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TIME SERIES ANALYSIS OF MATERNAL MORTALITY IN GHANA. A CASE STUDY OF THE KORLE-BU TEACHING HOSPITAL, ACCRA (2001 - 2013)

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JUNE, 2015
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DECLARATION

I hereby declare that except for references to other people’s work which have been duly acknowledged, this thesis is the result of my own research work carried out under the supervision of Dr. K. Doku – Amponsah and Dr. E. N. N. Nortey of the Statistics Department of the University of Ghana.

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DEDICATION

This thesis is dedicated solely to Grace Joy Quarcoo for her encouragement and love throughout the period of my university education. I pray that the Almighty God will give her good health and long life to enjoy the fruit of her labour.
ABSTRACT

This study examined the pattern of maternal mortality ratios as well as a spectral analysis of maternal mortality at the Korle - Bu Teaching Hospital in Accra from 2001 to 2013. It also fitted a stochastic model to forecast maternal mortality ratios for four quarters. Analyses were based on data available at the Bio-Statistics Department of the Obstetrics & Gynaecology directorate of the Korle - Bu Teaching Hospital in Accra for the period 2001 – 2013. The R-Consol statistical analysis software as well as the Statistical Analysis Software (SAS) was used in analysing the data. It was observed that the average Maternal Mortality Ratio (MMR) in Korle-Bu Teaching Hospital over the Thirteen (13) year period was 835 per 100,000 live births, which is over twice that of the national’s MMR of 380 per 100,000 live births. The time series plot of the monthly maternal mortality ratio data clearly shows volatility clustering in the data with constant mean and stable variance and hence considered stationary. An ARMA model was selected as the appropriate model for predicting future maternal mortality ratios for the hospital. The model satisfied all conditions of a good ARMA model and was used to predict Maternal Mortality Ratios (MMRs) for the next four quarters. The power spectrum of the series was obtained using the periodogram plot of the series and suggests smoothing. We conclude statistically that the maternal mortality ratio data has a platykurtic distribution, an ARMA model is adequate for forecasting Maternal Mortality Ratios (MMRs) and the power spectrum of maternal deaths has smoothing.
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LIST OF ABBREVIATIONS

ACF  
Autocorrelation Function

AIC  
Akaike Information Criterion

AIDS  
Acquired Immune Deficiency Syndrome

APE  
Absolute Percentage Error

AR  
Auto Regressive

ARIMA  
Auto-Regressive Integrated Moving Average

ARMA  
Auto Regressive Moving Average

BIC  
Bayesian Information Criterion

CSO  
Central Statistical Office

EmOC  
Emergency Obstetric Care

HIV  
Human Immunodeficiency Virus

KATH  
Komfo Anokye Teaching Hospital

KBTH  
Korle-Bu Teaching Hospital

MA  
Moving Average

MDG  
Millennium Development Goal

MMR  
Maternal Mortality Ratio

PACF  
Partial Autocorrelation Function

SAS  
Statistical Analysis software

UNICEF  
United Nations International Children’s Emergency Fund
WHO-ICD  World Health Organization - International Classification of Diseases

WHO  World Health Organization
ACKNOWLEDGEMENT

“In everything give thanks: for this is the will of God in Christ Jesus concerning you”.

(1 Thessalonians 5:18 KJV)

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CHAPTER ONE

1.0 INTRODUCTION

This study seeks to examine the patterns of maternal mortality ratios as well as fitting a stochastic model to forecast maternal mortality ratios at the Korle-Bu Teaching Hospital, Accra from 2001 to 2013. The study will explore the feasibility of time series plot and time series ARIMA in the study of pattern of Maternal Deaths and to predict Maternal Mortality Ratios respectively so as to provide the theoretical basis for continuing programmes to reduce this problem. This chapter takes a look at the background of the study, the general socioeconomic profile of the study area. The problem statement, research questions and objectives, research methodology, justification of the study as well as the scope and limitations of the study are also discussed.

1.1 BACKGROUND OF THE STUDY

Global attention began to focus more seriously on maternal mortality when in 1985; Rosenfield and Maine (1985) published a thought-provoking article in the Lancet. In this classic article titled 'Maternal Mortality - a neglected tragedy - where is the M in MCH?'. The authors alerted the world to the fact that many developing countries were neglecting this important problem and that existing programs were unlikely to reduce the high maternal mortality rates in the developing world. Another significant contribution to the crusade against maternal mortality was the WHO (1986) publication, 'Maternal Mortality: helping women off the road to death.'

All these led to the Safe Motherhood Conference in Nairobi, Kenya in 1987. Speakers at this conference presented global statistics on death and complications resulting from pregnancy. They also showed that in sub-Saharan African, the lifetime risk that a woman would die in childbirth is 1 in 21 and that this is 400 times higher than the lifetime risk for her
counterpart in Western Europe or North America. The conference concluded with strong recommendations about maternal health and that was when the Safe Motherhood Initiative was born. The reduction of maternal mortality by half the 1990 levels by the year 2000 was a goal common to several of such conferences, including in particular, the 1990 World Summit for Children, the 1994 Cairo International Conference on Population and Development and the 1995 Fourth World Conference on Women. At the Millennium Summit in September, 2000, the largest gathering of world leaders in history adopted the United Nations (UN) Millennium Declaration, committing their nations to a new global partnership aimed at eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality and empowerment of women, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases and ensuring environmental sustainability. These targets were all given a deadline of 2015 and have since been known and referred to as the Millennium Development Goals (MDGs).

Globally, 529,000 women die each year from pregnancy-related complications, of which about 90% occur in developing countries, the worst affected being West Africa, including Ghana (United Nations Millennium Project, 2006). In Africa 1 out of 16 women stand the risk of dying through pregnancy and childbirth. The risk of maternal deaths is highest in Africa, where countries struggle to provide health services for large number of its populations. The World Health Organization (WHO) states that worldwide 1500 women die each day, or one a minute, in pregnancy or due to childbirth related complications. It is estimated that over half of these deaths are in sub-Saharan Africa, with maternal mortality ratio of 910 deaths per 100,000 live births (WHO, 2007).

Maternal hemorrhage, hypertensive disorders, abortion, sepsis and obstructed labour are some of
the direct causes. Sickle cell diseases, anaemia, HIV/AIDS, cardiac arrest among others are the indirect causes of death among pregnant women in developing countries. These complications of pregnancy contribute significantly to the high levels of maternal and neonatal mortality in Sub-Saharan Africa. In addition to maternal deaths, millions more women suffer from near death complications and long-term disabilities as a result of pregnancy-related complications which also affect the lives of numerous babies. Contributory factors include lack of access to good quality maternal and neonatal health services and strong adherence to negative cultural beliefs and practices (AbouZahr & Wardlaw, 2001 and WHO, 2005). Globally, there is increasing evidence that reduction of maternal deaths is achievable with the timely provision of quality Emergency Obstetric Care (EmOC). The challenge is to focus and concentrate on improving efficient and timely delivery of emergency obstetric care. Studies have shown that most life-threatening obstetric complications cannot be predicted or prevented, but can be successfully treated if prompt access to quality Emergency Obstetric services and skilled attendance are available (UN Millennium Project, 2005).

In recent years, Ghana’s Maternal Mortality Ratio (MMR) declined from 560 deaths out of 100,000 live births in 2005, to 451 deaths in 2007 (WHO, 2005; GHS, 2007). However, statistics from Korle-Bu, Accra show that maternal deaths are rising. In 2007, Korle-Bu’s MMR was 1019 out of 100,000 live births while in 2011 it was 1138 out of 100,000 live births (KBTH, 2013). The majority of maternal deaths in Accra (about 90%) occurred at KBTH, most likely because this hospital is the referral hospital for complicated medical emergencies.
1.1.1 PROFILE OF THE STUDY AREA

- Accra Metropolitan Assembly (AMA)

![Map of Accra showing sub-metro areas.](image)

**Figure 1.1: Map of Accra showing sub-metro areas. (Source: Accra Metropolitan Assembly Official Website)**

The City of Accra is the capital and largest city in Ghana, with an estimated urban population of 2,269,143 million with a population density of 9,589.2 sq. km (24,836 per sq. mi). It is also the capital of the Greater Accra Region and the Accra Metropolitan District. It is estimated that the City's growth rate is around 4.4% per annum. The city has a total surface area of 173 sq. km (67 sq mi) and is divided into 11 sub-metropolitan areas, namely Ablekuma North, Ablekuma
Central, Ablekuma South, Ashiedu Keteke, Ayawaso Central, Ayawaso East, Ayawaso West, La, Okaikoi North, Okaikoi South and Osu Klottey.

- **Major Economic Activities**

Accra is a centre for manufacturing, marketing, finance, insurance, fishing and transportation. Its financial sector includes a central bank, nine commercial banks (with 81 branches), four development banks (with 19 branches), four merchant banks (with seven branches), three discount houses, one home finance mortgage bank, multiple building societies, Ghana Stock Exchange (GSE), foreign exchange bureauxs, finance houses, insurance companies, insurance brokerage firms, two savings and loans companies, and numerous real estate developers, with industrial sites and residential developments. The road network in the Accra Metropolitan Area totals 1,117 kilometres (694 mi) in length.

There are over 50,506 identified residential properties in Accra, and about 4,054 commercial, industrial and mixed properties, with a total rateable value of GH¢13,849,014. There are also supermarkets, 36 facilities for both on-street and off-street parking, and shopping malls, as well as several facilities for sports and recreation.

- **The Korle-Bu Teaching Hospital**

The Korle-Bu Teaching Hospital in Accra is the premier health care facility in Ghana. It is the only tertiary hospital in the southern part of Ghana. It is a teaching hospital affiliated with the medical school of the University of Ghana. It was established on October 9, 1923, the Korle Bu Teaching Hospital has grown from an initial 200 bed capacity to 2,000. It is currently the third largest hospital in Africa and the leading national referral centre in Ghana. Korle Bu, which
means the valley of the Korle lagoon, was established as a General Hospital to address the health needs of the indigenous people under Sir Gordon Guggisberg's administration, the then Governor of the Gold Coast.

