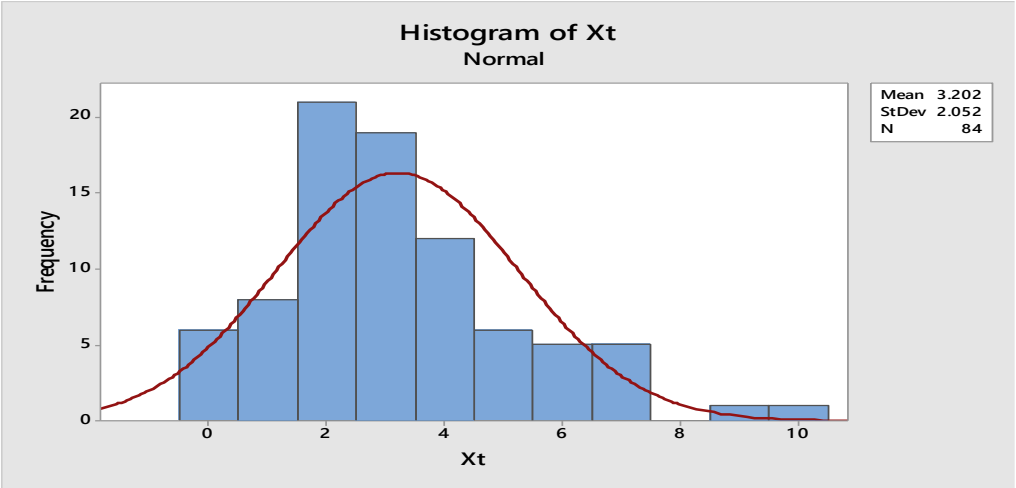


Figure 1 Histogram of OVC admission

Figure 1 further displays the shape of the distribution which showed that the right tail is longer and most of the distribution is at the left, this concludes that the distribution is moderately skewed right and close to a normal distribution.

Time Series Decomposition

The OVC data were decomposed using the three techniques discussed (multiplicative, additive, and pseudo-additive). The results for each outputted the values for Mean absolute percentage error (MAPE), Mean absolute deviation (MAD) and Mean squared deviation (MSD) as shown in Figures 2, 3 and 4. MAPE was used to select the most appropriate model.

Multiplicative Decomposition

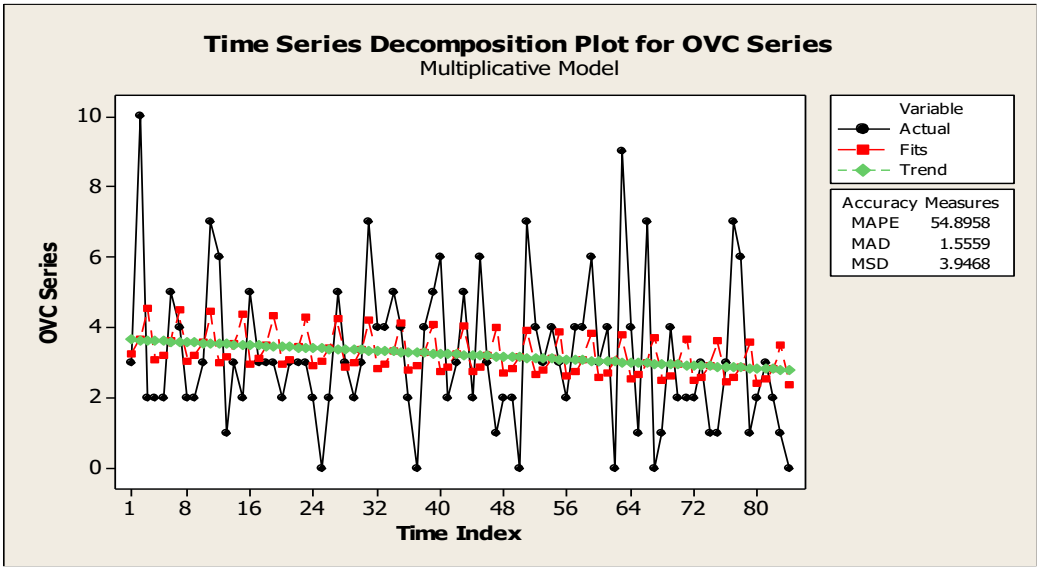


Figure 2 Multiplicative Decomposition Plot

Figure 2 shows the time series decomposition plot for the multiplicative decomposition model, which was obtained from the observed series on the number of OVC admitted into orphanage homes. In this model, the data on OVC admitted into orphanage homes in Niger State was expressed as the product of trend, seasonal and irregular components. The model fitted trend equation result was given as $X_t = 4.18400 - 0.01985t$ Where t is the time index of the observed series.

