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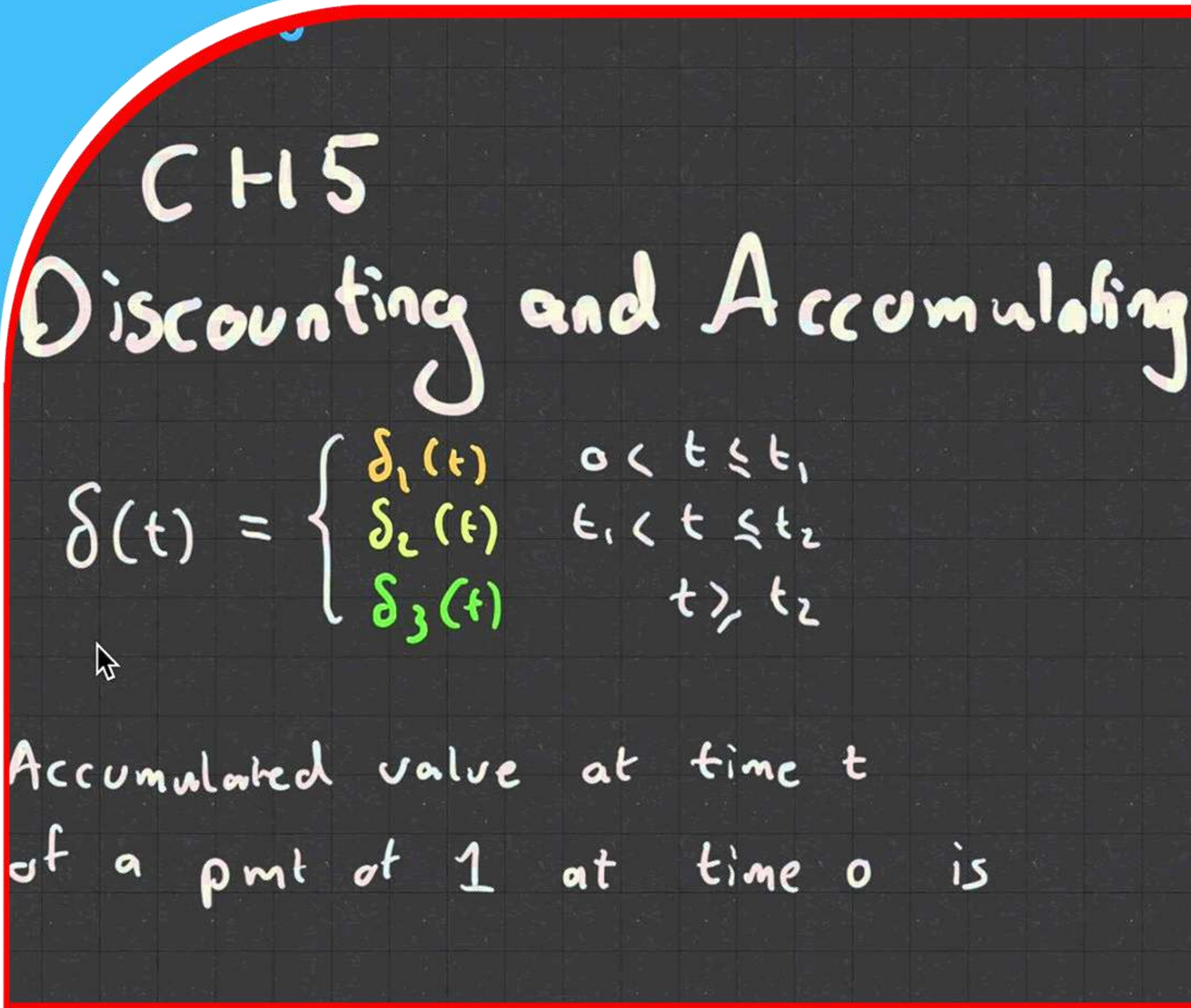

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The autoregressive integrated moving average models of the classical Box-Jenkins methods of Time Series Analysis

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ABSTRACT

Background: The increasing phenomenon in caesarean sections at the global as well as the national level is a public health concern. Periodic variations in Caesarean Sections incidences at the University of Cape Coast Hospital is currently unclear and the model that can best represent its movement is unknown. This study sought to model and predict the monthly incidence of Caesarean Sections at the hospital.

Methods: The study employed a monthly periodicity of 115 time-series data sourced from District Health Information Management Systems Two on Caesarean Section births at the University of Cape Coast Hospital over a 9-year period. The autoregressive integrated moving average models of the classical Box-Jenkins methods of Time Series Analysis were used to analyse the data. Analysis was performed in *EViews* 12 and *R* (version 4.0.4)

Results: There were six non-seasonal tentative candidate models for the hospital. The model autoregressive integrated moving average (1, 1, 2) with a first-order autoregressive and second-order moving average with one order of nonseasonal differencing emerged as the best fit model. The findings revealed an overall rising trend in the incidence of Caesarean section rates in the hospital over the study period with an average of 30.54% per month. This is expected to increase to over 40% per month over the next five-year period of August 2021 to July 2026 according to projections.

Conclusion: Non-Seasonal autoregressive integrated moving average (1,1,2) was identified as the best model that describes monthly expected Caesarean Sections births at the University of Cape Coast Hospital. Using this model to forecast the expected number of Caesarean Section births will facilitate health policy formulations and allow for the prudent use of available obstetric services.

Recommendations: Clinicians should be trained to improve their skills in the use of instruments in deliveries as well as in the safe conduct of vaginal breech deliveries.

Keywords: *Caesarean section, Time series modelling, Stationarity, Box-Jenkins Methods, Unit root testing, Forecasting.*

1. Introduction

The increasing rates of Caesarean sections (CS) globally is an issue of public health concern to the international community. Globally, it is estimated that over 18 million Caesarean cases are conducted annually with over a third of these cases being absolutely unnecessary [1]. Since 1985, the international healthcare community backed by the World Health Organization (WHO) considered the ideal rate for caesarean sections to be between 10% - 15%, and that there is no justification for any region to have a rate higher than stipulated [2]. Since then, caesarean sections have become increasingly common in both developed and developing countries [3, 4]. According to the American College of Obstetricians and Gynaecologists (ACOG), situations that may make a CS necessary include: medical concerns for the baby, multiple gestation, placenta problems, poor progress of labour, big baby, abnormal presentation and maternal infections and medical conditions, such as hypertension or diabetes. WHO (2014) undertook a worldwide study to assess the association between caesarean section and maternal and neonatal mortality, using the most recent available data at the time. The study revealed that increasing the rate of caesarean section beyond its recommended 15% threshold was not associated with reduced mortality [5].

