TRAFFIC ANALYSIS OF A MOBILE SWITCHING CENTRE - A CASE STUDY OF Celtel Plc LAGOS

BY

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DECLARATION

I, Sani Man-Yahaya, hereby declare that this thesis has been written by me and that it is a record of my research work. It has not been presented in any previous application for a higher degree. All quotations and sources of information as seen in thesis are specifically acknowledged by means of references.

…… …….

Sani Man-Yahaya Date

CERTIFICATION

This thesis entitled “Traffic Analysis of a Mobile switching centre – A Case Study of Celtel Plc Lagos” by Sani Man-Yahaya, meets the regulations governing the award of the degree of Master of Science (MSc.) in Electrical Engineering of Ahmadu Bello University, Zaria and is approved for its contribution of knowledge and literary presentation.

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DEDICATION

I dedicate this work to the memory of my late mother, Hajiya Khadijat Mohammad (Kaka). May her gentle soul rest in perfect peace, ameen.

ACKNOWLEDGEMENT

I am grateful to Almighty Allah, the Most Beneficent, the Most Merciful, for the guidance and strength to undergo this program successfully.

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Finally to my family members for their sacrifice. May Almighty God reward all of you in multi-fold.

ABSTRACT

The efficient task of network management which ensure proper monitoring and controlling of certain network parameters to enable performance evaluation is a primary concern of the services providers in global system of mobile telecommunication. A sampled of Celtel network traffic data in Lagos area, indicating subscriber's demands and responses for a period of six months were collected and studied. From the review of the network performance analysis presented and the subsequent application of such vital component of these parameters, it was shown that the mobile switching centres in Victoria Island exhibit low network performance for first two months of the year 2006 and the situation became worst in the month of March and April of the same year. However, considerable improvements were recorded in the months of May and June. Relative improvements were also observed in the Lagos main land and other areas. Essential parameters, including the grade of service clearly indicated this. This is a clear case of congestion or fault. However, those mobile switching centres located in the Main Island were fair and on the other areas due to their present capacities have better performance.

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LIST OF ACRONYMS

ABR	Answer Bid Ratio
ACE	Auxiliary Control Elements
ASR	Answer Seizure Ratio
BHT	Busy Hour Traffic
BTS	Base Transceiver Station
BSC	Base Station Controller
CCR	Call Completion Ratio
CDMA	Code Division Multiple Access
DSN	Digital Switching Network
EIR	Equipment Identity Register
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple access
GOS	Grade of Service
GSM	Global System for Mobile communications
ISDN	Integrated Services Digital Network
ISO	International Standard Organization
ITU	International Telecommunications Union
LMI	Lagos Main Land
ME	Mobile Equipment
MSC	Mobile Switching Centre
TMN	Telecommunication Management Network
OA	Other Areas
PCM	Pulse Code Modulation
PSTN	Public Switched Telephone Network

SCM	Service Circuit Modules
SIM	Subscriber Identity Module
TDMA	Time Division Multiple Access
TV	Television
VI	Victoria Island
VLR	Visitor Location Register
1G	First Generation
3G	Third Generation

LIST OF SYMBOLS

λ	Lambda	16
$\sum$	Summation	16
t	Time	16
μ	Mu	16
P	probability	16
Δ	Delta	18
!	Factorial	19
ℓ	Script ell	20
$\int$	Integral	20
$\sqrt{}$	Square root	21
ρ	Rho	30
ƛ	Small lambda	30

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CHAPTER ONE

INTRODUCTION

1.1 General

The purpose of any communication system is to convey a message from one point to another. The originating input is referred to as a source whereas the terminating end is the sink. If the message is understandable, then information has been conveyed from the source to the destination. The nature of the message can take on a variety of forms. It can be a continuous time-varying quantity such as speech, a discrete signal that only takes on fixed levels or values such as transmission of data by a digital computer, a continuous spatial varying quantity such as the image on a TV camera tube, or a combination of some of them [16].

The International Telecommunication Union (ITU) and the International Standardization Organization (ISO) have jointly defined a concept for standardizing protocols for monitoring and management of telecommunication equipment, called Telecommunication Management Network (TMN). This concept encompasses all issues related to system management of telecommunication systems. It provides support and tools for planning, provisioning, installing, maintaining, operating and administering these systems. The main area of interest in this work is performance management in communication networks with specific interest on the Mobile Switching Centre of Celtel limited Lagos area [17].

