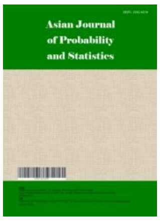

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# Circular Pattern of Temperature Changes and Its Effect on Workers' Attitude (A Case Study of the Federal Polytechnic Offa)

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***Author's contribution***

*The sole author designed, analysed, interpreted and prepared the manuscript.*

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## Abstract

This study is to determine the effect of temperature on workplace attitude, which led to the investigation of a circular pattern of temperature changes. The idea of time series data being presented in circular form since time itself rotates around the circle of a clock was the moving force in studying the pattern and behaviour of air temperature to identify peak periods. The data on air temperature (0C) in Offa was collected monthly from 2016 to 2020 from a reliable online source tcktcktck.org which tally with an available short period of temperature recorded by the Metrological Garden of Science Laboratory Department, The Federal Polytechnic Offa. While the data on workers' attitudes was from a questionnaire with an 8.5 reliability index. The study adopted a descriptive approach in the first instance, where responses from the questionnaire were in tabular form and the monthly means temperature in a circular plot before the application of cosinor regression to the original monthly temperature data for further examinations. The result of the circular plot indicated seasonality in the data because the monthly mean temperature differs, making the plot not perfectly circular. The presence of seasonality noticed in the cosinor plot was confirmed in the cosinor regression analysis as being significant at a 5% level of significance. The temperature amplitude from 2016 to 2020 had its peaks in February when 50.9% to 56% of workers are likely to experience fatigue (exhausted). The analysis for 2016 indicates temperature amplitude in Offa at 2.3$^0$C which peaks in early February. While in 2020, the temperature amplitude of 3.8$^0$C peaks at the beginning of February. The increase between 2016 and 2020 is due to climate change. The government and other stakeholders should provide facilities to reduce workers' fatigue and do more about climate change.

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*Keywords: Air temperature; amplitude; climate change; cosinor regression; circular time series.*

# 1 Introduction

The circular representation and analysis of time series data have been proposed and used for some time, but most time series data are still presented or used in linear form. Fisher and Lee [1] claimed that methods for analyzing time series of circular or angular data did not receive much-expected attention.

The circular plot is a representation of components of a time series by the sectors of a circle as bars. When using circular data, the unit circle is used as support, as opposed to the real line in linear data [2]. Circular data, as an example, can be found in the work of Barnett et al. [3], presented the mean number of cardiovascular deaths in Los Angeles in a circular plot. Circular time has its applications in many other areas like geology, medicine, meteorology, oceanography, physics and psychology [4,5]. Its application can also be in variables that characterize the phenology of species, for instance, flowering onset during the year [6]. Many of these examples indicate the importance of circular statistics to environmental climate-change analysis [2].

Since time is involved, the series should be in a circle, without a break. Therefore, any data indexed with time is better to be in circular form. For this reason, this paper presents and analyses temperature as a circular time series to uncover the underlying patterns such as peaks, amplitude and seasonality.

Attitudes in this study will be considered a useful guide to what is expected of a worker based on certain circumstances [7]. The attitude of workers towards work is very important to an organization because it makes or mars the organization if it is not appropriately monitored or controlled. Therefore, the identification of factors that may lead to a negative or positive attitude is eminent to any organisation/establishment. Many researchers have identified so many factors that influence workplace attitude Ndubuisi-Okolo et al. [8] in their study of factors influencing employees' job attitude in Nigeria, identified some of the factors as a person's abilities and traits, quality of work environment, job satisfaction, attitude as well as role perceptions.

Their research did not in totality identify all the factors, hence the need for further research. Yusuf and Metiboba [9] work on the relationship between work environment and work attitude and found out that there is a significant relationship between these two variables.

When the room temperature is all right, it increases productivity and can reduce stress in workers, meaning that temperature plays a role in a workplace environment that influences workers' attitudes. The effective temperature in Aamodt [10] is how hot or cold our environment makes us feel. The study also revealed that High temperatures affect employees' performance, particularly duties that require cognitive, physical and perceptual [11].

The role of temperature in the workplace was also established by Seppänen et at. [12] in their study of the effect of temperature on task performance and was discovered that performance increases with temperature up to 21-22$^{o}$C, and decreases with a temperature above 23-24$^{o}$C. The highest productivity is at a temperature of around 22$^{o}$C. Lan et al. [13] based their experiment on the effects of different levels of temperature and discovered that thermal discomfort caused by air temperature had a negative effect on workers' performance and productivity.