Time series techniques are invaluable tools in many fields of research including health. One study [6] used the autoregressive integrated moving average (ARIMA) techniques to model the prevalence of CS incidences in all the regions of Ghana and revealed that the trend in CS cases is rising nationwide. That study used monthly data from 2008 to 2017 for the analysis. Augmented Dicker-Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and the Philips-Perron (PP) unit root tests were performed to check stationarity of the various series. The results of KPSS were deemed robust and hence were preferred to that of ADF and PP. Tentative models were formulated for each region and the model with the lowest Akaike Information Criteria (AIC) was selected as the best model fit for the respective regions of Ghana. The best model fit for Greater Accra, Central and Eastern regions were the seasonal autoregressive integrated moving average (SARIMA) models and were respectively SARIMA (2, 0, 0) $(0, 1, 1)_{12}$, SARIMA (2, 0, 0) $(0, 1, 1)_{12}$ with a Drift and SARIMA (1, 1, 1) $(0, 1, 1)_{12}$. Similarly, the best fit models for Northern and Volta regions were SARIMA (3,0,2) $(0,1,1)_{12}$ with drift and SARIMA (0,1,1) $(0,1,1)_{12}$ respectively. Ashanti, Upper East and Western regions failed the Jarque-Bera (JB) test of normality for the residuals. Upper West and Brong Ahafo Regions data were not suitable for forecasting due to failure to depict white noise characteristics and ARCH test failure, respectively. The study used the best models fit to forecast for 2019 and 2020. The results confirmed the existence of regional variations in CS cases in Ghana. Another study [7] used the Box-Jenkins methods to model births in Korle-Bu Teaching Hospital. The study used monthly data for the analysis and selected SARIMA (2, 1, 1) $(1, 0, 1)_{12}$ as the best fit model for the hospital. The study was intended to model and predict the monthly number of births at the Department of Obstetrics and Gynaecology of the Korle-Bu Teaching Hospital in Ghana.

Pradhan and Bhandary [8] applied univariate time series analysis to model and forecast caesarean section deliveries in a tertiary health care hospital in India. Monthly data were taking from Patan Hospital in India for the period of 2010 to 2014 and the best SARIMA model (0,1,1) $(0,0,0)_{12}$ without autocorrelation was formulated to forecast caesarean section incidences in the hospital for the period of 2015-2017. The study revealed that there was a 47% CS rate in the Patan Hospital in 2014 but however indicated a decreasing trend in CS cases for the forecast period. Prah et al. [9] reiterated concerns about the rising incidence of Caesarean cases in both developed and developing countries and revealed a 26.7% prevalence rate of caesarean sections in University of Cape Coast Hospital alone for a study period of two years from January 2014 to December 2015.

Contemporary caesarean section rates at the national and international level make it obviously clear that there is other than the strict medical need for conducting CS and hence its possible abuse. This phenomenon has motivated research in the area to identify workable interventions and to control the excessive use and possible abuse of the CS mode of delivery. Pockets of disparity in Caesarean section rates represent underuse or possibly medically unjustified overuse of the procedure [10, 11]. Given this background and noting the fact that cases vary from facility to facility and from region to region the study intended to thoroughly investigate the specific case of the University of Cape Coast Hospital in order to establish its current situation on the incidence of Caesarean sections and make future projections to ascertain its severity or otherwise. This will enable the Hospital management committee to formulate health policies, make proper planning and prudent use of the hospital obstetric services and curb unnecessary CS deliveries without compromising on the quality of care at the facility.

The World Health Organization Global Survey on Maternal and Perinatal Health which was a large cross-sectional survey conducted in 24 countries provided evidence that unnecessary caesarean sections were associated with increased of adverse outcomes for mothers. The adverse maternal outcomes included increased risk of death, blood transfusions and hysterectomies [12, 13].

2. Materials and Methods

2.1 Design and Data Set

The research paradigm employed is positivism which emphasis on the objectivist approach. This paradigm and approach support quantitative and secondary data research. Monthly periodicity data on caesarean sections conducted in UCC Hospital were collected for the period of January, 2012 to July, 2021 from the District Health Information Management Systems Two (DHIMS-2). Other relevant data sets were also taken for thorough analysis among which include; Type of Caesarean section, normal deliveries, vacuum deliveries, forceps deliveries, single deliveries, multiple deliveries, total monthly deliveries, and the monthly total number of babies delivered at the hospital. The sample size was 115 monthly observations. The Box-Jenkins methodology which this paper adopted is suitable for application on a sample size of 50 observations and above [14]. The data was processed using *Eviews 12*, *RStudio* (version 4.0.4), and Microsoft Excel software packages.

2.2 The Theoretical Framework

2.2.1 The Box–Jenkins (BJ) Methodology

The publication by Box and Jenkins [15] of *Time Series Analysis: Forecasting and Control* ushered in a new generation of relatively powerful forecasting tools for which this paper employed. These methods emphasise analysing the probabilistic, or stochastic, properties of the time series on their own under the philosophy *let the data speak for themselves*. The Box-Jenkins time series models allow the series Y_t (Caesarean section deliveries) to be explained by its past, or lagged, values and stochastic error terms. For this reason, ARIMA models and their variants such as fractional autoregressive integrated moving averages (FARIMA), and SARIMA, are sometimes called *atheoretic* models because they are not based or derived from any theory and therefore there is no perfect ARIMA model; the fundamental idea here is purely based on parsimony.

2.2.2 Autoregressive (AR), Moving Average (MA), and Autoregressive Integrated Moving Average (ARIMA) Modelling of Time Series Data

2.2.2.1 An Autoregressive (AR) Process

Let Y_t represent the Caesarean section series at time *t*. Y_t can be modelled as

$$(Y_t - \delta) = \alpha_1(Y_{t-1} - \delta) + u_t \quad (1)$$

Where δ is the mean of *Y* and where u_t is uncorrelated random error term with zero mean and constant variance σ^2 (*white noise*), then Y_t follows a first-order autoregressive, or AR (1), stochastic process. Here the value of *Y* at time *t* depends on its value in the previous time period (*t-1*) and a random term u_t . Similarly, an AR (2) process can be modelled as

$$(Y_t - \delta) = \alpha_1(Y_{t-1} - \delta) + \alpha_2(Y_{t-2} - \delta) + u_t \quad (2)$$

Hence, a ***p***th-order autoregressive process is modelled as

$$(Y_t - \delta) = \alpha_1(Y_{t-1} - \delta) + \alpha_2(Y_{t-2} - \delta) + \cdots + \alpha_p\left(Y_{t-p} - \delta\right) + u_t \quad (3)$$

In the AR process only the current and previous *Y* values or lag values of *Y* are involved; there are no other regressors.