Telecommunications traffic simply referred to the amount of telephone calls or data conveyed over a network. However, due to a lot of factors it is not every initiated call that actually arrives at its destination. Any attempt

either by the customer or equipment to re-initiate the call greatly increases the loading on switching equipment and adds to the overall traffic volume.

Today, the Global System for Mobile Communication (GSM) Network operators are the most popular in the country. They have many subscribers and large networks but do not provide quality services to customer's satisfaction. There are frequent cases of call failures, handoff failures, network congestions, link failures, busy tones, which to date do not have total solution. The overall result is complete frustration on the part of the users, degrades the network quality and performance, and un-necessary efforts by network managers.

Monitoring and controlling the entire network in order to detect and avoid the resulting service degradation is a difficult work, but it is increasingly being undertaken by many of the worlds telecommunications services providers. Results of such studies have indicated by various models that under peak periods the effectiveness of switching centre is at its lowest level. It becomes imperative that early detection and analysis of these factors is as good as ability to maintain controls over the entire network.

The most common parameter used to study network performance in a circuit switched network is the traffic load over a period of time. To serve the purpose of switch management, the monitoring of these parameters needs to be done frequently, thereby giving the managers a real-time perception of the system.

Switching equipment is the brain of the cellular system. It consists of two major parts, the switch and the processor. The switch is no different from that used in the conventional telephone systems. The processor used in

cellular systems is a special-purpose computer. It controls all the functions which are specific for cellular systems, such as frequency assignment, decisions regarding handoff (including decisions regarding new cells for handoff), and monitoring of traffic. The smaller the cell, the more handoffs involved, and that explains why the traffic load will be greater thereby justifying needs to put in place facilities to reduce failure rate. The processor can be programmed to correct its own errors and to optimize system performance [18].

1.2 Network Overview

As Econet wireless Nigeria, Vee Network limited trading as Vmobil Nigeria and now Celtel was one of the three winners of the highly competitive Nigeria's GSM license bid in 2001. It pioneered GSM telephone services in the country with a rollout on August 6, 2001, two days ahead of competition and three days ahead of the regulatory deadline.

A truly Nigerian Company, Celtel is fully owned by indigenous investors including three state governments, banks and other institutional investors. The company was unveiled to Nigerian public on the 15th of March 2004. Since its inception, Celtel has continued to make good milestones, recording its one million subscribers in December of 2003.

The company has built a reputation for being a truly reliable network and one that cares for the community. Its aim has been:

- To provide first-rate communications services to the people of Nigeria, thus empowering them with the power of communication.
- To this end, Celtel continues to expand improve on its network, guaranteeing excellent services.

Celtel has acquired fairly good coverage through an aggressive rollout strategy. It presently operates in more than hundreds of cities and over thousands of communities with over 6 million active subscribers. Celtel was first to launch in Lagos, Port Harcourt, Uyo, Warri, Kano and Ibadan.

Since the commencement of its operations, the company has resolutely embarked on an aggressive pursuit of service and professional excellence, mindful of its place in the history of GSM telephone operation in Nigeria. It is therefore, imperative to study its operational performance in this case study with specific reference to the Mobile Switching Centres located in Lagos areas.

A basic cellular system consists of three parts: a mobile unit, a cell site, and a Mobile Telephone Switching Office (MTSO), as Fig. 1.1 shows, with connections to link the three subsystems.

- Mobile Units: a mobile telephone unit contains a control unit, a transceiver, and an antenna system.
- Site: The cell site provides interface between the MSC and the mobile units. It has control unit, radio cabinets, antennas, a power plant, and data terminals.
- MSC: The switching office, the central coordinating element for all cell sites, contains the cellular processor and cellular switch. It interfaces with land lines, controls call processing, and handles billing activities.
- Connections: The radio and high-speed data links connect the three subsystems. Each mobile unit can only use one channel at a time for its communication link. But the channel is not fixed; it can be any one in the entire band assigned by the serving area, with each site having

multi-channel capabilities that can connect simultaneously to many mobile units.

The MSC is the heart of the cellular mobile system. its processor provides central coordination and cellular administration.

The cellular switch, which can be either analog or digital, switches calls to connect mobile subscribers to other mobile subscribers and to the international telephone network. It uses voice trunks similar to land lines exchange centres voice trunks. It also contains data links providing supervision links between the processor and the switch and between the cell sites and the processor. The radio link carries the voice and signaling between the mobile unit and the cell site. The high-speed data links cannot be transmitted over the standard telephone trunks and therefore must use either micro links or T-carriers (wire lines). Microwave radio links or T-carriers carry both voice and data between the cell site and the MSC [3].