Population growth and the proven efficacy of hospital-based treatment caused a rise in hospital attendance in Korle-Bu. By 1953, demand for the hospital's services had escalated so high that the government was compelled to set up a task force to study the situation and make recommendations for the expansion of the hospital. The government accepted and implemented the recommendations of the task force which resulted in the construction of new structures, such as the Maternity, Medical, Surgical and Child Health Blocks. This increased the hospital's bed capacity to 1,200. It gained teaching hospital status in 1962, when the University of Ghana Medical School (UGMS) was established for the training of medical doctors. The UGMS and five other constituent schools are now subsumed under the College of Health Sciences to train an array of health professionals. All the institutions of the College, however, undertake their clinical training and research in the Hospital. At the moment, the Hospital has 2,000 beds and 17 clinical and diagnostic Departments/Units. It has an average daily attendance of 1,500 patients and about 250 patient admissions. Clinical and diagnostic departments of the hospital include Medicine, Child Health, Obstetrics and Gynaecology, Pathology, Laboratories, Radiology, Anaesthesia, Surgery, Polyclinic, Accident Centre and the Surgical/Medical Emergency as well as Pharmacy. Other Departments include; Finance, Engineering, and General Administration.

The Obstetrics and Gynaecology department provides 240 beds for Obstetrics and 114 beds for Gynaecology. The department is divided into five units. A senior consultant heads each unit with other consultants and doctors equally distributed among the units. It serves mainly as a referral center for the southern part of the nation, which has a population of over 10 million. The
Korle-Bu Teaching Hospital (KBTH) as a policy requires audits to be conducted on all maternal deaths occurring within the hospital. It includes the examination of the standards of care given, parity and age of deceased, gestational age and the cause of death. Family Planning services are comprehensively organized by the Family Planning unit of the directorate. (Source: Korle-Bu Teaching Hospital official website)

1.2 PROBLEM STATEMENT

Maternal mortality is one of the most sensitive indicators of the health disparity between richer and poorer nations. The lifetime risk of dying due to maternal causes is about one in six in the poorest countries, compared with about one in 30,000 in Northern Europe (Ronsmans and Graham, 2006). Every minute, a woman dies from complications of pregnancy and childbirth. The available record indicates that about 530,000 deaths per year worldwide are caused by complications associated with pregnancy and childbirth. In Africa 1 out 16 women stand the risk of dying through pregnancy and childbirth. Ghana’s Maternal Mortality Ratio (MMR) declined from 560 deaths out of 100,000 live births in 2005, to 451 deaths in 2007 but this rate is still too high (WHO, 2005; GHS, 2007).

Statistics from Korle-Bu, Accra show that maternal deaths are rising. In 2007, Korle-Bu’s MMR was 1019 out of 100,000 live births while in 2011 it was 1138 out of 100,000 live births (KBTH, 2013). Also, questions as to what statistical model would be reliable for a comprehensive study of Maternal Mortality incidence in the facility needs to be made evident. It is against this background that this study is being undertaken to assess the pattern and trend of maternal mortality and to predict future incidence as well future maternal mortality rates.
1.3 RESEARCH QUESTIONS

- What is the pattern of maternal mortality ratios (MMR’s) in the Korle-Bu Teaching Hospital, Accra?
- To what extent can Korle-Bu Teaching Hospital as a facility achieve a reduction in the Maternal Mortality ratio?
- What is the significance of the incidence and occurrence of maternal mortality of the facility?

1.4 RESEARCH OBJECTIVE

Generally, the study will aim at examining the patterns of maternal mortality ratios as well as fitting a stochastic model to forecast maternal mortality at the Korle-Bu Teaching Hospital, Accra, using ARIMA model.

1.4.1 SPECIFIC OBJECTIVE

The specific objectives which the study shall focus on are as follows:

- To examine the pattern of maternal mortality ratios (MMR’s) using time series plot
- To fit a stochastic model to forecast maternal mortality ratios (MMR’s) over four (4) quarters.
- To have a spectral analysis of the maternal death over the period of time under study

1.5 METHODOLOGY

Time series ARIMA models would be adopted for the estimation of patterns and predictions of future maternal mortality ratios. ARIMA models are, in theory, the most general class of models for forecasting a time series which can be stationarized by transformations such as
differencing and taking log. The ARIMA by Box and Jenkins (1976), consist of the following steps:

- Model identification
- Parameter estimation
- Model diagnostic (goodness of fit)

Time series plot is used to examine and evaluate the pattern maternal mortality ratios. A spectral analysis of the maternal mortality over the period of time under study is also considered.

1.5.1 DATA

The analyses would be based on data (secondary data) available at the Bio-Statistics Department of the Obstetrics & Gynaecology directorate of the Korle-Bu Teaching Hospital in Accra for the period 2001 - 2013. The required data are:

- Quarterly recorded maternal mortality ratios (MMR)
- Monthly recorded maternal deaths
- Monthly recorded deliveries

1.5.2 SOFTWARE USED

The Statistical Analysis Software (SAS) would be used for examining and evaluating the pattern of maternal mortality ratios while the R-Console statistical software would be used in analysing and fitting ARIMA models. Other statistical and numerical simulation methods of parameter estimation were utilized as and when deemed fit.
1.5.3 SOURCE OF KNOWLEDGE

The main source of knowledge for the successful completion of this study would be the Korle-Bu Teaching Hospital Library, the University of Ghana Library (Balm Library) and the Ministry of Health Research Centre - Accra. However, the internet and other obstetrics and gynecology professionals would continue to help enrich the progress and outcome of the study.

1.6 JUSTIFICATION

According to WHO, Ghana has one of highest maternal mortality rates in the West African region, 540 deaths per 100,000 live births (WHO, 2007). Accra’s challenges in the public health arena remain formidable. In addition, data from 2007 - 2011 for Accra show that maternal and infant deaths were on the rise and diseases such as malaria and tuberculosis continued to be major causes of morbidity. However, on a positive note, Maternal Mortality Ratio fell significantly in 2009, and projections for 2014 show that it will most likely continue to decline (AMHD, 2010). Selection of the Maternal Mortality Ratio (MMR) as the primary indicator for Millennium Development Goal number 5 (MDG-5) on improving maternal health has increased interest in programs to improve maternal health and in having reliable sources of data on maternal mortality rates.

The study would provide the needed statistical evidence to justify the success or failure of the set target with respect to the Korle-B Teaching Hospital. The forecast models to be generated would also be useful for predicting future maternal deaths at Korle-Bu Teaching Hospital and the Accra Metropolitan Area.

On the basis of available empirical evidence, this study would seek to furnish decision makers and other stakeholders with vital information regarding the trend of maternal mortality in the
facility for possible policy interventions. Additionally, this study would also contribute to knowledge on the use of ARIMA Models in the area of maternal health and other related areas with a view to, among other things, stimulating further research.

1.7 SCOPE AND LIMITATION

The scope of this study is restricted to the Korle-Bu Teaching Hospital in Accra. It is the premier health care facility in Ghana. It is the only tertiary hospital in the southern part of Ghana. It is the main referral hospital for the Greater Accra, Central, Volta, Western and Eastern Regions. Particularly in the Accra Metropolitan Area, this facility record a high number of all pregnancy related cases and has an Obstetrics & Gynaecology department that takes care of maternal health issues in and around Accra. This may be a limitation to the study. It is also envisage that, the study will suffer constraints of time, resource inadequacy, unavailability of relevant literature and others of the like. The study would be structured within the confines of the thesis study matter.

1.8 THESIS ORGANISATION

This thesis is organised in five chapters. Chapter one is the introductory chapter to the entire study. It takes a critical look at the general background of maternal mortality as well as maternal health and also looks at the general socio-economic profile of the study area. The problem statement, research questions and objectives, research methodology, justification of the study as well as scope and limitations of the study are discussed in this chapter. Chapter two reviews related literature based on the thesis objectives and preferred models to be used in achieving these objectives. Expected outcome of the study and other comparative results of similar studies are also discussed in this chapter. Chapter three describes the theory of history model to be used,
formulations and methods of solution. Chapter four is dedicated to data collection, analysis and results. Chapter five concludes the entire study by stating specific recommendations to stakeholders based on the major findings made in the study.
CHAPTER TWO
LITERATURE REVIEW

2.0 INTRODUCTION

This chapter discusses the literature available on Maternal Mortality in general. It also looks at the summary of abstracts on various literatures with regard to the model being used and the general working title.

2.1 THE MATERNAL MORTALITY SITUATION

Maternal mortality is defined as the death of a woman while pregnant or within forty – two (42) days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management (WHO-ICD 10).

Globally, the lifetime risk for women of maternal death is 1 in 74. In industrialized countries this risk is 1 in 2,800. In the least developed countries, they face a 1 in 16 chance of dying in childbirth in their lifetime (DFID, 2004). The fifth Millennium Development Goal is to improve maternal health, with a target to reduce the maternal mortality ratio by three quarters, between 1990 and 2015. Yet, maternal mortality in developing countries has barely decreased over the past decade, and in parts of Africa it has increased. The national target was to reduce the 1990 maternal mortality rate of 740 per 100,000 live births by 3/4 to 185 per 100,000 live births by 2015. In this thesis, we also looked at the pattern and prevalence of maternal mortality using the ARIMA models. The international definition of the Maternal Mortality Ratio (MMR) is the number of Direct and Indirect deaths per 100,000 live births (ICD-10).
Maternal Mortality Ratio (MMR) = \frac{\text{Total Maternal Deaths}}{\text{Total Livebirths}} \times 100,000 \text{ livebirths}

In many countries of the world this is difficult to measure due to the lack of death certificate data as well as a lack of basic denominator data, since baseline vital statistics are also not available or unreliable.

Lee (2010) of the University Of Leicester conducted a Hospital-Based Review of Maternal Mortality in Ghana. This retrospective review was undertaken at the Obstetrics and Gynaecology Department of Komfo Anokye Teaching Hospital (KATH) in Kumasi, Ghana. Data from Bio-statistics unit as well as all maternal deaths following admission from the period 1st January 2008 to 31st May 2010 were analyzed. The result revealed an estimated maternal mortality ratio of 1021.9 per 100,000 live births (95% Confidence Interval: 906.6 - 1130.8). Many of such studies have given specific MMR’s however, we seek to access the patterns of the ratios over the period under study.