2.2.2.2 The Moving Average (MA) Process

When a series is regressed against its own error term and past or lagged values of the error term then the process is a moving average (MA) process. Hence, an MA (1) process is modelled as

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} \quad (4)$$

Where μ is a constant and *u*, as mentioned before, is the white noise stochastic error term. Equation (4) means that *Y* follows a first-order moving average, or an MA (1), process. Generally, a q^{th} order MA process or MA (q) can be expressed as

$$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_q u_{t-q} \quad (5)$$

Simply put, a moving average process is simply a linear combination of white noise error terms.

2.2.2.3 An Autoregressive and Moving Average (ARMA) Process

Sometimes a series may exhibit characteristics of both AR and MA processes together and is therefore an ARMA process. An ARMA (1, 1) process can be expressed as

$$Y_t = \theta + \alpha_1 Y_{t-1} + \beta_0 u_t + \beta_1 u_{t-1} \quad (6)$$

Where θ represents a constant term together with one autoregressive and one moving average terms. The generalised ARMA (p, q) process can be expressed as

$$Y_t = \gamma + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \beta_0 u_t + \sum_{j=1}^{q} \beta_j u_{t-j} \quad (7)$$

Where model contains ***p*** lags of the dependent variable, ***q*** lags of the error term with γ being a constant.

2.2.2.4 An Autoregressive Integrated Moving Average (ARIMA) Process

The Box-Jenkins [15] methods work on the assumption that the time series involved is (weakly) stationary. However, it is well known from the literature that many time series variables are non-stationary, for example, the Caesarean section incidence series of the UCC Hospital for the period of 2012M1-2021M7 is non-stationary at level and has to be differenced once (i.e., it is *I*[1]), to become stationary. Therefore, if a time series is integrated of order ***d*** -*I*(*d*), to become stationary after differencing it ***d*** times then a series integrated of order **0**- an *I*(0) series is obtained. Therefore, if a time series would have to be differenced ***d*** times to make it stationary and then apply the ARMA (*p*, *q*) model process to it, then the original time series is an ARIMA (*p*, *d*, *q*), that is, it is an autoregressive integrated moving average time series, where ***p*** denotes the number of autoregressive terms, ***d*** the number of times the series has to be differenced before it becomes stationary, and ***q*** the number of moving average terms in the series. Hence, an ARIMA (2, 1, 2) time series has to be differenced once (***d*** = 1) before it becomes stationary and the (first-differenced) stationary time series can be modelled as an ARMA (2, 2) process, that is, the series has two AR and two MA terms.

ARIMA modelling has gained popularity because it is more successful in forecasting and is also considered more reliable relative to the traditional methods of forecasting. The Box-Jenkins methodology is a four-step process in handling the ARIMA model building concept: Identification, Estimation, Diagnostic checking, and finally Forecasting. The main tools for the identification process include the autocorrelation function (ACF), and the partial autocorrelation function (PACF) with their corresponding correlograms. Table 1 gives the theoretical application of ACF and the PACF in the model identification process.

Table 1: Theoretical Application of ACF and PACF in Model Identification

Model structure	ACF	PACF
AR(*p*)	Decays exponentially or with damped sine wave pattern or both	Significant spikes through *p* lags
MA(*q*)	Significant spikes through *q* lags	Decays exponentially
ARMA(*p*, *q*)	Exponential decay	Exponential decay

p denotes the number of autoregressive terms, ***d*** the number of times the series has to be differenced before it becomes stationary, and ***q*** the number of moving average terms in the series.

ACF- auto-correlogram function; PACF- partial auto-correlogram function; AR-autoregressive; MA- moving average; ARMA- autoregressive and moving average

The parameters of the identified tentative models are estimated and diagnosed for best fit model. Model with the maximum number of significant coefficients, minimum level of volatility, highest R sq. adjusted value, and minimum Akaike Information Criteria (AIC) or Bayesian Schwartz Information Criteria (BSIC) value emerges as the best fit model for forecasting.

3. Results

3.1 Descriptive Analysis

Time series plot of Caesarean section births in UCC Hospital for the study period is depicted in figure 1. This figure apparently indicates an upward or increasing trend of Caesarean sections in the hospital.

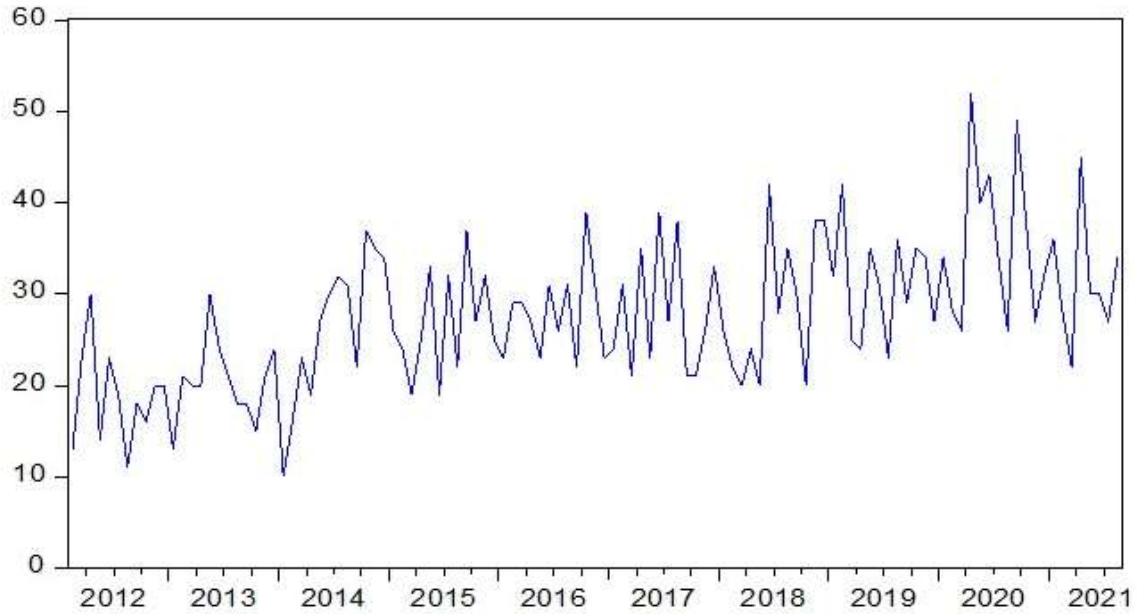

Figure 1: Monthly Caesarean section incidences in University of Cape Coast Hospital from 2012M1-2021M7

Figure 2 give a comparative graphical display of the movements of both Normal and Caesarean deliveries in the facility for the period of January 2012 to July 2021.