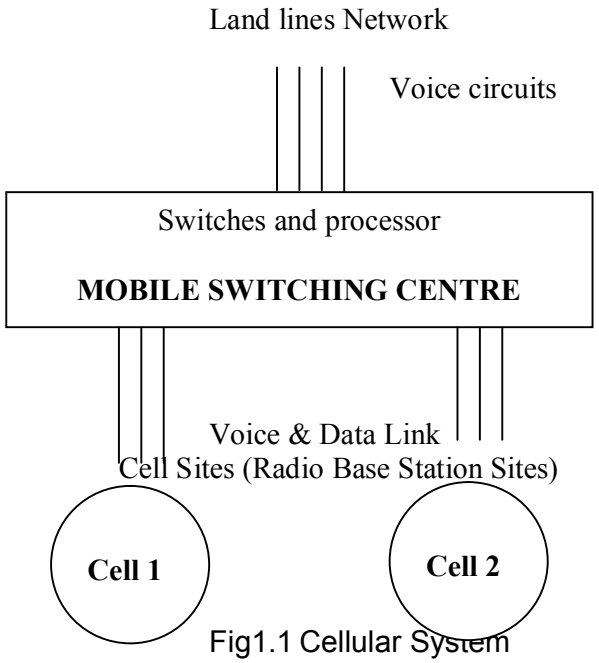


Fig1.1 Cellular System

The general GSM network architecture is presented in Fig 1.2. All the

interfaces are standard which permits a fierce competition among the vendors and a multi vendor network.

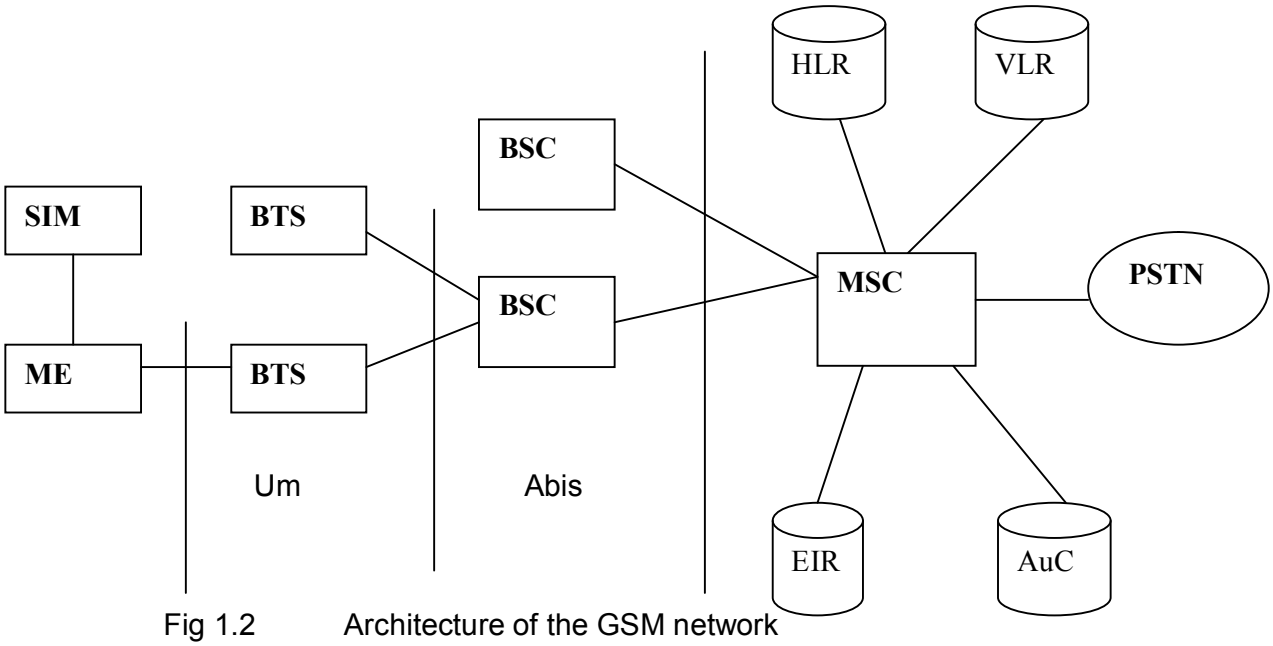


Fig 1.2 Architecture of the GSM network

- SIM: Subscriber Identity Module contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication.
- ME: Mobile Equipment
- BTS: Base Transceiver Station handles the radio-link protocols with the Mobile Station.
- BSC: Base Station Controller handles radio-channel setup, frequency hopping, and handovers.
- HLR: Home Location Register –all the administrative information of each subscriber, and the current location of the mobile.
- VLR: Visitor Location Register contains selected information, for call control and services for mobiles located in its geographic area.
- MSC: Mobile services Switching Centre – normal switching node of the