Gumanga et al. (2010) did a study titled – Trends in maternal mortality in Tamale Teaching Hospital, Ghana. The objective of the work is to determine the yearly maternal mortality ratio over the period 2006 – 2010 and trends in causes of 139 audited maternal deaths from 2008 – 2010 at the Tamale Teaching Hospital in Ghana. There were 280 maternal deaths from 1st January 2006 to 31st December 2010. The maternal mortality ratio dropped from 1870 per 100,000 live births in 2006 to 493 per 100,000 live births in 2010, a fall of nearly 74% using 2008 as a baseline MMR dropped from 842 per 100,000 live births in 2008 to 493 per 100,000 live births in 2010, a fall of 41.4%. The main causes of 139 audited maternal deaths from 2008 to 2010 were sepsis (19.8%) hypertensive disorders (18.6%), haemorrhage (15.8%), unsafe abortion (11.5%), obstructed labour (5.7%), anaemia (8.7%), sickle cell disease (5.7%) and malaria (5.0%). The ages of the 139 audited maternal deaths ranged from 14 - 48 years; with a mean age of 26.5 ±
4.6 years. Nearly 50% of the maternal deaths were aged 20 - 29 years and about 10% were 14 - 19 years. Eighteen (13%) of the maternal deaths were from towns over 150km from Tamale. A retrospective descriptive review of maternal deaths and they concluded that there has been a significant reduction in maternal mortality at the Tamale Teaching Hospital, it is however still unacceptably high.

Aikins (2010) in her thesis titled —Female Health and Development; A case study regarding a maternal Health Scheme in Ghana. The study conducted at the Komfo Anokye Teaching Hospital (KATH) in Kumasi, revealed an unstable situation regarding maternal deaths, even though pregnant women have free access to antenatal care. The study aimed at finding out whether the free antenatal and delivery care provided by the Ghanaian government is encouraging pregnant women to access the facility in order to improve maternal health and also, whether it is aiding in the reduction in maternal deaths. A total of three health personnel’s and fifty-five pregnant women participated in the study. Semi - structured interviews and observation were the main tools employed for data collection. The study indicated that the presence of skilled birth attendants at delivery as per pregnant woman ratio is quite poor. The ratio is one doctor is to 17,733 and the Nurse-Population ratio is 1: 1,510 with disparities between urban and rural settings and dwellers. In Kumasi for instance, the Ratio of Midwives to Women of Reproductive Age is 1:427.

Yoko et al. (2011) did a study titled —Make it happen 2015: validation of the maternal mortality ratio in Trinidad and Tobago for 2000-06. The aim of their work was to examine the quality of the data used for the estimates of MMR provided by the Trinidad and Tobago Central Statistical Office (CSO). A retrospective reproductive age mortality survey (RAMOS) was applied for 2000 - 2006 to evaluate national estimates. The authors found that, data from CSO and external data sources yield conflicting results. The CSO estimate of MMR in 2005 was 34.8,
while those provided by UNICEF and the World Bank were 45·0 and 55·0, respectively. The authors recommended that specific maternal death review committee be established as the ideal maternal death review mechanism across all health jurisdictions in Trinidad and Tobago.

Hogan and Foreman (2010) assessed levels and trends in maternal mortality for 181 countries in their report titled —Maternal mortality for 181 countries, 1980—2008: a systematic analysis of progress towards Millennium Development Goal 5. They constructed a database of 2651 observations of maternal mortality for 181 countries for 1980—2008, from vital registration data, censuses, surveys, and verbal autopsy studies. The authors used robust analytical methods to generate estimates of maternal deaths and the MMR for each year between 1980 and 2008. They explored the sensitivity of the data to model specification and show the out-of-sample predictive validity of the methods. As a result, they estimated that there were 342,900 maternal deaths worldwide in 2008, down from 526 300 in 1980. The global MMR decreased from 422 in 1980 to 320 in 1990, and was 251 per 100 000 live births in 2008. The yearly rate of decline of the global MMR since 1990 was 1·3%. They found out that in the absence of HIV, there would have been 281 500 maternal deaths worldwide in 2008. The report concluded that, although substantial progress has been made towards MDG 5, only 23 countries are on track to achieving a 75% decrease in MMR by 2015 and that countries such as Egypt, China, Ecuador, and Bolivia have been achieving accelerated progress.

Worawan (2010) undertook a study aimed at using multiple sources of data to calculate the Maternal Mortality Ratio (MMR) in 2004-09, and to illustrate the difference between the official causes of death with the research findings. In their research titled —Thailand’s approach to measuring maternal mortality ratio individual data from civil registration and inpatient records from all public hospitals were used. The civil registration
contains data about individual’s Personal Identification (PID) etc. Their results showed that, the number of maternal deaths declined from 362 in 2004 to 269 in 2009. The country’s MMR declined from 44.5 to 35.2, a 21% reduction. Their conclusion was that, using matching techniques together with individual data, policy makers can get reliable information about the causes of maternal death.

2.2 USE OF ARIMA MODEL IN MATERNAL MORTALITY

The Journal of China Medical University in March 2011 conducted a study. The study was to explore the feasibility for application of time series ARIMA model to predict the Maternal Mortality Ratio (MMR) in China so as to provide the theoretical basis for continuing to reduce the MMR. ARIMA model was established based on the MMR of China from 1991 to 2009. Using difference method to smooth the sequence, the authors determined the order and established the 2010 national maternal mortality ratio forecast model to evaluate the predicting results. It was found that the ARIMA model fitted very well, the residual autocorrelation function graph showed the residuals were white noise sequences, the prediction results showed that the maternal mortality ratios in national urban and rural areas would be 30.39%, 24.73% and 28.80% in 2010, which showed MMR, would decline and reach a lower level. The researchers concluded that the fitting result in the ARIMA model of the incidence of the MMR is satisfactory, the forecasting achieves good effects, which also provides a scientific basis for the prevention and control of maternal mortality ratio.

Asomaning (2010) did a study titled Analysis of Maternal Mortality with time; a case study of the Okomfo Anoye Teaching Hospital – Kumasi (2000 – 2010). The study explored the feasibility for application of Poisson models and time series autoregressive integrated moving average (ARIMA)
in the study of occurrence and incidence of Maternal Deaths and to predict Maternal Mortality ratios respectively. The author found that, the mean number of occurrences of maternal death cases were high for all the years considered and established that the mean number of occurrences of maternal death cases has not significantly reduced over the period 2000 to 2010. The result also shows that there was a statistically significant in the incidence of maternal deaths difference between year 2010 (the referenced year) and years 2004, 2005 and 2008. Their chi-square values were 3.95, 5.12 and 5.83 with p-values of 0.0469, 0.0236 and 0.0158 respectively. Finally, the hospitals Maternal Mortality Ratio (MMR) is relatively stable but has a very high average MMR of 967.7 per 100,000 live births, which is about twice the National ratio of 451 per 100,000 live births. An ARIMA model fitted was used to predict maternal mortality ratios (MMRs) for the next eight quarters. The author conclude that statistically the mean rate of maternal death cases is not significant over the period of time under study, mean number of occurrence of maternal death cases has not significantly reduced over the period 2000 to 2010 and that the ARIMA model is adequate for forecasting quarterly maternal mortality ratios at the hospital.

Koch (2009) on behalf of The Chilean Maternal Mortality Group, Faculty of Medicine, University of Chile, wanted to find out whether there exist an association between maternal mortality reduction and abortion legalization? Time series of Maternal Mortality Ratio (MMR) and Abortion Mortality Ratio (AMR) from 1960 to 2007 were analyzed using multiple autoregressive moving average (ARIMA) models. Therapeutic abortion was legal until 1989 and was considered as a dummy variable in statistical analyses along time series of social and demographic factors and maternal health facilities. During the study period, MMR was found to
have decreased from 293.7 to 18.2 per 100,000 live births (-93.8%); AMR decreased from 92.5 to 1.7 per 100,000 live births (-98.1%). No significant effect of legal and illegal abortion periods on these decreasing trends was observed in ARIMA models. After abortion was fully prohibited, MMR and AMR decreased from 41.3 to 18.2 (-44.1%) and 16.5 to 1.7 (-10.3%) per 100,000 live births respectively. The average of education years, illiteracy rate, GDP per capita, and the percentage of delivery by skilled attendants were all significant predictors of MMR. The same factors along decreasing fertility rate were significant predictors of AMR trends. The study concluded that reductions in MMR and AMR are not related to legal or illegal therapeutic abortion periods in Chile. The increasing education level appears as the most important factor predicting maternal mortality reduction in this developing country, likely influencing other factors such as fertility and maternal health facilities.

The Ethiopian Government through their Ministry of Health (MoH Ethiopia, 2000) undertook a study to analyze trends and develop models for prediction of Health and Health related indicators. Key indicators of Mortality and Morbidity, Health service coverage, Health systems resources, Demographic and socioeconomic, and Risk factor indicators were extracted and analyzed. The trends in these indicators were established using trend analysis techniques. The determinants of the established trends were identified using ARIMA models in STATA. The trend-line equations were then used to predict future values of the indicators. Among the mortality indicators considered in this study, it was only Maternal Mortality Ratio that showed statistically significant decrement within the study period. The trends in Total Fertility Rate, physician per 100,000 population, skilled birth attendance and postnatal care coverage were found to have significant association with Maternal Mortality Ratio trend. Based on the prediction from the current trend, they concluded that the Millennium Development Goal target
for under-five mortality rate and proportion of people having access to basic sanitation can be achieved.

### 2.3 OTHER USE OF ARIMA MODELS

Yun-li et al. (2004), tried to understand the prevalence and changing trends of the Infant Mortality Rates (IMR) in China from 1991 to 2004, and to forecast the IMR in China from 2005 to 2007. The average velocity of increase was calculated and trend analysis was done simultaneously; the ARIMA model was used to forecast IMR in China from 2005 to 2007. The authors found that, from 1991 to 2004, the IMR of China has decreased, the average rate of decay of the urban IMR and the rural IMR is 3.77% (mean, $\mu = 3.9964$, p-value, $P < 0.001$) and 5.97% (mean, $\mu = 4.7628$, p-value, $P < 0.001$) respectively. And the rural IMR is obviously higher than the urban IMR. From 2005 to 2007, the rural IMR would descend obviously; while the urban IMR would keep steady. They concluded that though the IMR in urban areas and rural areas have both decreased, the urban-rural difference was obvious. Compared with the urban IMR, the rural IMR has greater space to descend because of the previous higher IMR.