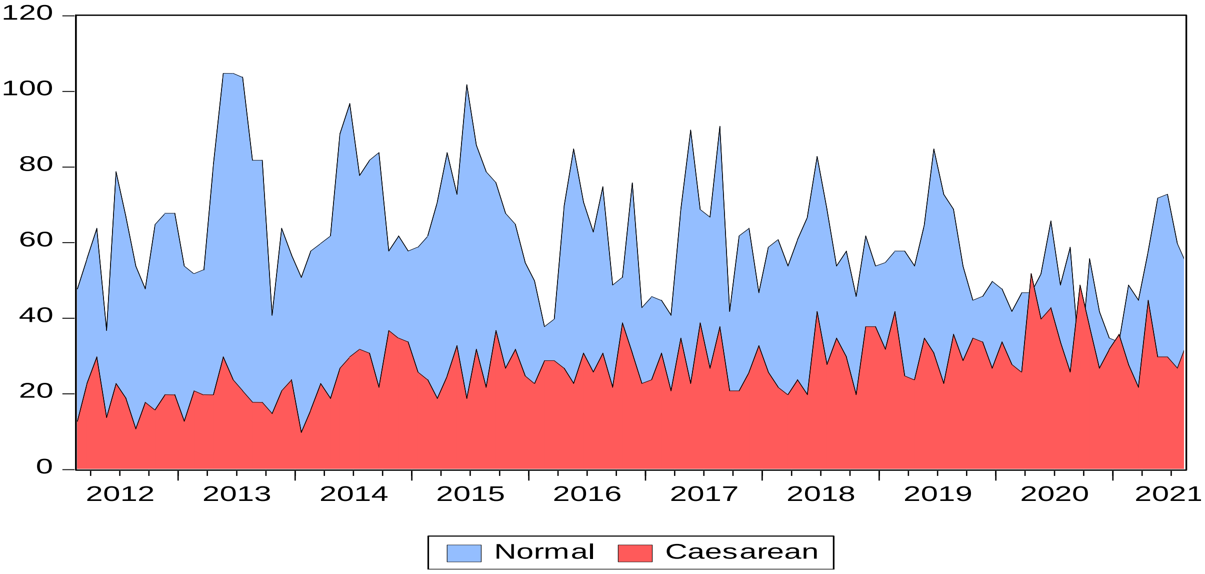

Figure 2: Monthly movements of Normal and Caesarean section deliveries in University of Cape Coast Hospital from 2012M1-2021M7

The graph revealed a closing gap between the two modes of delivery in the later part of the study period.

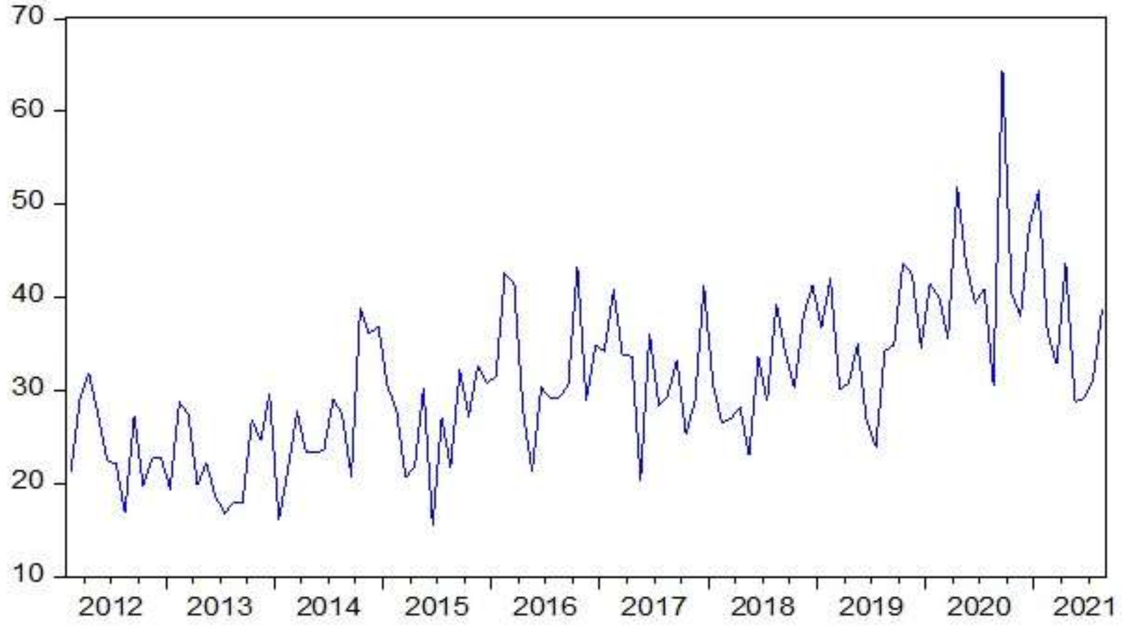

Figure 3: Monthly proportion of Caesarean Sections to total delivery incidences in University of Cape Coast Hospital from 2012M1-2021M7

From figure 3 it is clear that movement of the CS rate in the hospital is over and above the WHO [2] recommended rate of 10%-15% except for the month of May, 2015 which was around 15%. The facility registered its highest CS cases in the month of August, 2020 with a record highest of 64.5% (49/76).

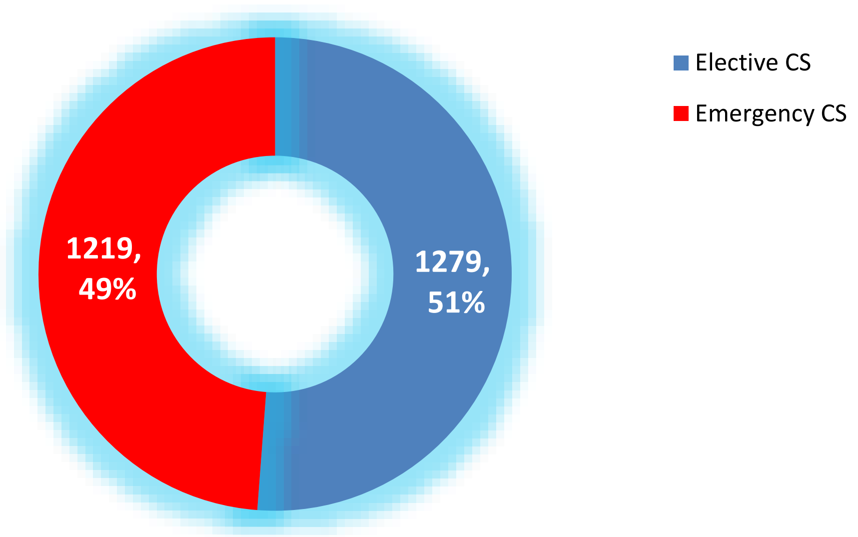

Figure 4: Doughnut Chart of Caesarean Section type in University of Cape Coast Hospital from 2013M1-2021M8

Figure 4 displays doughnut chart for CS type for the study period in the hospital. It is vividly clear from figure 4 that there are more elective CSs than emergencies (51% as against 49%).