PSTN (Public Switched Telephone Network), plus functionality for registration, authentication, location updating, handovers, and call routing to a roaming subscriber.

- EIR: Equipment Identity Register
- AuC: Authentication Center stores a copy of the secret key of each subscriber's SIM card, used for authentication and encryption.

1.3 Problem Definition and Methodology

Telecommunication development plans and investments are current network performance based. The major aim of this thesis is to study the performance and efficiency of the nine mobile switching centres in Lagos area. A good network ensures proper usage of the available capacities to deliver traffic demands at all time. To achieve this, a proper monitoring, analysis and forecasting are essential tools.

Traffic profiles on different routes vary greatly according to the nature of the route and its users. Highly peaked and busy hour oriented profiles can be problematic for network operators as congestion and faults will be highly likely and as a whole there will be little network use [1]. It is hoped that the study will reveal the right control mechanisms by which recommendations for possible optimization and dimensioning of the network under typical normal-day loading conditions will be achieved. This endeavour falls under the trunk and traffic analysis administration in multi-exchange networks.

The methodology adopted in the study includes first collection of data for such parameters as:

- Traffic intensity
- Total number of calls completed, total number of calls attempted

- Total number of minutes of usage.

and there after the analysis of this network data was conducted.

The analysis of Erlang formulae will be used for a statistical analysis of the network data.

1.4 Thesis Outline

Chapter One is the introduction, which covers the fundamental theories, past works, objective of the study, and the chosen approach. Chapter Two reviewed the general concept of the telecommunication traffic theory with relevant laws and proofs. Chapter Three describes the specific nature of GSM network data relating to the Celtel in Lagos area. Chapter Four is the analysis of the data to arrive at certain parameters that were used to predict the Mobile Switching Centre performance behaviour. Chapter Five simply outlines conclusion drawn, recommendations, limitations and significance of the research work.

CHAPTER TWO

TELECOMMUNICATIONS TRAFFIC THEORY

2.1 General

Traffic is said to be that series of homogenous events, occurring one after another at random moments in time. It may be viewed simply as a series of random points on the time axis and differentiated by their internal structures or distribution patterns such as the intervals (T) between events, their dependence or independence etc [7]. An accumulation of these homogenous events is a random process and in the present context are related to the occurrence of what are called 'telephonic events' such as subscriber on/off-hook, dialed digits, digital signaling messages, and circuit seizures etc, indicated by electrical signals arriving at the switching accesses. The traffic events are characterized by the following properties:

- Singularity of Occurrence
- Absence of After-effect
- Stationarity

The singularity of occurrence implies that the probability of two or more events occurring in a time interval Δt is negligibly small. This leads to the definition of traffic intensity as a representation of the average number of events which may occur in a unit time for a given time interval Δt.

A traffic is said to be without after-effect, if for any non-overlapping intervals of time (Δt_1, Δt_2,….), the number of events in these intervals are independent random values. This implies that, the probability of the occurrence of any number of events in an interval does not depend on how many events occurred in the other intervals.

Stationarity here implies that the probability characteristics of the traffic do not change with time (remain the same) and the number of events in any time interval depends on its length. For a stationary traffic, the traffic intensity is constant [8].

If any traffic event satisfies the conditions of singularity of occurrence and the absence of after-effect and has a constant intensity λ_1, then the number of events occurring in an interval of time Δt has Poisson distribution (the number of events occurring in any time interval is independent of those in any non-overlapping interval and depends only upon the length of the given interval) and is said to be 'Poisson Traffic'. Any traffic events that satisfy all these three properties, however, are called 'simply traffic' or 'Stationary Poisson Traffic'. Other traffic of this kind but more complex includes traffic events with limited after-effect called the 'Palmer Traffic'. The palmer traffic is a notion combining a wide class of traffic, each differing from the other laws of the distribution of the time intervals between events. An example is the Erlang traffic [7].