Kuhn et al. (1993) used Poisson regression and time series analysis to analyze changes in child injury incidence after implementation of community-based injury prevention program in Central Harlem, New York City. Rates of severe injury during the period from 1983 to 1991 among children under the age of 17 years living in Central Harlem and in the neighbouring community of Washington Heights are analyzed. The two methods provide similar point estimates of the effect of the intervention and have a good fit to the data. Although the time series analysis has been promoted as the method of choice in analysis of sequential observations over long periods of time, this illustration suggests that Poisson regression is an attractive and viable
alternative. Poisson regression provides a versatile analytical method for quantifying the time
trends of relatively rare discrete outcomes, such as severe injuries, and provides a useful tool for
epidemiologists involved with program evaluation.

Mulu and Tilahun (2009) did a study that sort to analyze trends of and develop models for
prediction of Health and Health related indicators of Ethiopia from the year 1987 to 2000. The
determinants of the established trends were identified using ARIMA models in STATA.
Among the mortality indicators considered in this study, it was only Maternal Mortality Ratio
that showed statistically significant decrement within the study period. The trends of Total
Fertility Rate, physician per 100,000 population, skilled birth attendance and postnatal care
coverage were found to have significant association with Maternal Mortality Ratio trend. The
authors concluded that current trend indicates the need to accelerate the progress of the
indicators to achieve MDGs at or before 2015, particularly for Maternal Health and access to
safe water supply.
CHAPTER THREE

3.0 INTRODUCTION

This chapter presents the theory of models to be used, formulations and methods of analyzing the available data to satisfy the objectives of the study. It focuses on the detail and comprehensive understanding of The Box - Jenkins methodology for ARIMA models. Among the aspects that will come under discussion include the methodologies used in modeling, the software specifications, and the features that are incorporated in the model.

3.1 DATA SOURCE AND TYPE

This study essentially seeks to model the maternal mortality patterns to be used in predicting future maternal mortality ratios using the Korle - Bu Teaching Hospital as the case study. The analysis is based on secondary data available at the Bio-Statistics Department of the Obstetrics & Gynaecology directorate of the Korle - Bu Teaching Hospital in Accra for the period 2001 - 2013. The required data include: Monthly recorded live births, Monthly recorded maternal deaths and Monthly recorded deliveries. Maternal mortality ratios were also computed using the tenth revisions of the International Classification of Diseases (ICD-10). The data has only one variable under study, which is time in months. In all, there are 156 monthly observations under the thirteen years' duration.

3.2 THE CONCEPT OF TIME SERIES

Time series is a time dependent sequence $Y_t$, where $t$ belongs to the set of integers and denotes the time steps. If a time series can be expressed as a known function, $Y_t = f(t)$, then it is said to be a deterministic time series. If it is however expressed as $Y_t = X(t)$, where $X$ is a
random variable then \( \{ Y_t \} \) is a stochastic time series. The basis for analyzing a time series may be classified as prediction, description and control. Time series analysis mainly decomposes the variations in a series into the various components of trend, periodic and stochastic.

### 3.2.1 Stationary and Non-stationary Series

A time series is said to be strictly stationary if the joint distribution of \( X_{i_1}, X_{i_2}, \ldots, X_{i_n} \) is the same as the joint distribution of \( X_{i_1+T}, X_{i_2+T}, \ldots, X_{i_n+T} \), for all \( i_1 \leq T \ldots i_n \). Thus, shifting the time position by \( T \) periods has no effects on the joint distributions, which depends on the interval between \( t_1 \ldots t_n \).

If a time series is not stationary, then it is said to be non-stationary. A simple non-stationary time series model is given by

\[
Y_t = \mu_t + e_t, \ldots,
\]

where the mean \( \mu_t \) is a function of time and \( e_t \) is a weakly stationary series. Unlike the stationary time series, the mean and variance of the non-stationary process changes with time. If a non-stationary series is differenced one or more times it becomes stationary and that series is then said to be homogeneous.

The stationarity condition ensures that the autoregressive parameters in the estimated model are stable within a certain range as well as the moving average parameters in the model are invertible. If this condition is assured then, the estimated model can be forecasted (Hamilton, 1994). To check for stationarity, we usually test for the existence or nonexistence of what we called unit root. The unit root test is performed to determine whether a stochastic or a deterministic trend is present in the series. There are several statistical tests in testing for presence of unit root in a series. For series with seasonal and non-seasonal behaviour, the test must be conducted under the seasonal part as well as the non-seasonal part. Some example of
the unit root test for the non-seasonal time series are the Dickey-Fuller and the Augmented Dickey-Fuller (DF, ADF) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test and Zivot-Andrews (ZA) test (see Dickey & Fuller, 1979; Kwiatkowski et al., 1992; Zivot & Andrews, 1992).

- **UNIT ROOT TEST**

Unit Root Test was derived in 1979 by Dickey and Fuller to test the presence of a unit root versus a stationary process. The unit root process and a stationary process are given by equations

\[
\rho_t = \alpha_0 + \alpha_1 \rho_{t-1} + \epsilon_t
\]

If \( \alpha_1 = 1 \) then the series is said to have unit root and is not stationary.

The Unit Root Test as proposed by Kwiatkowski-Phillips-Schmidt-Shin (KPSS), test the hypothesis below

- \( H_0 : \alpha_1 = \) Series is level or trend stationary
- \( H_A : \alpha_1 = \) Series is level or trend non-stationary

If test statistic value of the KPSS test is less than critical value we accept the null hypothesis that data is level or trend stationary. Similarly, the Unit Root Test as proposed by Dickey and Fuller (ADF), test the hypothesis below:

- \( H_0 : \alpha_1 = \) Series has unit root
- \( H_A : \alpha_1 = \) Series has no unit root

If the test statistic of the ADF test is less than critical value we reject the null hypothesis that the
data has a unit root.

3.2.2 Lag

Lag is a difference in time between an observation and a previous observation. Thus $Y_{t-k}$ lags $Y_t$ by $k$ periods.

3.2.3 White Noise

A collection of uncorrelated random variables, $\omega_t$ with mean 0 and finite variance $\sigma_{\omega}^2$ was first used as a model for noise in engineering applications, where it is called white noise. We denote this process as $\omega_t \sim wn\left(0, \sigma_{\omega}^2\right)$. The designation white originates from the analogy with white light and indicates that all possible periodic oscillations are present with equal strength. We will, at times, also require the noise to be iid random variables with mean 0 and variance $\sigma_{\omega}^2$. We shall distinguish this case by saying white independent noise, or by writing $\omega_t \sim iid\left(0, \sigma_{\omega}^2\right)$. A particularly useful white noise series is Gaussian white noise, wherein the $\omega_t \left(\mathcal{N}\right)$ or more succinctly, $\omega_t \sim iid \mathcal{N}\left(0, \sigma_{\omega}^2\right)$.

3.2.4 Autocorrelation Function (ACF)

The Autocorrelation function is extremely useful for describing the general process used to develop a forecasting model. It measures the degree of correlation between neighbouring observations in a time series. The autocorrelation at any lag $k$ is defined as $COR\left(Y_t, Y_{t-k}\right)$ and is measured by
\[
\rho_k = \frac{COV(Y_t, Y_{t-k})}{\delta_t \delta_{Y_{t-k}}} = \frac{E\left[(Y_t - \mu_Y)(Y_{t-k} - \mu_Y)\right]}{E(Y_t - \mu_Y)^2 (Y_{t-k} - \mu_Y)^2}
\]

where \(Y_t\), the observation at time \(t\), \(Y_{t-k}\) is observation at time \(t-k\) and \(\mu_Y\) is the observed mean. The theoretical autocorrelation function is generally unknown, but may be estimated from the sample autocorrelation function as follows:

\[
\rho_k = \frac{\sum_{i=1}^{n} (Y_i - \overline{Y})(Y_{i-k} - \overline{Y})}{\sum_{i=1}^{n} (Y_i - \overline{Y})^2}
\]

where \(t\) is the length of the time series under study \(\overline{Y}\) is the mean of the \(Y_i\) observation and \(k = 1, 2, ..., k\)

Normally we compute the first \(k\) to be less than \(N/4\) sample autocorrelations.

If we define the covariance between \(Y_t\) and \(Y_{t-k}\) as \(\gamma_k\), then

\[
\rho_k = \frac{\gamma_k}{\gamma_0}
\]

Thus for any stochastic process \(\rho_0 = 1\). It is also true that \(\rho_k = \rho_{-k}\)

For a series to be white noise all \(\rho_k = 0\) for \(k > 0\). This may be tested using the Box - Pierce test statistic:

\[
Q = n \sum_{k=1}^{k} \rho_k^2
\]

which is approximately distributed as chi-square with \(k\) degrees of freedom. Thus a
value below the critical value would lead to acceptance of white noise. If a series is stationary, the sample autocorrelations will tail off quickly as k increases. The expression tails off means that the function decays in an exponential, sinusoidal, or geometric fashion, with a relatively large number of nonzero values. A function is said to cut off if the function truncates abruptly with only a few nonzero values.