3.1.1 Birth Statistics Analysis

It is well known that giving birth to more than one baby at once is not common almost everywhere. However, the public fascination, as well as parents-to-be about this phenomenon, continues to prevail across the globe. Multiple births and the terms associated with these births ranging from one to nine babies (delivered at once) respectively may include Singleton, Twins, Triplets, Quadruplets, Quintuplets, Sextuplets, Septuplets, Octuplets, and Nonuplets. According to the National Vital Statistics Report for the United States in 2018 [16], twin statistics stands at approximately 33.4 for every 1000 live births and 101.4 sets of triplets or more for every 100,000 live births. This implies that twin births account for about 3% of all live births whereas triplets or higher account for about 0.1% of all live births. These statistics are attested in the case of UCC Hospital as shown in Table 2.

Table 2: Birth Statistics for UCC Hospital over January, 2012 to July, 2021

From Table 2, it is clear that for the entire study period there were a total of 10344 deliveries at the UCC Hospital with 10107 of these deliveries being singleton and 388 being multiple births. The birth statistics shown in Table 2 about the University of Cape Coast Hospital are perfectly in conformity with the National Vital Statistics Report for the United States in 2018

Number of Deliveries by Mode					
Mode	Normal	Caesarean	Vacuum	Forceps	Total
Count	7152	3159	31	2	10344
Percent	69.14	30.54	0.3	0.02	100
Number of Babies Delivered per Singleton and Multiple Births					
Birth(s)	Singleton	Twins	Triplets	Higher	Total
Count	10107	382	6	0	10495
Percent	96.3	3.64	0.06	0	100

on multiple birth statistics.

3.2 Stationarity Test

The Box-Jenkins [13] methods work on the assumption that the time series involved is (weakly) stationary. Hence, the autocorrelogram and partial autocorrelogram functions together with Augmented Dicker-Fuller (ADF) unit root testing were deployed to examine the stationarity or otherwise of the Caesarean section series variable in the hospital. Table 3 gives the results of the ADF unit root test for the CS variable.

Table 3: ADF Unit Root Test of Caesarean Section at 5% significance level

Caesarean Variable	At level		1st Difference	
Equation Form	*t-stat*	*p-value*	*t-stat*	*p-value*

Intercept	-4.572837	0.0003	-8.195014	0.0000
Trend & Intercept	-10.58950	0.0000	-8.161706	0.0000
None	-0.245546	0.5956	-9.832580	0.0000

The ADF has three forms or equations and all these must agree on the stationarity or otherwise of a particular time series variable. These forms include intercept, trend & intercept and none and they must all agree on the stationarity or otherwise of a given series. From Table 3 it is clear that the Caesarean section time series variable was integrated of order 1, $I(1)$. This means that the series was not stationary at level. Hence the Caesarean variable attained stationarity at first difference.

In *Eviews 12* the auto-correlogram function (ACF) of the CS variable decays slowly up to about 17 lags. This is indicative of non-stationarity since most of the autocorrelations are outside the 95% Confidence Intervals. That is many of the ACF spikes are outside the 95% confidence interval or the standard error bounds while the partial autocorrelation function (PACF) cuts of to zero after the first three significant spikes. Similarly, the Q-Stats and the corresponding *p-values* of AC and PAC values performed in *Eviews 12* are significant even up to lag 36 which is indicative of non-stationarity of the series. Hence, the Caesarean section variable is not stationary at level as confirmed by the ADF unit root test in Table 3.

3.2.1 Model Identification and Parameter Estimation

By deploying the Box-Jenkins methods on the differenced Caesarean section series variable six tentative models were identified for estimation. Table 4 displays the tentative models identified and their estimates with the objective of selecting the model that best fit the UCC Hospital Caesarean section incidences.

Table 4: Identification and Estimation of tentative ARIMA models for CS Variable

Model	Number of Sig. Coefficients	Sigma sq. (volatility)	Adjusted R. sq.	AIC	SIC
ARIMA (1, 1, 1)	0	42.90693	0.484062	6.708562	6.804569
ARIMA (1, 1, 2)	2	42.25778	0.491867	6.701186	6.797193
ARIMA (1, 1, 4)	1	59.76578	0.281341	7.001779	7.097786
ARIMA (1, 1, 5)	1	60.19721	0.276153	7.008856	7.104863
ARIMA (1, 1, 10)	1	59.64207	0.282828	7.000661	7.096668
ARIMA (1, 1, 11)	1	59.36578	0.286151	6.996341	7.092348

The criteria for choosing the most appropriate model for the Caesarean series data are; the model with the highest number of significant coefficients, minimum variance (volatility), highest adjusted R sq., lowest AIC value, and lowest SIC value. These are the required variables for the purpose of the study. Table 4 revealed that ARIMA (1, 1, 2) proved to be the most appropriate model fit because it has satisfied the requirements of the criteria prescribed. Hence, diagnostics checks were performed on this model and were successful and finally used for forecasting the Caesarean section incidences in the hospital.

Considering the fact that ARIMA models are *atheoretic*, the following estimated parameters for the selected model were tabulated in Table 5.

Table 5: Estimated Parameters for ARIMA (1, 1, 2) model for CS Variable

ARIMA(1, 1, 2)	AR(1)	MA(2)	*t-statistic*	*p-value*
Coefficient	-0.999976	-0.998195	-54.27384	0.0000
SE	0.018425	0.019096	-52.27320	0.0000

As seen in the table estimated parameters of the selected model were significant (*p-values* < 0.05).

3.2.2 Model Diagnostics and Forecasting

The last two stages of the ARIMA model development involve model diagnostics and finally forecasting. In this regard, figures 5&6 display the residual diagnostics of the selected model ARIMA (1, 1, 2).