2.2 Literature Review

The wireless communications system used in commercial services date back to the 1940s in Bell Laboratories of the United States but due to technological constraints, mobile sector was left dormant. However, the discovery of microprocessors as a result of large scale integrated circuit technology have paved the way to the spontaneous development of the commercial applications of cellular mobile communications [19].

The cellular mobile communication technology has basically been developed based on exploring new mobile communication frequency bands,

reasonable use of frequency resources, portability and multifunction of various stations. As far back as early 1970s, cellular mobile communications have found extensive applications as a result of the developments in other technological areas such as microelectronics, computer, communications network, signal coding and digital signal processing. Consequently, great progresses were recorded in various aspects of switching, signal network mechanism and wireless modulation coding. The gradual development leads to changes from analog to digital, and FDMA to TDMA /CDMA, which represent the evolution from the 1G to 3G.

The first commercial cellular telephones were tested in the late 1970s by Illinois Bell in Chicago, Illinois, and they were a great success. Cellular service carriers began nationwide operations in the mid-1980s operating in the 800- to 900-MHz frequency band. Before the availability of cellular radio service, mobile telephone service consisted of bulky mobile telephone radio units. These two-way radio units communicated with a single antenna in a city or area. The radio signals often interfered with those of other commercial radios, and due to the technology of the day the frequencies could not be reused as they can today. Therefore, limited numbers of channels were available for callers, and the service was unreliable and costly. Because of the consumer demand for cellular telecommunications for instance in USA, the Federal Communications Commission (FCC) in the mid-1990s authorized up to six additional mobile telephone service providers in each service area.

There were more than 120 million wireless subscribers in the US in 2001 and about 50 million Nigerians were using cellular phones by mid 2006, according to the Cellular Telecommunications and Internet association, with

the number of new users increasing significantly each year. Forecasters and regulators did not anticipate this growth, however. Network equipment and start-up costs were substantial, and the cost to consumers was high. Providers had limited their networks to a small group of high-volume business users. Eventually, the providers recognized that their business would be more profitable if they created innovative service packages and aggressively marketed their services to the general public. As a result, prices for cellular telephones and network access have dropped considerably.

Cellular radio telephone service has achieved great commercial success because users recognize that mobile telephone access can improve productivity and enhance safety. Delivery drivers, repair technicians, lawyers, and other professionals were early adopters of mobile telephone service. As cellular networks cover more geographic areas and as rates drop, new subscribers are buying cellular services for personal security, safety on the road, and general convenience.

The ever-growing popularity of the cellular network systems in various sectors for variety of applications has led to an increase attention on performance management. It was in 1989 in the United States that a study to undertake the vulnerability of public switching centres was carried out. It was as a result of public concern over the dependency of the business community on the network performance and the consequences that might arise as a result of failures.

L. Bernstein and C. M. Yuhas [20] presented an anecdotal view of practices used by some network providers to access network performance. S. Ketker and K. Geihs [21] in their work presented a method of isolation by

integrating network, system and service management layers. M. Mac Gregor, W. Grover and K. Ryhorchuk [22] focused on the restoration recovery period by setting aside preconfigured networks to be available immediately through the use of real-time processes. The work of A. Snow and M. Weiss [23] capture failure pattern recovery by utilizing analysis of the primary performance parameters to predict network behavior; it is essentially good for network modeling. J. S. Baras, H. Li and Mykoniatis [24] were thought to be the foremost in designing an integrated distributed performance management in telecommunication networks at the centre of hybrid and communication networks of the University of Maryland, USA. They were able to provide a hierarchical and distributed system with probabilistic networks as the basis for performance analysis by using mathematical formulations and troubleshooting strategies. Somewhere in another work of the same authors they divided the entire system into domains and thereby attached an intelligent agent to analyse the performance of every domain independently [25].

Various techniques are certainly in use to evaluate blocking probability of any switching centre. Every technique is at variance with the other, depending on the complexity, level of accuracy and applicability to different cases of network structures and carried traffic. A. K. Erlang is however foremost in the formation of blocking probability which has become the basic tool of analysis. He defined a number of parameters and developed a set of formulae, which together give a framework of rules for planners to design and monitor the performance of networks. Numerous researchers have produced modified versions of the same approach – of course more advanced and complicated techniques intended to predict accurately the traffic carrying

capacity of various sizes and grades [26].