Additive Decomposition

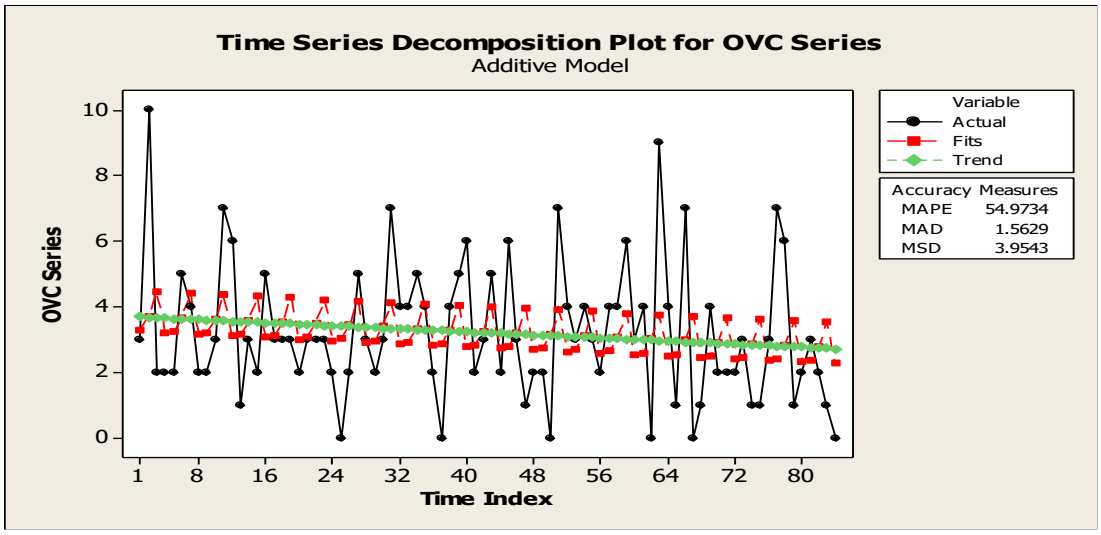


Figure 3. Additive Decomposition Plot

Figure 3 shows the time series decomposition plot for the additive decomposition model. In this model, the data on OVC admitted into orphanage homes in Niger State was expressed as the sum of trend, seasonal and irregular components. The model fitted trend equation result was given as $X_t = 3.72486 - 0.01229t$