This paper in addition to their studies will look at the attitude (fatigue level) of workers, which is also a determinant of performance, on changes in temperature instead of a particular temperature that increases or decreases performance. Also, no similar research was carried out in Offa on the effect of temperature on workplace attitude.

The circular pattern of temperature in the context of this study will be of use in determining the attitude of workers at particular seasons (months) of the year in Offa Metropolis using The Federal Polytechnic Offa as a case study. The reason for the choice of the case study is that it comprises different types of tasks because the effects of the thermal environment on task performance are different among the task types [14].

# 2 Circular Time Series

A time series data can be directional or circular data that arises from many scientific fields including meteorology, oceanography, biology, neuroscience, bioinformatics, geoscience and cosmology [15]. Circular data can be described as data measured in angles, directions or orientations [16,5].

There are many statistical models which use circular data to make inferences. The models are categorized into three groups which are intrinsic, wrapped and embedded models. An example of the intrinsic model is a distribution defined on the circle, such as the von Mises distribution. Further details on intrinsic and wrapped circular models and their applications can be found in Pewsey et al. [2]. While further discussion on embedded models is found in Nuñez-Antonio and Gutiérrez-Peña [17].

# 3 Methodology

## 3.1 Source of data

The secondary data for this study is the monthly temperature in Offa from January 2016 to December 2020 extracted from tcktcktck.org and recorded in degrees centigrade. The data collected from this source tally with the short period record of temperature in Offa available in the Meteorological Garden of the Department of Science Laboratory Technology, The Federal Polytechnic Offa.

Primary data required by this study will be through the use of a well-constructed and tested questionnaire with a reliability index of 8.5 within the range of high reliability as suggested by Hinton et al. [18]. The purposive sampling is adopted for this study and questionnaire will be administered to the selected member of staff of The Federal Polytechnic Offa.

## 3.2 Circular plot

The circular time can be showcased as descriptive statistics just as is obtained in linear time series. The common visualization of this type of data is the circular data plot instead of a histogram. A linear description of a time series data disadvantage is that the periodical nature cannot be visualized [2]. This limitation is overcome by a circular plot where data can be viewed easily.

## 3.3 Cosinor regression

Among all the models cosinor regression model is chosen in analyzing the data collected, because of its advantage on the nature of data collected. One of the advantages of these cosinor models is that they can be fitted to unequally spaced data (A. Barnett et al., 2012). Another advantage is that it can be used for short and sparse data series (originally developed for short data) and long time series by an extension [19] because monthly data for five years in a contemporary study is small.

There are stationary and non-stationary cosinor regression models. This study is to make use of stationary cosinor regression because the seasons of the year do not change over the years. Cosinor model [20] is a popular parametric seasonal model based on a sinusoidal pattern with the assumption of a smooth seasonal pattern that is symmetric about its peak.

$$S_t = A\cos(\frac{2\pi t}{c} - P), \ \ t = 1,...,n$$

Where A = the amplitude of the sinusoid (size of the seasonal change), P = its phase (where the size of the seasonal change peaks), c = the length of the seasonal cycle (12 for monthly data with an annual seasonal pattern), t = the time of each observation and n = the total number of times observed.

# 4 Frequency Table

The response from workers to the questionnaire administered to staff of the Federal Polytechnic Offa are presented in Table 1 in which a total of 320 questionnaires were given out and 289 were able to be retrieved.

**Table 1. Frequency distribution of workers fatigue level on changes in temperature**

| Fatigue | Temperature Drops | | Temperature Increases | | Temperature Fluctuates | |
|---|---|---|---|---|---|---|
| | frequency | % | frequency | % | frequency | % |
| Not tired | 180 | 62.3 | 10 | 3.5 | 22 | 7.6 |
| Little tired | 73 | 25.3 | 65 | 22.5 | 80 | 27.7 |
| Exhausted | 31 | 10.7 | 162 | 56.0 | 147 | 50.9 |
| Completely Exhausted | 5 | 1.7 | 52 | 18.0 | 40 | 13.8 |
| **Total** | **289** | **100** | **289** | **100** | **289** | **100** |

Table 1 shows that 62.3 % of workers are not tired when the temperature drops representing the highest number of workers in this category, while 31 out 289 representing 10.7% were exhausted. On the contrary, when the temperature increases up to 52 % of workers are exhausted, while 3.5 % are not tired. This is in line with Seppänen, Fisk and Lei [12] study of temperature and performance, whereby performance decreases as temperature increases.