### 3.2.5 Partial Autocorrelation Function

A partial autocorrelation coefficient measures the degree of association between an observation \( Y_t \) and \( Y_{t-k} \). When the effects of the other time lags are held constant. We consider partial autocorrelation when we are unaware of the appropriate order of the autoregressive process to fit the time series. PACF is denoted by \( Q_{kk} \) and defined by

\[
Q_{kk} = \frac{|P_k^*|}{|P_k|}
\]

where \( P_k \) is a \( k \times k \) auto correlation matrix and \( P_k^* \) is \( P_k \) with the least column replaced by \( [\rho_1, \rho_2, ..., \rho_k]^T \)

The partial autocorrelation coefficient of order \( k \) is denoted by \( \alpha_k \) and that can be calculated by regressing \( Y_t \) against \( Y_{t-1}...Y_{t-k} \)

\[
Y_t = b_0 + b_1Y_{t-1} + b_2Y_{t-2} + ... + b_kY_{t-k}
\]

Here, explanatory variables on the right hand side are previous values of the forecast variable \( Y_t \), whereas the partial autocorrelation \( \alpha_k \) is the estimated coefficient \( b_k \) from the regression equation above.
3.2.6 Auto regressive model AR (p)

Autoregressive models are based on the idea that the current value of the series \( X_t \) can be explained as a function of \( p \) past values, \( X_{t-1}, X_{t-2}, ..., X_{t-p} \), where \( p \) determines the number of steps into the past needed to forecast the current value. An autoregressive model of order \( p \), abbreviated AR (p), is of the form

\[
X_t = \alpha + \phi_1 X_{t-1} + \phi_2 X_{t-2} + ... + \phi_p X_{t-p} + \omega_t
\]

where \( X_t \) is stationary, \( \phi_1, \phi_2, ..., \phi_p \) are constants. Unless otherwise stated, we assume that \( \omega_t \) is a Gaussian white noise series with mean \( \mu \) zero and variance \( \sigma^2_\omega \). However, if the mean \( \mu \) of \( X_t \) is not zero, replace \( X_t \) with \( X_t - \mu \) in the AR (p) model

\[
X_t - \mu = \phi_1 (X_{t-1} - \mu) + \phi_2 (X_{t-2} - \mu) + ... + \phi_p (X_{t-p} - \mu) + \omega_t
\]

Alternately we write it as

\[
X_t = \alpha + \phi_1 X_{t-1} + \phi_2 X_{t-2} + ... + \phi_p X_{t-p} + \omega_t
\]

where \( \alpha = \mu \left(1 - \phi_1 - ... - \phi_p \right) \)

A more concise form of the AR (p) model is

\[
\phi(B) X_t = \omega_t
\]

where \( \phi(B) \) is an autoregressive backward shift operator defined as
\[ \phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p \]

### 3.2.7 Moving Average Model MA (q)

The moving average model of order q, or MA (q) model, is defined to be

\[ X_t = \omega_t + \theta_1 \omega_{t-1} + \theta_2 \omega_{t-2} + \ldots + \theta_q \omega_{t-q} \]

where there are q lags in the moving average and \( \theta_1, \theta_2, \ldots, \theta_q \) (\( \theta_q \neq 0 \)) are parameters. The noise \( \omega_t \) is assumed to be Gaussian white noise. We may also write the MA (q) process in the equivalent form

\[ X_t = \theta(B) \omega_t \]

where \( \theta(B) \) is a moving average backward shift operator defined as

\[ \theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \ldots + \theta_p B^p \]

### 3.2.8 ARMA model

A time series \( \{X_t; t = 0, \pm 1, \pm 2, \ldots\} \) is ARMA (p, q) if it is stationary and

\[ X_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \ldots + \phi_p X_{t-p} + \omega_t + \theta_1 \omega_{t-1} + \theta_2 \omega_{t-2} + \ldots + \theta_q \omega_{t-q} \]

\( \phi_p \neq 0, \phi_q \neq 0 \) and \( \sigma^2 > 0 \). The parameters p and q are called the autoregressive and the moving average orders, respectively.

If \( X_t \) has a non-zero mean \( \mu \), we set \( \alpha = \mu \left( 1 - \phi_1 - \ldots - \phi_p \right) \) and write the model as

\[ X_t = \alpha + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \ldots + \phi_p X_{t-p} + \omega_t + \theta_1 \omega_{t-1} + \theta_2 \omega_{t-2} + \ldots + \theta_q \omega_{t-q} \]

Unless otherwise stated, \( \{ \omega_t; t = 0, \pm 1, \pm 2, \ldots\} \) is a Gaussian white noise sequence.
As previously noted, when \( q = 0 \), the model is called an autoregressive model of order \( p \), AR (\( p \)), and when \( p = 0 \), the model is called a moving average model of order \( q \), MA (\( q \)).

The ARMA (\( p, q \)) model can then be written in concise form using the AR operator, and the MA operator, as

\[
\phi(B)X_t = \theta(B)\omega_t
\]

### 3.2.9 ARIMA models

The acronym ARIMA stands for "Auto-Regressive Integrated Moving Average." Lags of the differenced series appearing in the forecasting equation are called "auto-regressive" terms, lags of the forecast errors are called "moving average" terms, and a time series which needs to be differenced to be made stationary is said to be an "integrated" version of a stationary series. A non-seasonal ARIMA model is classified as an "ARIMA (p, d, q)" model, where \( p \) is the number of autoregressive terms, \( d \) is the number of non-seasonal differences, and \( q \) is the number of lagged forecast errors (moving average) in the prediction equation.

A process, \( X_t \), is said to be ARIMA (\( p, d, q \)) if

\[
\nabla^d X_t = (1 - B)^d X_t
\]

is ARMA (\( p, q \)). In other words, the process should be stationary after differencing a non-seasonal process \( d \) times. In general, we will write the model as

\[
\phi(B)(1 - B)^d X_t = \theta(B)\omega_t
\]
If $E(\nabla^d X_t) = \mu$ we write the model as

$$\phi(B)(1 - B)^d X_t = \alpha + \theta(B) \omega_t$$

where $\alpha = \mu(1 - \phi_1 - ... - \phi_p)$

### 3.3 THE BOX-JENKINS ARIMA MODEL

The Box-Jenkins methodology refers to the set of procedures for identifying, fitting, and checking ARIMA models with time series data. Forecasts follow directly from the form of the fitted model. By Box-Jenkins, a $p^{th}$ order autoregressive model: AR (p), has the general form

$$X_t = \alpha + \phi_1 X_{t-1} + \phi_2 X_{t-2} + ... + \phi_p X_{t-p} + \omega_t$$

where $X_t$ = Response (dependent) variable at time $t$, $X_{t-1}, X_{t-2}, ... X_{t-p}$ = Response variable at time lags $t-1, t-2, ... , t-p$, respectively

$\phi_1, \phi_2, ... , \phi_p$ = Coefficients to be estimated, and $\omega_t$ = Error term at time $t$.

Also, a $q^{th}$- order moving average model: MA (q), has the general form

$$X_t = \mu + \omega_t + \theta_1 \omega_{t-1} + \theta_2 \omega_{t-2} + ... + \theta_q \omega_{t-q}$$

where $X_t$ = Response (dependent) variable at time $t$, $\mu$ = Constant mean of the process,

$\phi_1, \phi_2, ... , \phi_p$ = Coefficients to be estimated, $\omega_t$ = Error term at time $t$, and $\omega_{t-1}, \omega_{t-2}, ... \omega_{t-p}$ = Errors in previous time periods that are incorporated in the response $X_t$.

Autoregressive Moving Average Model: ARMA (p, q), which has the general form

$$X_t = \alpha + \phi_1 X_{t-1} + \phi_2 X_{t-2} + ... + \phi_p X_{t-p} + \omega_t + \theta_1 \omega_{t-1} + \theta_2 \omega_{t-2} + ... + \theta_q \omega_{t-q}$$

We can use the graph of the sample autocorrelation function (ACF) and the sample partial
autocorrelation function (PACF) to determine the model which processes can be summarized as follows:

<table>
<thead>
<tr>
<th>MODEL</th>
<th>ACF</th>
<th>PACF</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR (p)</td>
<td>Dies down</td>
<td>Cut off after lag ( q )</td>
</tr>
<tr>
<td>MA (q)</td>
<td>Cut off after lag ( p )</td>
<td>Dies down</td>
</tr>
<tr>
<td>ARMA (p, q)</td>
<td>Dies down</td>
<td>Dies down</td>
</tr>
</tbody>
</table>

Table 3.1: How to determine the model by using ACF and PACF patterns

Box-Jenkins forecasting models consist of a four-step iterative procedure as follows; Model Identification, Model Estimation, Model Checking (Goodness of fit) and Model Forecasting. The four iterative steps are not straightforward, but are embodied in a continuous flow chart, depending on the set of data under study. Figure 3.1 describes the Box-Jenkins modeling approach for an ARIMA model.
Box-Jenkins Modeling Approach

Plot Series

Is Variance stable?

Yes

Obtain ACs and PACs

Is Mean Stationary?

No

Apply Regular and Seasonal Differencing

Yes

Model Selection

Estimate Parameter Values

Are Residuals Uncorrelated?

No

Modify Model

Are Parameters Significant and Uncorrelated?

Yes

Forecast


Figure 3.1: Time series analysis: Forecasting and control
• **STEP 1: Model Identification (Selecting an initial model)**

We first determine whether the series is stationary or not by considering the graph of ACF. If a graph of ACF of the time series values either cuts off fairly quickly or dies down fairly quickly, then the time series values should be considered stationary. If a graph of ACF dies down extremely slowly, then the time series values should be considered non-stationary. If the series is not stationary, it would then be converted to a stationary series by differencing. That is, the original series is replaced by a series of differences. An ARMA model is then specified for the differenced series. Differencing is done until a plot of the data indicates the series varies about a fixed level, and the graph of ACF either cuts off fairly quickly or dies down fairly quickly. Once a stationary series has been obtained, then identify the form of the model to be used by using the theory in Table 3.1.

• **STEP 2: Model Estimation and Evaluation**

Once a model is identified, the next stage for Box-Jenkins approach is to estimate the parameters. In this study, the estimation of parameters was done using the R-Consol statistical software.

➢ **Method of moments estimators**

We begin with method of moments estimators. The idea behind these estimators is that of equating population moments to sample moments and then solving for the parameters in terms of the sample moments. We immediately see that, if \( E(X_i) = \mu \) then the method of moment estimator of \( \mu \) is the sample average \( \bar{X} \). Thus, while discussing method of moments, we will assume \( \mu = 0 \). Although the method of moments can produce good estimators, they can sometimes
lead to suboptimal estimators.