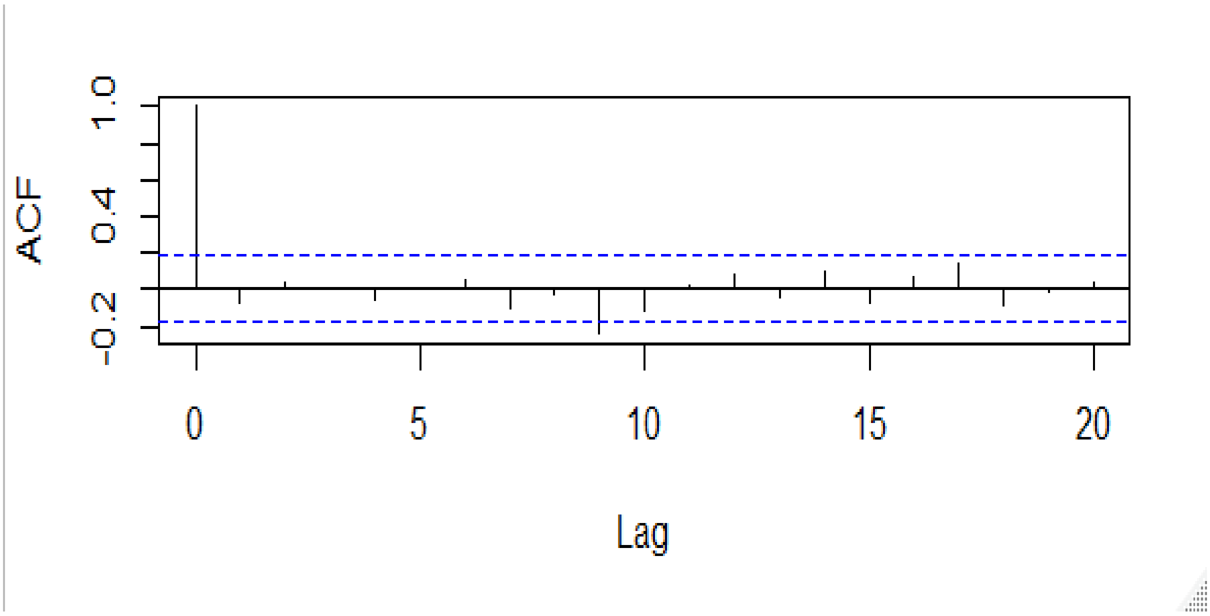

Figure 5: Auto-correlogram function (ACF) plot of residuals for the model ARIMA (1, 1, 2)

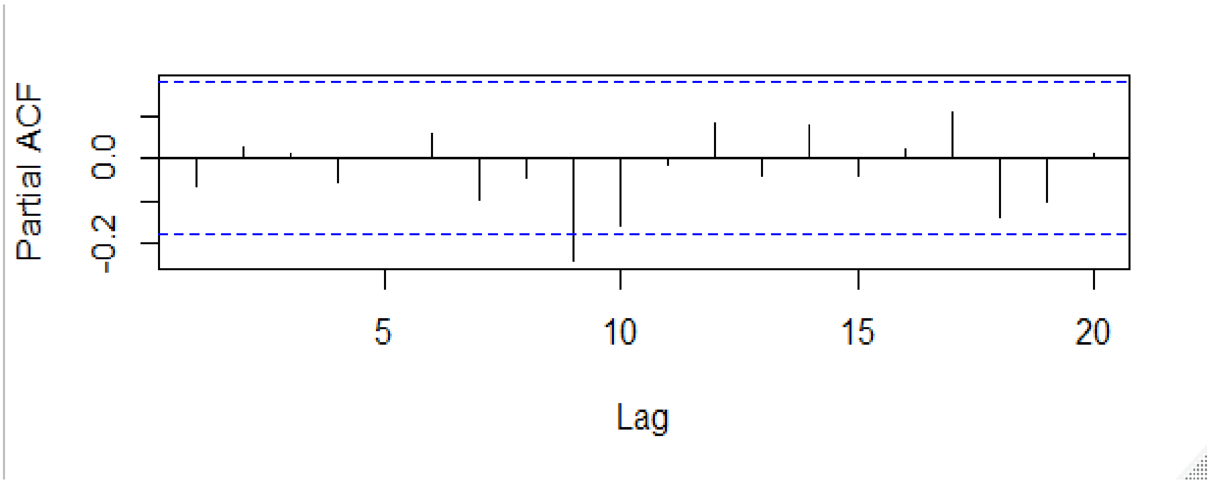

Figure 6: Partial autocorrelation function (PACF) plot of residuals for the model ARIMA (1, 1, 2)

The ACF and PACF of residuals in *figures 5&6* show no significant autocorrelations. This implies that the residuals of the selected model ARIMA (1, 1, 2) are random or *white noise*. Secondly, the Ljung-Box test conducted using *RStudio (version 4.0.4)* had a chi-square value of 0.48645 with a corresponding *p-value* of 0.9926 at lag 5 and also a chi-square value of 27.643 with a *p-value* of 0.5894 at lag 30, indicating non-significance even at other variant lags. Hence the Ljung-Box test confirmed that there are no autocorrelations in the residual of the model meaning that the null hypothesis of no autocorrelation in the residual should not be rejected. Hence, there may not be any need to look for another ARIMA model. Therefore, ARIMA (1, 1, 2) can be used to forecast the Caesarean section incidence in UCC Hospital. It should however, be noted that ARIMA models are *atheoretic* meaning that they are not based on any theory and hence not perfect.

Figures 7 & 8 take on the assumption of normality by the residual of the chosen model ARIMA (1, 1, 2).