Unstable (fluctuates up and down) temperature is another scenario that causes workers to be exhausted. Under this fatigue situation, 50.9 % of the workers indicate being exhausted, that is more than half of the workers.

# 5 Results and Discussions

The analysis of data in this section is to be done by R version 4.0.1 Statistical software by R Core Team [21] with cosinor package version 1.1(Sachs, 2014) and season package version 0.3.11 package [22,23].

## 5.1 Circular plot of temperature time series of offa

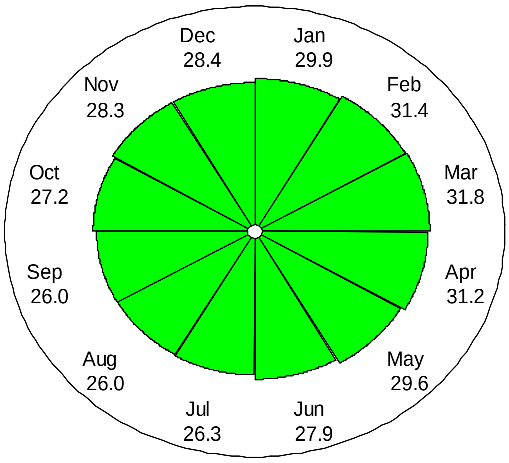


**Fig. 1. A circular plot of the monthly mean temperature of Offa from January, 2016 to December, 2020**

The circular plot in Fig. 1 shows the data exhibit a seasonal pattern because the sectors in green do not show a perfect circle indicating a monthly seasonal pattern. Even though, the mean temperature in August and September are the same due to approximation of the monthly means.

### 5.2 Estimation of the parameters of the cosinor regression model

The parameters of the cosinor model are estimated by year, from 2016 to 2020. The parameters are the estimate of amplitude and phase. Conducted also is the seasonality test for each of the years.

**Table 2. Parameters of the regression model and seasonality test**

| Year | Amplitude (A)' $^0$C | Phase (P)'Month | Significant Seasonality |
|---|---|---|---|
| 2016 | 2.31 | 2.1 | True |
| 2017 | 2.59 | 2.0 | True |
| 2018 | 2.48 | 2.4 | True |
| 2019 | 4.3 | 2.3 | True |
| 2020 | 3.89 | 2.0 | True |

In Table 2, the amplitude for 2016 is 2.31$^0$C which peaks in early February. The amplitude for the following year 2017 is an increase of 0.28$^0$C with the peak still in February. It also follows in 2018 that the peak of the amplitude of 2.48$^0$C is in February but not in early February as it is in 2017 but towards the middle of February. The same month February also witnesses the peak of the amplitude in 2019 and 2020 with amplitudes of 4.3$^0$C and 3.89$^0$C respectively. The annual temperature change from 2016 to 2017 is indicated by the amplitude peaks in February all through the five years. This by implication from Table 1 that in February the highest percentage of workers between 50.9% and 56% are likely to experience fatigue (exhaustion) at work. The amplitude over the five years increases from 2.31$^0$C to approximately 4$^0$C.

The last column of Table 2 indicates the existence of significant seasonality based on an adjusted significance level of 0.025 as a confirmation of the circular plot in Fig. 1.

## 6 Conclusion

The annual temperature change measured by the yearly amplitude is increasing because climate change is still a world phenomenon. Although some succeeding years witness a decrease, which may be due to various efforts put in place to fight climate change worldwide. This notwithstanding, one may see a worse situation in the succeeding years as it is in the case of 2017 to 2019, leading to workplace fatigue.

## 7 Recommendations

Temperature is an essential variable in which many people daily seek information on temperature. The out outcome of this research will help in proffering the following solutions.

The issue of climate change should be managed more seriously by governments, international bodies, scientists and other stakeholders.

More facilities should be put in place, especially in February, to reduce workers' fatigue.

## Competing Interests

Author has declared that no competing interests exist.

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