- **Maximum Likelihood Estimators**

Let $X_t = \mu + \phi (X_{t-1} - \mu) + \omega_t$

be a time series process, where $|\phi| < 1$ and $\omega_t \sim iid \ N(0, \sigma^2)$. Given the data $X_1, X_2, \ldots, X_n$ we seek the likelihood

$$L(\mu, \phi, \sigma^2) = f_{\mu,\phi,\sigma^2}(X_1, X_2, \ldots, X_n)$$

In the case of an AR (1), we may write the likelihood as

$$L(\mu, \phi, \sigma^2) = f(X_1) f(X_2 / X_1) \cdots f(X_n / X_{n-1})$$

Where we have dropped the parameters in the densities, $f(.)$. We may then write the likelihood as

$$L(\mu, \phi, \sigma^2) = f(X_1) \prod_{t=2}^n f_{\omega}[(X_t - \mu) - \phi(X_{t-1} - \mu)]$$

To find $f(X_1)$ we can use the causal representation

$$X_i = \mu + \sum_{j=0}^{\alpha} \phi^j \omega_{i-j}$$

To see that $X_i$ is normal, with mean $\mu$ and variance $\frac{\sigma^2}{(1-\phi^2)}$

- **AIC, AICc, BIC**

The final model can be selected using a penalty function statistics such as Akaike Information Criterion (AIC or AICc) or Bayesian Information Criterion (BIC). See Sakamoto et al. (1986); Akaike (1974) and Schwarz (1978). The AIC, AICc and BIC are a measure of the goodness of fit of an estimated statistical model. Given a data set, several competing models may be ranked
according to their AIC, AICc or BIC with the one having the lowest information criterion value being the best. These information criterion judges a model by how close its fitted values tend to be to the true values, in terms of a certain expected value. The criterion value assigned to a model is only meant to rank competing models and tell you which the best among the given alternatives is. The criterion attempts to find the model that best explains the data with a minimum of free parameters but also includes a penalty that is an increasing function of the number of estimated parameters. In the general case, the AIC, AICc and BIC are calculated as;

$$AIC = 2k - 2\log(L)$$ OR $$2k + n\log\left(\frac{RSS}{n}\right)$$

$$AICc = AIC + \frac{2k(k+1)}{n-k-1}$$

$$BIC = -2\log(L) + k\log(n)$$ OR $$\log(\sigma^2) + \frac{k}{n}\log(n)$$

where

- $k$ : is the number of parameters in the statistical model
- $L$ : is the maximized value of the likelihood function for the estimated model. RSS: is the residual sum of squares of the estimated model.
- $n$ : is the number of observations, or equivalently, the sample size
- $\sigma^2$ : is the error variance

The AICc is a modification of the AIC by Hurvich and Tsai (1989) and it is AIC with a second order correction for small sample sizes. Burnham & Anderson (1998) insist that since AICc converges to AIC as $n$ gets large, AICc should be employed regardless of the sample size.
• **STEP 3: Model checking (Goodness of fit)**

In this step, the model must be checked for adequacy by considering the properties of the residuals whether the residuals from an ARIMA model must have the normal distribution and should be random. An overall check of model adequacy is provided by the Ljung-Box Q statistic. The test statistic $Q$ is

$$Q_m = n(n+2)\sum_{k=1}^{m} \frac{r_k^2(e)}{n-k} \sim X^2_{m-r}$$

where $r_k(e) =$ the residual autocorrelation at lag $k$, $n$ is the number of residuals and $m$ is the number of times lags includes in the test. If the p-value associated with the Q statistic is small (P-value < $\alpha$), the model is considered inadequate. We then consider a new or modified model and continue the analysis until a satisfactory model has been determined. Moreover, we can check the properties of the residual with the following graph:

1. We can check about the normality by considering the normal probability plot or the p-value from the One-Sample Kolmogorov - Smirnov Test.
2. We can check about the randomness of the residuals by considering the graph of ACF and PACF of the residual. The individual residual autocorrelation should be small and generally within $\pm 2/\sqrt{n}$ of zero. Residuals should at all cost be white noise. A test of whether the residuals form a white process is given by a modified version of the Box-Pierce Q statistic in the form:

$$Q = (T-d)\sum_{k=1}^{k} \rho_k^2$$

where $\rho$ hat is the autocorrelations of the residuals, $d$ is the order of differencing to obtain a
stationary series, $T$ is the length of the series, and $k$ is the number of autocorrelations being checked. Here if $Q$ is larger than the critical value for the chi squared distribution with $K - p - q$ degrees of freedom, the model should be considered inadequate.

- **STEP 4: Forecasting**

Once the model has been selected, estimated and checked, and once residuals are carefully examine and seen to be uncorrelated and parameters assessed to be significant and uncorrelated, then we can go ahead and forecast. Forecasting with this system is straightforward; the forecast is the expected value, evaluated at a particular point in time. Confidence intervals may also be easily derived from the standard errors of the residuals.

The general forecasting equation for ARMA models is given by

$$\hat{Y} = \mu + \sum_{i=1}^{p} \phi_i Y_{t-i} - \sum_{j=1}^{q} \theta_j \epsilon_{t-j}$$

### 3.4 STATISTICAL SOFTWARE USED

The Statistical Analysis Software (SAS) would be used in examining the pattern of maternal deaths while the R-Consol statistical software would be used in analysing and fitting the stochastic models. Other statistical and numerical simulation methods of parameter estimation were utilized as and when deemed fit.
CHAPTER FOUR
RESULTS AND DISCUSSION

4.0 PRELIMINARY ANALYSIS

The data used in this thesis is the monthly observations of Maternal Mortality cases and total deliveries as well as the quarterly maternal mortality ratios at the Korle - Bu Teaching Hospital from 2001 to 2013. The data were obtained from the Bio-Statistics Department of the Obstetrics & Gynaecology directorate. Firstly, the raw data is plotted and the patterns of maternal deaths and deliveries for the facility over the thirteen (13) years period under study are observed. Figure 4.0 presents the observed bar plot of the delivery data while Figure 4.1 presents the observed bar plot of the maternal mortality data.

![Figure 4.0: Bar Plot of deliveries from 2001 to 2013](http://ugspace.ug.edu.gh)

From Figure 4.0, deliveries at the hospital appear to be in the range of 6834 as the lowest from year six (2006) and 12,273 as the highest in year one (2001). The highest delivery in the
period started from the first year (2001) and was relatively high until it dropped to 6,834 in the sixth year (2006). The deliveries started rising from the seventh year (2007) that is 7,361 and kept increasing to the thirteenth year (2013) with 11,148 deliveries.

![Maternal Mortality in Korle - Bu from 2001 - 2013](image)

**Figure 4.1: Bar Plot of maternal mortality from 2001 to 2013**

The period under study recorded a maternal mortality of 96 in 2001 and dropped a little, but increased rapidly in 2005 with the figure of 103 deaths. The highest maternal mortality figure of 119 was recorded in the eleventh year (2011) while the lowest figure of 56 was recorded in the sixth year. The period under study ended with maternal mortality of 86 in the year 2013.
Figure 4.2 Bar Plot of Maternal Mortality Ratio from 2001 to 2013

The data used in this section of the thesis are monthly observations of Maternal Mortality Ratios at the Korle-Bu Teaching Hospital from 2001 to 2013. The data were obtained from the Bio-Statistics Department of the Obstetrics & Gynaecology directorate. Firstly, the raw yearly data are plotted.

4.1 DATA DESCRIPTION AND STATISTICS

The R-Consol statistical software was used in analysing and fitting ARIMA models for the maternal mortality cases. Monthly maternal mortality ratio dataset obtained from the Korle-Bu Teaching Hospital in Accra, Ghana was used in the analysis of this thesis. The data were in the form of monthly maternal mortality and monthly live births for the period, from January, 2001 to December, 2013 with One Hundred and Fifty-Six (156) observations. The monthly maternal mortality ratio was obtained by dividing the monthly maternal mortality by the respective live birth for each month. The dataset was divided into a training set and the test set. The training set
spanning from January, 2001 to June, 2013 was used in the estimation of the parameters of the models, whereas the test set consisting of observations from July, 2013 to December, 2013 was used to validate the selected model.

Table 4.1.1 shows the descriptive statistics of the monthly maternal mortality ratio in Korle-Bu Teaching Hospital, Accra, Ghana from January, 2001 to December, 2013.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Value</th>
<th>Statistics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>156</td>
<td>Sum</td>
<td>130180.2676</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>SE Mean</td>
<td>30.1258</td>
</tr>
<tr>
<td>Maximum</td>
<td>2054.7945</td>
<td>Variance</td>
<td>141580.342</td>
</tr>
<tr>
<td>1st Quartile</td>
<td>576.2041</td>
<td>Standard Deviation</td>
<td>376.271633</td>
</tr>
<tr>
<td>3rd Quartile</td>
<td>1095.2942</td>
<td>Skewness</td>
<td>0.3143</td>
</tr>
<tr>
<td>Mean</td>
<td>834.4889</td>
<td>Kurtosis</td>
<td>-0.2129</td>
</tr>
<tr>
<td>Median</td>
<td>787.8449</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4.1.1 Descriptive Statistics for Monthly Maternal Mortality Ratio in Ghana (Korle-Bu Teaching Hospital) January, 2001 – December, 2013**

From Table 4.1.1, it could be observed that the average maternal mortality in Korle-Bu Teaching Hospital over the Thirteen (13) year period was approximately 835 per One Hundred Thousand live births with a standard error of 30.1258. The extent to which the observed data fall within the centre of the distribution was -0.2129 which implies that the distribution was platykurtic with a fat midrange on either side of the mean and a lower peak as compared to the standard normal distribution. The degree of asymmetry (Skewness) of the distribution of the monthly maternal mortality ratio was 0.3143. This implies that the distribution is skewed to the right with a heavier right tail.
4.2 PRELIMINARY ANALYSIS ON MATERNAL MORTALITY RATIO

The time series plot of the monthly maternal mortality ratio data is shown in Figure 4.2.1. The time horizon of the dataset comprises monthly maternal mortality ratios in Korle-Bu Teaching Hospital from January, 2001 to December, 2013. The plot of monthly ratio series in Figure 4.2.1 clearly shows volatility clustering in the data with constant mean and stable variance and hence considered stationary. To confirm stationary of the series, the Augmented Dickey-Fuller (ADF) unit root test used. The ADF test regresses each series on its lagged value in different time points. The test showed a p-value of less than 0.01 which led to the rejection of the null hypothesis that the series is not stationary at 5% level of significance. This implies that the series was characterized by stable mean and constant variance and hence satisfies the assumption of stationary of time series modeling.
Figure 4.2.1: Time Series Plot of Monthly Maternal Mortality Ratio in Korle-Bu Teaching Hospital, Ghana (January, 2001 – December, 2013)