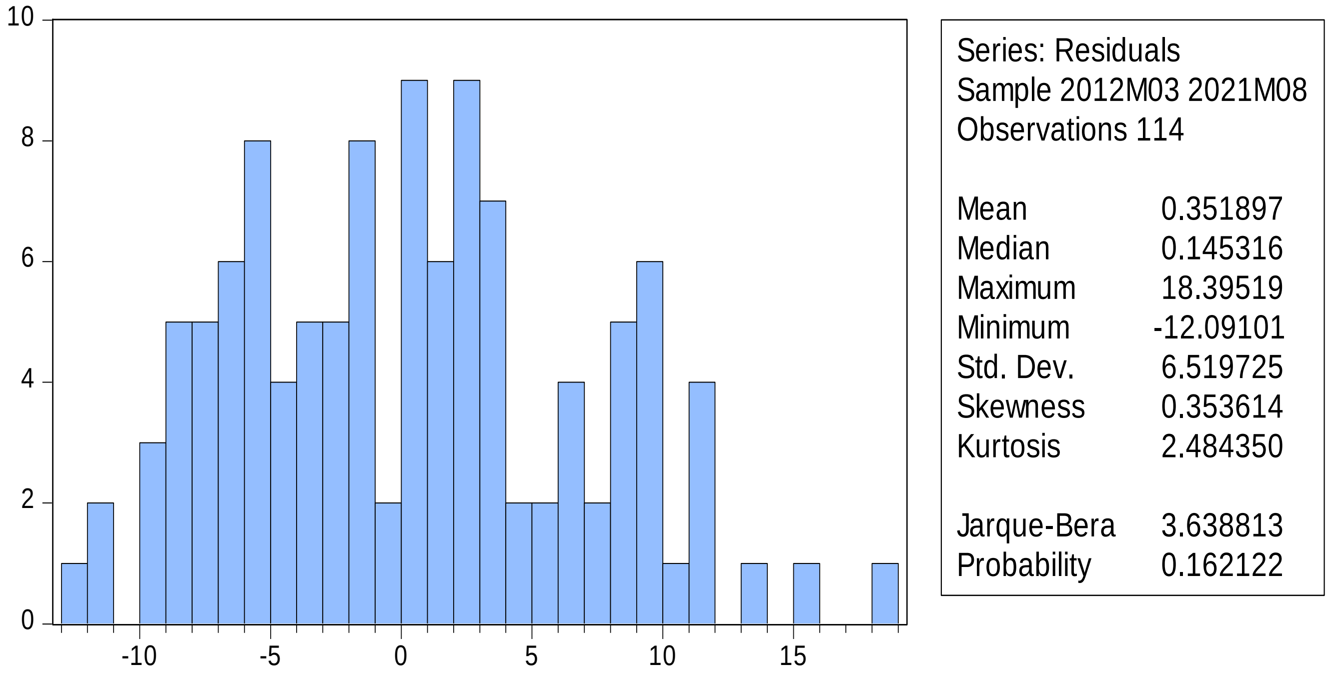

Figure 7: Normality of Residuals of ARIMA (1, 1, 2)

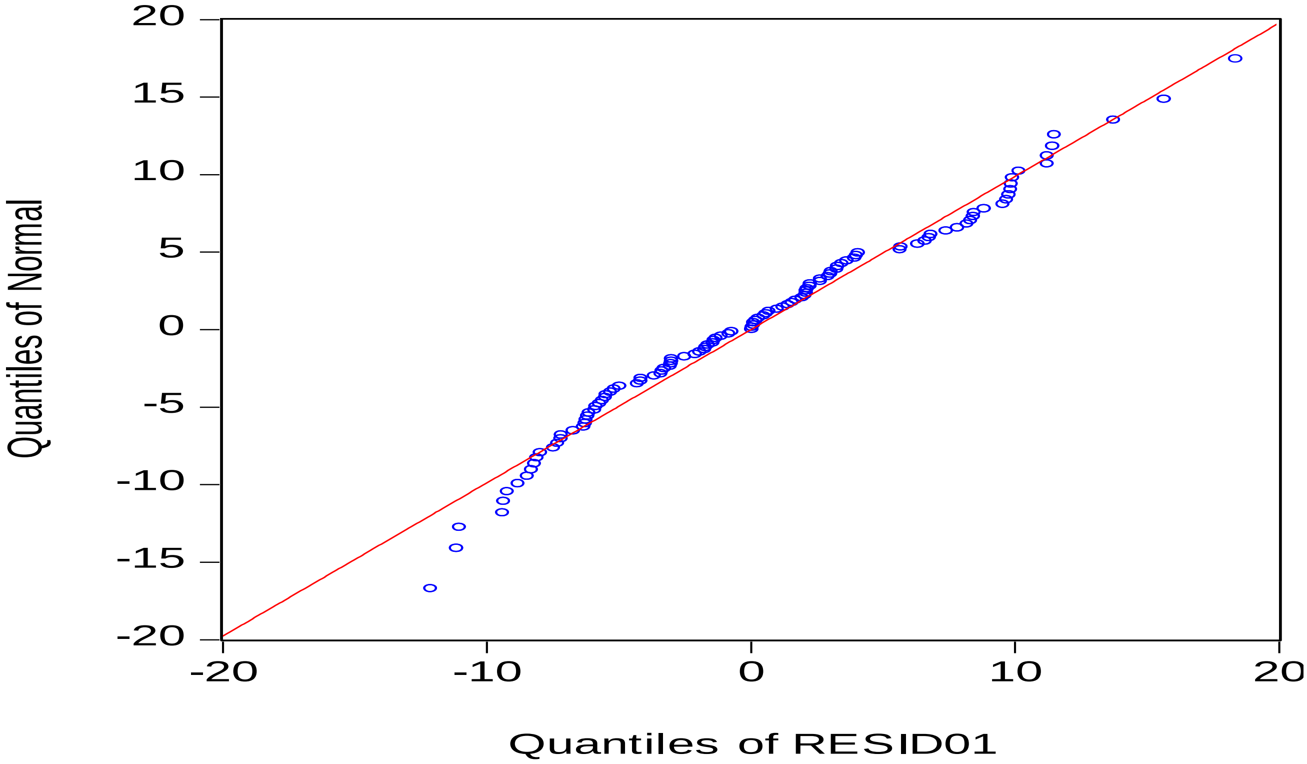

Figure 8: Q-Q Plot of normality of residuals of selected model ARIMA (1, 1, 2)

The Jarque-Bera (JB) statistic of 3.688 with a *p-value* of 0.1621 > 0.05 was not significant indicating normality of the residual. Also, the Q-Q plot of normality also indicated that almost all of the residuals are lying along the theoretical normality line and are not distinctively far from the normality line. This supports the assumption that there is no pattern in the residuals of the selected model and hence can be used for forecasting. Table 6 gives the forecast values of Caesarean sections in UCC Hospital for the next five years.

Table 6: A 5-year Caesarean Section incidence Forecasts for UCC Hospital

Year/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2021								36	35	36	35	36
2022	35	37	35	37	36	37	36	38	36	38	37	38
2023	37	38	37	39	37	39	38	39	38	39	38	40
2024	38	40	39	40	39	41	39	41	40	41	40	41
2025	40	42	40	42	41	42	41	42	41	43	41	43
2026	42	43	42	43	42	44	43					

Figure 9 displays the corresponding forecast graph of Caesarean sections in UCC Hospital for the same period running from August 2021 to July 2026.