Pseudo-Additive Decomposition

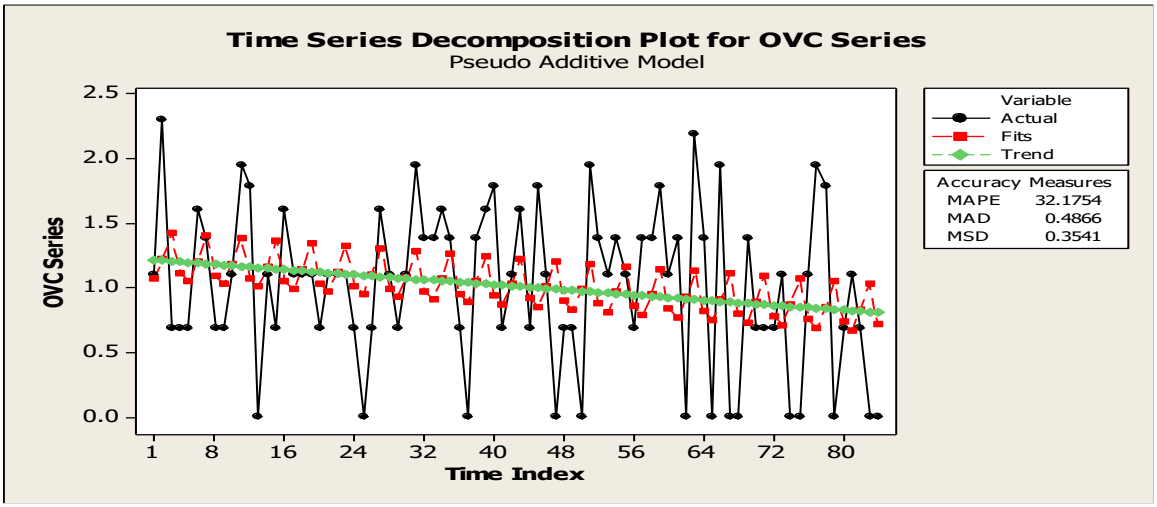


Figure 4. Pseudo-Additive Decomposition Plot

Figure 4 shows the time series decomposition plot for the pseudo-additive decomposition model. In this model, the data on OVC admitted into orphanage homes in Niger State was expressed as the product and sum of trend, seasonal and irregular components. The model fitted trend equation result was given as $X_t = 1.23932 - 0.05375t$

Table 2: Model Comparison using Accuracy Measures

	Multiplicative model	**Additive Model**	**Pseudo Additive Mode**
MAPE	54.8958	54.9734	32.1754

Table 2 shows a comparative analysis of model performance using the accuracy measures; Mean Absolute Percentage Error (MAPE). Since the model with the least accuracy measures is the pseudo-additive model (32.1754), it follows that the most appropriate model of admittance into orphanage homes is the pseudo-additive model.

Trend of the admission of OVC in the orphanage homes

Figure 5 shows the trend analysis of the number of orphans and vulnerable children admitted into the orphanage home using the de-seasonalised series. The plot shows that the admission follows a linear downward trend. This fitted linear trend equation was given as $X_t = 1.22031 - 0.00493t$