The Autocorrelation Factor (ACF) and Partial ACF (PACF) plot of the series were obtained to check for serial correlation in the series of monthly maternal mortality ratio in Korle-Bu Teaching Hospital (KBTH). A slow decay in the ACF will imply that differencing of the series would not be necessary since the series is independent of serial correlation. The ACF of monthly MMR in Figure 4.2.2 shows a slow decay, which dies off as the length of time increases and hence it was concluded that the series was independent of serial correlation. This was confirmed by the Ljung-Box test for the null hypothesis of serial independence of the series, which gave p-values greater than 0.05 at all lags of the series as shown in Figure 4.2.3 in Appendix. The Ljung-Box test led to the failure to reject the null of serial independence at 5% level of significance.
Again the check for the presence of white noise was carried out using the ACF plot of the series in Figure 4.2.2. If the entire sample ACFs are close to zero, then the series is said to be characterized by white noise. The ACFs plot in Figure 4.2.2 was not significant with the exception of lag 0 ACF since all the ACFs falls below the confidence region. It was therefore concluded that the series of monthly MMR was characterized by white noise. The ACF and PACF also suggest the following ARMA models to be appropriate for the modeling of monthly maternal mortality ratio in Ghana; ARMA (0,1), ARMA (1,0) and ARMA (1,1). In addition to the Box-Jenkins method (assuming that the intercept term in the model is not zero), the AIC, the
conditional sum of square and log-likelihood of the suggested modes were compared to check and identify the order of the appropriate fitting model. The AIC conditional sum of squares and log likelihood were obtained using the “stats” function in R by fitting ARMA (p, q) models for the series and the results shown in Table 4.2.1. The test was carried out using the Maximum Likelihood estimation techniques and the Method of least square.

<table>
<thead>
<tr>
<th>Model</th>
<th>Log-Likelihood</th>
<th>AIC</th>
<th>Conditional Sum of Square</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>-1101.26</td>
<td>2208.52</td>
<td>20902568</td>
<td>2208.41</td>
</tr>
<tr>
<td>MA(1)</td>
<td>-1101.29</td>
<td>2208.58</td>
<td>20907168</td>
<td>2208.44</td>
</tr>
<tr>
<td>ARMA(1,1)</td>
<td>-1101.26</td>
<td>2210.51</td>
<td>20898132</td>
<td>2210.38</td>
</tr>
</tbody>
</table>

It was evident from Table 4.2.1 that both the AR(1) and MA(1) shows minimal AIC and therefore it was concluded that the suitable model for the series would be either of those two models.

4.3 MODEL ESTIMATIONS AND FITTING

The significance of the select ARIMA model parameters was also compared to ascertain which model has the most significant parameter estimate. This was carried out by estimating the parameters of the model using the Maximum Likelihood Estimation (MLE) technique and assuming normality of the model residuals. Table 4.2.2 presents the estimation and evaluation summary of the suggested ARIMA models.

From Table 4.3.1, it was obvious that the MA(1) showed more significant parameter estimates as compared to the AR(1) and therefore it was concluded that ARMA(0,1) would be the appropriate
model fit for the series of monthly maternal mortality ratio in Ghana. The specification of the selected model is therefore depicted as:

\[ r_t = \alpha_0 + \alpha r_{t-1} \]  

\[ 4.3.1 \]

**Table 4.3.1: Model Estimates of Suggested ARMA Models with their respective p-Values**

<table>
<thead>
<tr>
<th>Model</th>
<th>Intercept</th>
<th>p-value</th>
<th>AR</th>
<th>p-value</th>
<th>MA</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARMA(1,0)</td>
<td>676.30245</td>
<td>0.0162</td>
<td>0.19332</td>
<td>0.0000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ARMA(0,1)</td>
<td>838.35706</td>
<td>0.0151</td>
<td>-</td>
<td>-</td>
<td>0.1948</td>
<td>0.0000</td>
</tr>
<tr>
<td>ARMA(1,1)</td>
<td>742.75281</td>
<td>0.0504</td>
<td>0.11398</td>
<td>0.8005</td>
<td>0.08217</td>
<td>0.8562</td>
</tr>
</tbody>
</table>

On the assumption of normality of the series residuals, the MLE technique was used to estimate the parameters of the model. The fitted model based on equation 4.3.1 and the MLE parameter estimates of the MA(1) model is given by:

\[ r_t = 838.6777 + 0.1919r_{t-1} \]  

\[ 4.2.1 \]

**4.4 DIAGNOSTIC CHECKING OF THE MODEL**

The adequacy of the MA (1) model was checked by plotting the residuals of the model, normal Q-Q plot and the histogram plot of the residuals. A bell shaped histogram plot and a linear normal Q-Q plot would indicate confirmation of the assumption of the model’s residuals. From Figure 4.4.1, it was evident that the residuals plot exhibit some level of volatility clustering whereas the histogram plot was a little skewed to the left. The normal Q-Q plot is approximately linear. It was concluded that the MA(1) fit the series of monthly maternal mortality ratio in Ghana from January, 2001 to June, 2013 since it obeys all the assumptions of the model estimation.
The goodness of fit of the model was confirmed using the Ljung-Box chi-square test of goodness of the model. The null hypothesis of goodness of fit could not be rejected at 5% level of significance with Ljung-Box test p-value of 0.9629. It was therefore confirmed and concluded that the MA(1) model was the best fit for the series of monthly MMR in Ghana.

![Residual Plot of ARMA(0,1) of monthly Maternal Mortality Ratio in Ghana](image)

**Figure 4.4.1: Time Series Plot of Residuals with its Histogram Plot and Normal Q-Q Plot (January, 2001 – June, 2013)**

The plot of the squared residuals, ACF of residuals and PACF of the residuals of the model in Figure 4.4.2 was ascertain to check for the presence of ARCH effect in the models residuals. The squared residuals plot shows some level of volatility clustering and hence the presence of ARCH effect was suspected. The various spikes in the ACF and PACF of the squared residuals plot in
Figure 4.4.2 also show that the model’s residuals exhibit a suspected pattern that could be modeled using ARCH models.

A formal test of heteroscedasticity of the models residuals was carried out by obtaining the Ljung-Box statistics and p-value for the null hypothesis that the model’s residual contains ARCH effect. The result of the test on some selected lags of the model’s residuals is shown in Table 4.4.1 in Appendix. From Table 4.4.1, it was evident that there was the presence of ARCH effect at all lags levels of the Ljung-Box test at 5% level of significance. The null hypothesis of independence of the squared residuals could not be rejected at 5% level of significance since all the p-values
obtained from the Ljung-Box test were all greater than 0.05. It was concluded that the residuals of the ARMA model were independent and hence contains no ARCH effect.

Table 4.4.1 shows several six steps forecasting of maternal mortality ratio by difference orders of ARMA models, with the average percentage of predicted error (APE) defined as:

$$APE = \frac{1}{6} \sum_{k=1}^{6} \left| \frac{\text{Forecast}(k) - \text{Real}(k)}{\text{Real}(k)} \right|$$

The six steps ahead forecasting of the maternal mortality ratio in Korle-Bu Teaching Hospital shows that the APE of the ARMA (0,1) is the minimum compared with ARMA (1,0) and ARMA (1,1) suggested by the ACF and PACF of the series.

<table>
<thead>
<tr>
<th>Step</th>
<th>Real</th>
<th>ARMA(0,1)</th>
<th>ARMA(1,0)</th>
<th>ARMA(1,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>656.045</td>
<td>925.124</td>
<td>916.337</td>
<td>921.543</td>
</tr>
<tr>
<td>2</td>
<td>840.336</td>
<td>839.411</td>
<td>854.26</td>
<td>849.695</td>
</tr>
<tr>
<td>3</td>
<td>763.359</td>
<td>839.411</td>
<td>842.327</td>
<td>840.733</td>
</tr>
<tr>
<td>4</td>
<td>412.371</td>
<td>839.411</td>
<td>840.033</td>
<td>839.615</td>
</tr>
<tr>
<td>5</td>
<td>898.876</td>
<td>839.411</td>
<td>839.592</td>
<td>839.475</td>
</tr>
<tr>
<td>6</td>
<td>809.249</td>
<td>839.411</td>
<td>839.508</td>
<td>839.458</td>
</tr>
<tr>
<td>APE</td>
<td>0.27498</td>
<td>0.2762</td>
<td>0.27611</td>
<td>0.27611</td>
</tr>
</tbody>
</table>

**Table 4.4.1: Different Methods of Forecasting with ARIMA Models**
Six months out sample forecast were obtained using the most appropriate ARMA (0,1) model and results compared to the actual monthly maternal mortality in Ghana. Table 4.5.1 shows the results of the forecast using ARMA(0,1) model.

**Table 4.4.2: Six Months out sample forecast of Monthly Maternal Mortality Ratio from ARMA (0,1) Model**

<table>
<thead>
<tr>
<th>Month</th>
<th>Actual</th>
<th>Forecast</th>
<th>95% Lower</th>
<th>95% Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>July, 2013</td>
<td>656.045</td>
<td>925.1236</td>
<td>193.1159</td>
<td>1657.131</td>
</tr>
<tr>
<td>August, 2013</td>
<td>840.3361</td>
<td>839.4113</td>
<td>94.06334</td>
<td>1584.759</td>
</tr>
<tr>
<td>September, 2013</td>
<td>763.3588</td>
<td>839.4113</td>
<td>94.06334</td>
<td>1584.759</td>
</tr>
<tr>
<td>October, 2013</td>
<td>412.3711</td>
<td>839.4113</td>
<td>94.06334</td>
<td>1584.759</td>
</tr>
<tr>
<td>November, 2013</td>
<td>898.8764</td>
<td>839.4113</td>
<td>94.06334</td>
<td>1584.759</td>
</tr>
<tr>
<td>December, 2013</td>
<td>809.2486</td>
<td>839.4113</td>
<td>94.06334</td>
<td>1584.759</td>
</tr>
</tbody>
</table>

The forecasted values were close to the actual values as shown in Table 4.2.3. The actual values fall within the confidence intervals of the forecast and hence confirming that the ARMA(0,1) model is the best fit for the series of monthly maternal mortality ratio in Ghana.