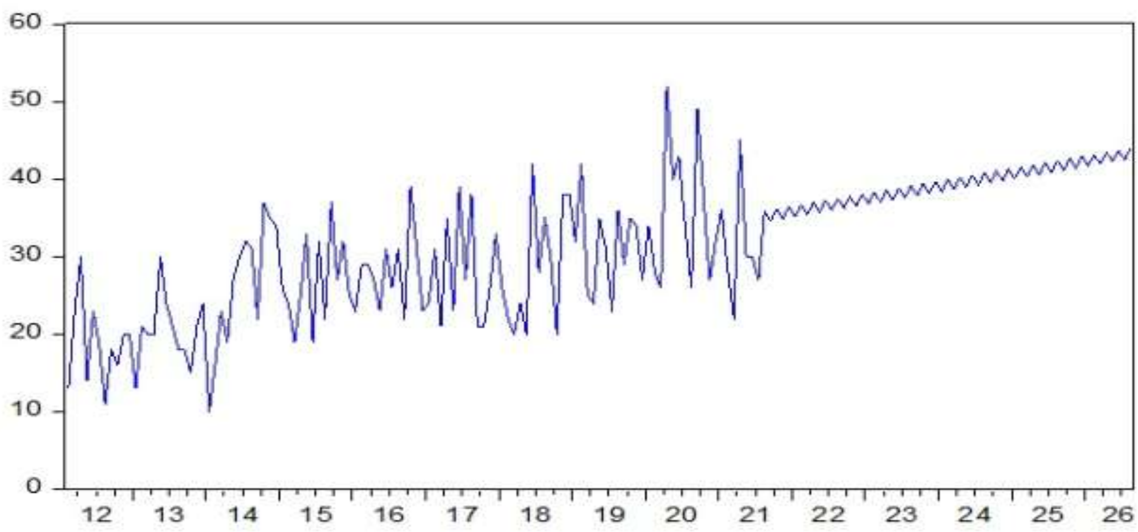

Figure 9: A five-year Forecast of Caesarean Sections from ARIMA (1, 1, 2)

The forecast clearly indicates a rising trend in CS incidence rate in the hospital.

4. Discussion

For the entire study period of 115 months (over nine years) ranging from January 2012 to July 2021, there were a total of 10344 deliveries at the maternity unit of the UCC Hospital. These total deliveries were of different modes namely; Caesarean section mode of delivery which constituted 3159 (30.54%), Normal or Vaginal mode of delivery which constituted 7152 (69.14%), Vacuum extraction mode of delivery constituted 31 (0.30%), and Forceps mode of delivery constituted 2 (0.02%). Total number of babies delivered in the study period was 10495 made of 10107 (96.30%) single babies, 382 (3.64%) twin babies, and 6 triplet babies (0.06%). There was no reported incidence (0%) of delivering more than three set of babies at the facility. Prah, et al [9] study investigated the CS prevalence rate for the period of 2014-2015 and had a CS prevalence rate of 26.7% (645/2397) in the hospital. Out of these results, 51.9% (335/645) were emergency caesarean sections whilst 48.1% (310/645) were electives. There were no reported cases of forceps delivery, but however, recorded 0.42% of vacuum extraction with 73.1% vaginal delivery. This study result of 30.54% prevalence rate in Caesarean sections in the University of Cape Coast Hospital with 51.2% elective is even more severe than reported by the previous study of Prah et al. More so, a time series plot of CS type also revealed that the elective CS cases conducted in the hospital are recently on the rise (figure 2). The elective prevalence rate of 51.2% as against 48.8% of emergency CS cases (figure 4) clearly indicated this fact and this may mean that the CS mode of delivery at the facility for the most part could probably be overly done or abused [1, 2, 4].

The study findings revealed six non-seasonal tentative ARIMA models shown in Table 4 and ARIMA (1, 1, 2) with a first-order autoregressive and second-order moving average with one order of nonseasonal differencing selected as the best model fit based on the criteria that it had the highest number of significant coefficients of 2, the lowest volatility of 42.2578, highest adjusted R.sq value of 0.491867, lowest AIC value of 6.701186, and also lowest SIC value of 6.797193. The correlogram of residuals for ARIMA (1, 1, 2) was formulated and all lags were within the 95% confidence interval or the standard error bounds. Also, Jarque-Bera (JB) statistic of 3.6388 with a *p-value* of 0.1621 of the residuals proved that the residuals were normally distributed; this is equally attested by the Q-Q plot of normality of residual. The Ljung-Box test was conducted at various lags and all *p-values* were well above 0.05 indicating no significant autocorrelations in the residuals. This finding completely rejects the null hypothesis that the residual of the model ARIMA (1, 1, 2) is auto correlated. This means that there was no significant autocorrelation between residuals at different lag times and that the residuals were *white noise* hence model was suitable for forecasting.

The increasing or upward trend in CS cases revealed in this study also concurs with the findings of other researchers [6, 8, 9, 17]. Bosson-Amedenu et al [6] study exhibited an increasing or upward trend for CS incidence rate (both within the study period and the forecast period) for all the then ten (10) regions of Ghana, however, that study showed seasonal pattern in CS incidence rate for Eastern, Greater Accra and Ashanti regions respectively. The seasonal pattern for Eastern region peaked in January; Greater Accra peaked in May whereas Ashanti region peaked in both May and October. Pradhan, and Bhandary [8] in their study rather had a decreasing CS rate in their forecast though the study period exhibited increasing CS rate. The forecast of Caesarean section incidences in UCC hospital for the period of August 2021 to July 2026 indicates an increasing trend or an upward movement for the CS mode of childbirth with an expected rate of over 40%. And despite WHO recommended level of 10%-15% for CS, the facility registered a monthly highest volatility of 64.5% (49/76) CS incidence rate for the entire study period in the month of July 2020. These recorded high CS incidence rates in the University of Cape Coast Hospital must be thoroughly investigated and checked to curtail any possible abuse of the CS method. Since some studies have shown associations between caesarean section rates and non-clinical factors [18], it is recommended that further studies be conducted to ascertain the various indications for the very high rate of caesarean sections found in this study.

5. Conclusion

The study has successfully identified ARIMA (1, 1, 2) as the model that best fit the hospital's observed CS monthly rates data and accurately projects CS rates for August 2021 to July 2026. The study reports a high prevalence rate of 30.54% Caesarean section incidences in the hospital with a monthly volatility ranging from 15.4% to 64.5% for the entire period of study.

6. Recommendations

Thus, as an intervention to reduce the incidence of CS rates in the hospital, the study recommends the provision of tailored patient education materials and training of healthcare professionals to provide patient education to low-risk women who make demands for caesarean sections. These non-clinical educational interventions may include: childbirth training workshops, nurse-led applied relaxation training programme, psychosocial couple-based prevention programme, and psychoeducation for women with fear of pain. Recommendations targeted at health-care professionals may include: training clinicians on safely handling instrumental as well as vaginal breech deliveries, implementing a mandatory second opinion for conducting caesarean section (high-certainty evidence), and finally there should be mandatory caesarean section audits and timely feedback to health-care professionals within the facility and beyond.

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