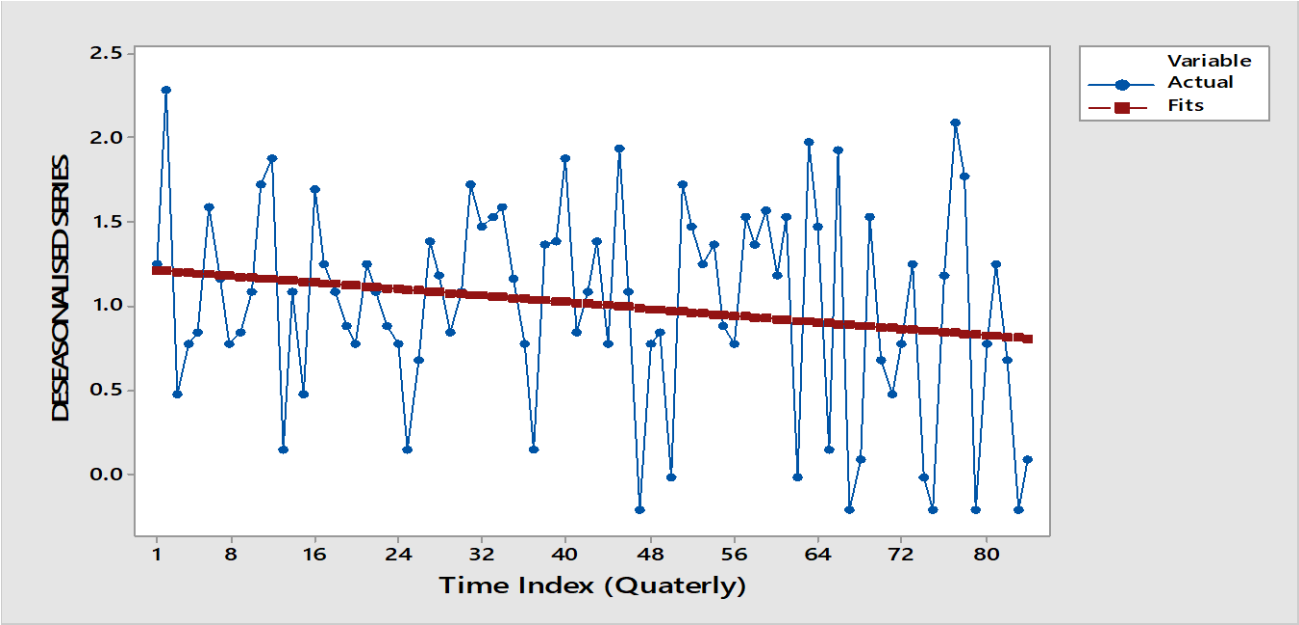


Figure 5. Trend Analysis Plot

Seasonal Analysis

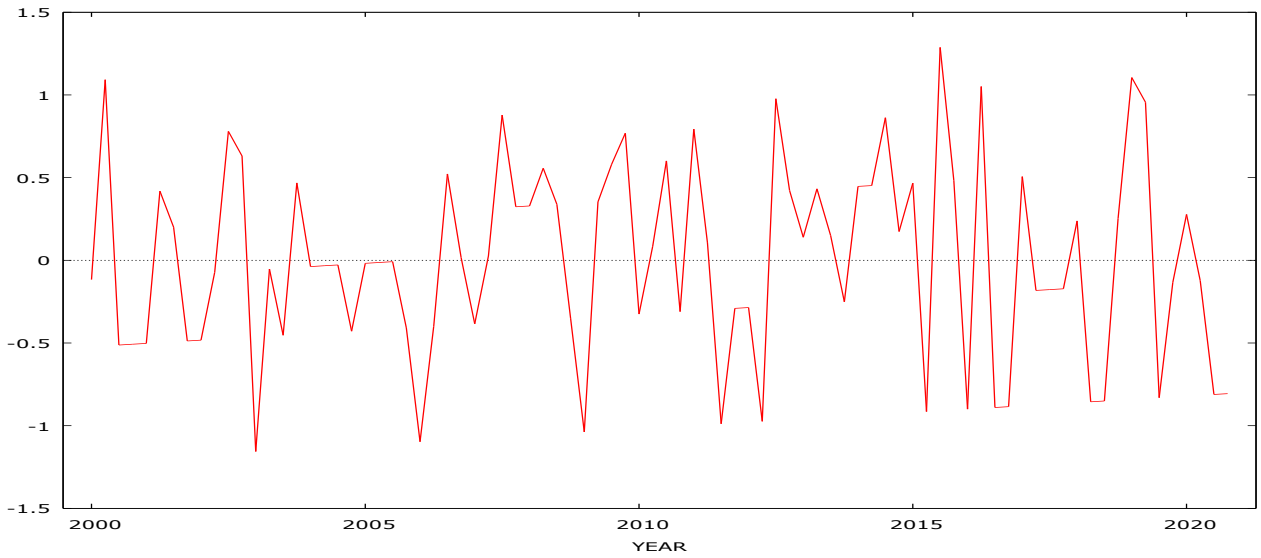


Figure 6. Time plot of the Detrended Series

Figure 6 shows the time plot of the detrended series from the decomposed data using the pseudo-additive model. The detrended series has the trend component removed so that the seasonal and other components can be observed clearly. From the plot, it can be observed that there is seasonal variation throughout the entire series. Figure 7 was used to further confirm the presence of seasonality.

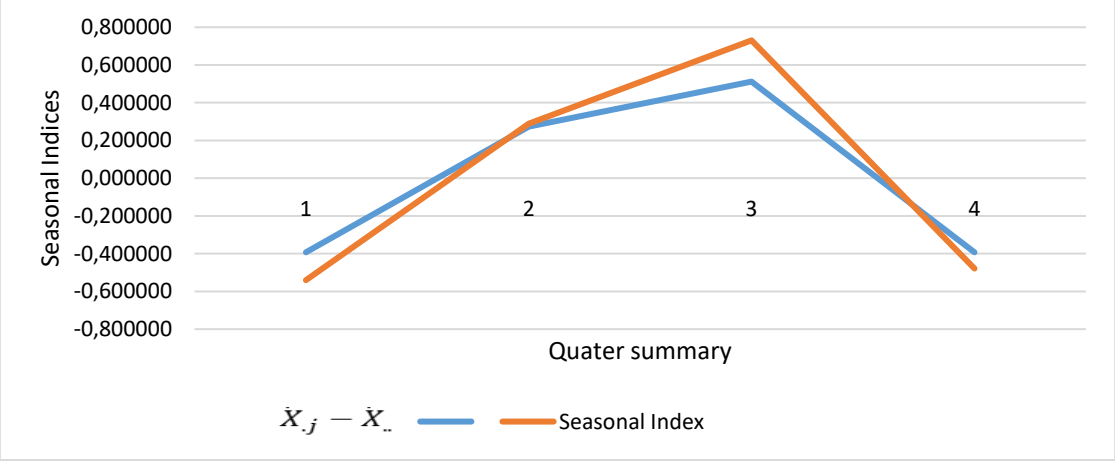


Figure 7. Assessment of seasonal effects

Figure 7 displays a line graph of the seasonal index and the difference between the seasonal average and the overall average $(\bar{X}_{.j} - \bar{X}_{..})$. The line plot shows the presence of seasonal effects since the pattern of deviations of the seasonal average from the overall average mimics those of the actual seasonal index. The seasonal effects are observed in quarter 3 and 2.