**FORECAST OF MATERNAL MORTALITY RATIO**

The fitted model for forecasting monthly maternal mortality ratio in Ghana based on a dataset from January, 2001 to December, 2013 is depicted as:
Table 4.4.3: One Year Out Sample Forecast of Monthly Maternal Mortality Ratio from ARMA(0,1) Model

<table>
<thead>
<tr>
<th>Month</th>
<th>Forecast</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>January, 2014</td>
<td>825.2235</td>
<td>102.8166</td>
<td>1547.63</td>
</tr>
<tr>
<td>February, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>March, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>April, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>May, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>June, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>July, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>August, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>September, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>October, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>November, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
<tr>
<td>December, 2014</td>
<td>834.5919</td>
<td>100.0701</td>
<td>1569.114</td>
</tr>
</tbody>
</table>
4.5 SPECTRAL ANALYSIS OF MATERNAL DEATHS

Apart from the time domain method of time series analysis, such as ARIMA and ARCH type models, frequency domain analysis, such as the spectral analysis was also carried to identify and quantify the different frequency components of the monthly maternal mortality series from January, 2001 to December, 2013. Figure 4.5.1 shows the time plot of the monthly maternal mortality in Korle-Bu Teaching Hospital, Accra, Ghana from the period January, 2001 to December, 2013. Result from Figure 4.5.1 indicates that the series is stationary, thus has constant mean and stable variance which is desirable for fourier transform (spectral analysis). This was confirmed by the ADF test for unit root which gave a p-value of less than 0.01 leading to the rejection of the null hypothesis that the series is not stationary at 5% level of significance.

Figure 4.5.1: Time Series Plot of Monthly Maternal Mortality in Korle-Bu Teaching Hospital, Ghana (January, 2001 – December, 2013)
The autocorrelation and partial autocorrelations of the monthly maternal mortality were estimated and results plotted in Figure 4.5.2. The structure of both the ACF and PACF indicates that the maternal mortality is significantly autocorrelated and it also suggests a seasonal behavior of the series.

![ACF and PACF of Monthly Maternal Mortality](image)

**Figure 4.5.2: Plot of Autocorrelation Factor (ACF) and Partial ACF (PACF) of Monthly Maternal Deaths in Ghana (January, 2001 – December, 2013)**

In order to gain more insight into the presence of such autocorrelated pattern, the power spectrum of the series was obtained using the periodogram plot of the series. Secondly, since a small amount of smoothing will ensure that any periodic component in the series are precisely looked at, the smoothed periodogram was also computed and plotted. Figure 4.5.3 represents the plot of
the power spectrum of the series with the lower panel representing the smoothed power spectrum of the series of monthly maternal mortality in Ghana.

**Figure 4.5.3: Power spectrum of the maternal death in Ghana (January, 2001 – December, 2013)**

It was evident from Figure 4.5.3 that strong seasonality affects maternal mortality and has a frequency of recurrence of 2 months. This implies that maternal deaths increase within every two months.
CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter consists of the summary of the findings of the study, conclusions drawn from these findings and results as well as recommendations for all stakeholders.

5.1 SUMMARY

The purpose of the study was to examine the pattern of maternal mortality ratios as well as a spectral analysis of maternal mortality at the Korle - Bu Teaching Hospital in Accra from 2001 to 2013. This study also was to fit a stochastic model to forecast maternal mortality ratios for four quarters. A secondary data were obtained at the Bio-Statistics Department of the Obstetrics & Gynaecology directorate of the Korle-Bu Teaching Hospital in Accra for the period 2001 – 2013. The R-Consol statistical software was used in analysing and fitting ARIMA models for the maternal mortality cases. Monthly maternal mortality ratio dataset obtained from the Korle-Bu Teaching Hospital in Accra, Ghana was used in the analysis of this thesis. The data were in the form of monthly maternal mortality and monthly live births for the period, from January, 2001 to December, 2013 with One Hundred and Fifty-Six (156) observations. The monthly maternal mortality ratio was obtained by dividing the monthly maternal mortality by the respective live birth for each month.

The time series plot of the monthly maternal mortality ratio data clearly shows volatility clustering in the data with constant mean and stable variance and hence considered stationary. An ARMA(0, 1) model was selected as the appropriate model for predicting future maternal mortality ratios for the hospital. The model satisfied all conditions of a good ARMA model and was used to predict Maternal Mortality Ratios (MMRs) for the next four quarters. The power spectrum of the series was obtained using the periodogram plot of the series and suggests smoothing. We
conclude statistically that the maternal mortality ratio data has a platykurtic distribution, an ARMA(0, 1) model is adequate for forecasting Maternal Mortality Ratios (MMRs) and the power spectrum of maternal deaths has smoothing.

5.2 CONCLUSION

This study examined the pattern of maternal mortality ratios as well as a spectral analysis of maternal mortality at the Korle - Bu Teaching Hospital in Accra from 2001 to 2013. This study also fitted a stochastic model to forecast maternal mortality ratios for four quarters. The study explored the feasibility for application time series plot and time series ARMA in the study of pattern in Maternal Mortality Ratios and to predict Maternal Mortality Ratios respectively so as to provide the theoretical basis for continuing programs to reduce this problem. The study also had a spectral analysis of Maternal Death of the hospital. After careful analysis of data and available literature, we found the following:

The time series plot of the monthly maternal mortality ratio data clearly shows volatility clustering in the data with constant mean and stable variance and hence considered stationary. ARMA (0, 1) model was selected as the appropriate model for predicting future maternal mortality ratios for the hospital. The forecasted values were close to the actual values as shown in Table 4.4.2. Also the actual values fall within the confidence intervals of the forecast and hence confirming that the ARMA (0, 1) model is the best fit for the series of monthly maternal mortality ratio in Ghana. The model satisfied all conditions of a good ARMA model and was used to predict MMRs for the next four quarters.

The time plot of the monthly maternal deaths at the hospital over the period indicates that the series is stationary, thus has constant mean and stable variance which is desirable for fourier
transform (spectral analysis). The power spectrum of the series was obtained using the periodogram plot of the series. It was evident that strong seasonality affects maternal death and has a frequency of recurrence of 2 months. This implies that the rate at which maternal deaths occur is six times in a year that is once every two months.

5.3 RECOMMENDATIONS

The study of the pattern of the maternal mortality ratio data clearly shows volatility clustering in the data with constant mean and stable variance over the period 2001 to 2013. We therefore recommend that management of the hospital to put in more efforts at implementing existing intervention programs aimed at reducing this problem.

Although the ARMA model adequately fits the data and is useful for predicting future mortality ratios, it is not recommended for medium and long term predictions. We therefore recommend that future studies look at other models which have the ability to do medium and long term predictions.

Spectral analysis derivatives are computed exactly. It can obtain power spectra directly and more accurate with the same number of degrees of freedom, however, when the number of samples available for the analysis is low it's more complicated to implement. We therefore recommend that further research should be done in the area of its implementation.

Finally, this study limited itself to the analysing maternal mortality cases in the hospital regardless of the cause. We recommend further studies into the actual causes of maternal mortality in the hospital.
REFERENCE


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APPENDIX A

Table 3.1: How to determine the model by using ACF and PACF patterns

<table>
<thead>
<tr>
<th>MODEL</th>
<th>ACF</th>
<th>PACF</th>
</tr>
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<tbody>
<tr>
<td>AR (p)</td>
<td>Dies Down</td>
<td>Cut off after lag q</td>
</tr>
<tr>
<td>MA (q)</td>
<td>Cut off after lag p</td>
<td>Dies Down</td>
</tr>
<tr>
<td>ARMA (p, q)</td>
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<td>Dies Down</td>
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</tbody>
</table>

Table 4.1.1 Descriptive Statistics for Monthly Maternal Mortality Ratio in Ghana (Korle-Bu Teaching Hospital) January, 2001 – December, 2013

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<th>Value</th>
<th>Statistics</th>
<th>Value</th>
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<tr>
<td>Number of Observations</td>
<td>156</td>
<td>Sum</td>
<td>130180.2676</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>SE Mean</td>
<td>30.1258</td>
</tr>
<tr>
<td>Maximum</td>
<td>2054.7945</td>
<td>Variance</td>
<td>141580.342</td>
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<td>1st Quartile</td>
<td>576.2041</td>
<td>Standard Deviation</td>
<td>376.271633</td>
</tr>
<tr>
<td>3rd Quartile</td>
<td>1095.2942</td>
<td>Skewness</td>
<td>0.3143</td>
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<tr>
<td>Mean</td>
<td>834.4889</td>
<td>Kurtosis</td>
<td>-0.2129</td>
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<td>Median</td>
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Table 4.2.1 Comparison of Log-likelihood, Conditional sum of square and AIC of some selected ARMA (p, q) models

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<th>Model</th>
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<th>AIC</th>
<th>Conditional Sum of Square</th>
<th>AIC</th>
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<td>Model</td>
<td>Intercept</td>
<td>p-value</td>
<td>AR</td>
<td>p-value</td>
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<td>---------</td>
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Table 4.3.1  Model Estimates of Suggested ARMA Models with their respective p-Values

Table 4.4.1 Different Methods of Forecasting with ARIMA Models

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<tr>
<th>Step</th>
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<th>ARMA(1,0)</th>
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<td>656.045</td>
<td>925.124</td>
<td>916.337</td>
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<td>839.411</td>
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Table 4.4.2  Six Months out sample forecast of Monthly Maternal Mortality Ratio from ARMA (0,1) Model

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<th>Month</th>
<th>Actual</th>
<th>Forecast</th>
<th>95% Lower</th>
<th>95% Upper</th>
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<td>763.358</td>
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<td>December, 2013</td>
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Table 4.4.3 One Year Out Sample Forecast of Monthly Maternal Mortality Ratio from ARMA (0,1) Model

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APPENDIX B

Table 4.2.1: Ljung-Box Chi-Square Statistics and p-value for Testing for Serial Correlation

<table>
<thead>
<tr>
<th>Lag</th>
<th>χ-Squared</th>
<th>p-value</th>
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<td>1</td>
<td>5.6386</td>
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<td>6</td>
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Table 4.3.2: Ljung-Box Q-Statistics and p-value for Testing for ARCH effect in the Series of Monthly Maternal Mortality Ratio

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Table 4.4.1: Ljung-Box Chi-Square Statistics and p-value for Testing for ARCH effect in the Series of Monthly Maternal Mortality Ratio

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## Maternal Mortality in Korle-Bu from 2001 - 2013

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