Test for randomness

In the residual analysis, the residual series would be used and the technique would be to plot the autocorrelation function and examine if the series is random. For randomness, the autocorrelation coefficients are expected to lie between $\pm \frac{1.96}{\sqrt{n}}$ at 5% level of significance. The plot of the autocorrelation function is given in figure 8

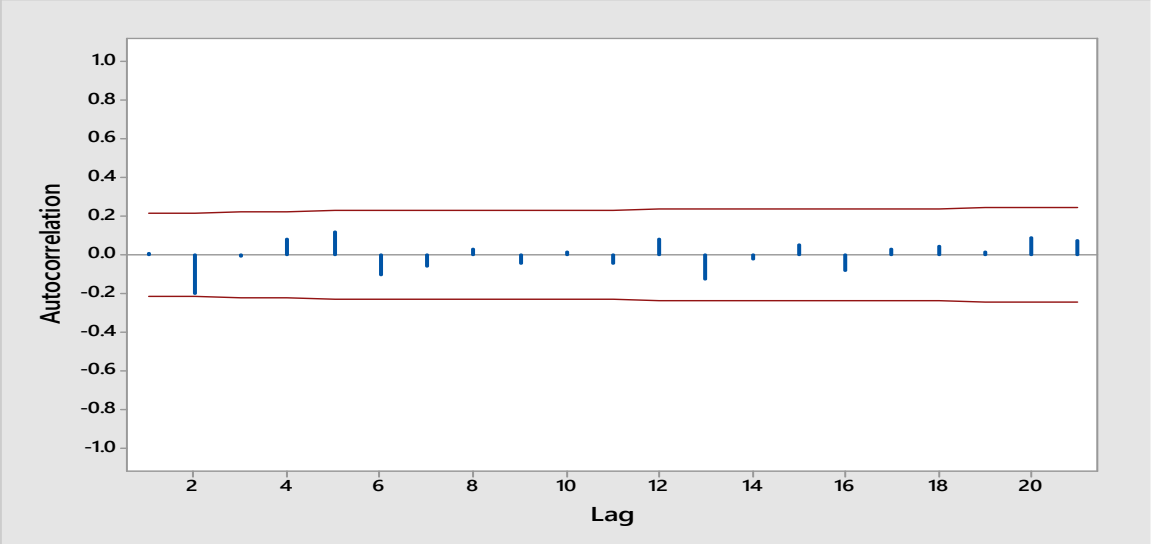


Figure 8 Autocorrelation plot of the Residual series (Irregular component)

The autocorrelation function of the residual series suggests a lack of no fit since all the lags lie within the control limit. This indicates that the order of the data is random.

CONCLUSION

This study has examined the three techniques of time series data for decomposition (Additive, Multiplicative and Pseudo-additive model). The application of the technique to the number of admittance into orphanage homes have shown that the pseudo-additive model has the best fit on the data among the models considered in this work. The data includes discrete values that contained small or zero values, this justifies the studies by Australian bureau of statistics (2020) and Iwueze *et al.*, (2016), which illustrated that the pseudo-additive model should be used when the time series data contain zero values or values close to. The result of the trend analysis shows that the rate of admission follows a negative linear trend which indicates that the rate of child abandonment is on the decrease and the actions put in place to curb the rate of child abandonment are being adhered to. The study also revealed the presence of seasonal effects in the series. It was observed that there is a seasonal pattern in the admittance of orphans during the second and third quarters of the year. This is in agreement with the study carried out by Ibor & Jaiyeoba (2021) which indicated that high birth rates are recorded in the month of July and August. This suggests that fertility and reproductive health outcomes are seasonally related. Similarly, research by Osei, *et al.*, (2016) showed that there is a peak in the rate of delivery in the month of May and September.

Recommendations

i. A pseudo additive decomposition model should be adopted when there is a presence of small and zero values in a series.
ii. The Ministry of women's affairs and child development should facilitate family planning and sensitisation programs to help reduce the rate of child abandonment.

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