C. Y. Lee proposed a direct approach of using probability graphs to analyse network performance. The greatest value of this approach lies in the ease of formulation and the fact that the formulas directly relate to the underlying network structures. Therefore, the formulations help provide insight into the network structures and how these structures might be modified to change the performance [27].

2.3 Traffic Characteristics and Models

The techniques of traffic analysis can be divided into two general categories; loss systems and delay systems. The appropriate analysis category for a particular system depends on the systems treatment of overload traffic and based on the model representing the system. Models may be physical or mathematical. A physical model is an imaginary physical system resembling the actual system in certain salient features but which is simpler and therefore more amenable to analytical studies. For certain phenomena, the fundamental concepts are interpreted in the form of equations, which can be solved. This set of equations gives us a mathematical model. Physical and mathematical models are used to predict the behaviour of the system over a range of operating conditions [2].

In loss systems, overflow traffic is rejected. Thus, of most concern here is the blocking probability of arrivals into the system; (not the information flow) and the holding times of common equipment such as links, digit receivers, switching stages etc that are held for the duration of a call as events which comprise the system model. Generally, loss systems are designed to avoid a mismatch of the arrival rate and that of the service rate. This finds most

application in real-time systems like the telephone [3].

In applied mathematics, blocking probability analysis is referred to as 'congestion theory' while delay referred to as 'queuing theory'. Mathematical models range from simple tables and graphs to complicated sets of equations and algorithms for performing computer simulations. Based on the models, two main techniques of telecommunications traffic analysis may be identified. First, a purely mathematical approach (Analytical method) and secondly, simulation techniques which is a statistical experiment on a hypothetical model (a procedure for determining from information contained in a random sample whether to accept or reject a certain statement about the values of one or more of the parameters of a given distribution) of the system under study. These are used to:

- Determine the most efficient size of switching blocks, and their interconnections i.e. trunk arrangements.
- Determine the traffic capacity for selected grade of service standards and to obtain rules for practical dimensioning [2].

2.4 Congestion Theory

Two major random processes characterize telecommunications traffic behaviour. These are the call arrival times and the holding times.

$$p_o(\lambda t) = e^{-\lambda t} \quad \text{..... 2.1}$$

$$p_n(\lambda t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \quad \text{.....2.2}$$

Equation (2.1) defines the probability that no arrivals occur in a randomly selected interval t or the probability that t seconds elapses from one arrival to the next. Equation (2.2) is a Poisson distribution and provides a means of determining the

distribution of the inter-arrival times. For arrivals from a large number of independent sources, the equation defines the probability of experiencing exactly n arrivals in t seconds [3].

$$p \geq n(\lambda t) = \sum_{i=n}^{\infty} p_i(\lambda t)$$

$$= 1 - \sum_{i=0}^{n} p_i(\lambda t)$$

$$= 1 - p \leq n(\lambda t) \quad \ldots\ldots 2.3$$

where $p_i(\lambda t)$ is as defined in equation (2.2)

In call arrival, the concern is to evaluate the blocking probability presented to them at the switching center. Evaluation techniques however, vary according to complexity, accuracy and applicability to different scenario and network structures.

The probability of arrival of n calls during a time interval is expressed as:

$$p(n,t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \quad \ldots\ldots 2.4$$

which is a Poisson distribution with mean λ. Here, an arriving call is abandoned if all servers/channels or circuits are busy [9]. The system is considered to be in statistical equilibrium and the equation of state becomes:

$\lambda p(0) = \mu p(1)$

$(\lambda + \mu_n) p(n) = \lambda p(n-1) + \mu(n+1) p(n+1), n<k$

$\mu_n p(n) = \lambda p(n-1)$; where

$$\sum_{n=1}^{k} p(n) = 1 \quad \ldots\ldots 2.5$$

The solution for equation (2.5) is obtained as:

$$P(n) = \frac{a^n / n!}{\sum_{u'=0}^{m} a^{u'} / u'!} \qquad \ldots\ldots\ldots\ldots 2.6$$

Note that a = λ/μ

Where u' is the number of servers, channels or circuits and μ is a constant [3].

The blocking probability, that is, the probability that an incoming call will be blocked is given by:

$$B = p(k) = \frac{a^k / k!}{\sum_{u'=0}^{m} a^{u'} / u'!} \qquad \ldots\ldots\ldots\ldots 2.7$$

Equation (2.7) is called the Erlang formula of the first kind or Erlang B formula. It represents the attribute of a loss system or a blocking system [10].

Employing the Kendal notation, the blocking system may be characterized as a $M_1/M_2/M/N/O$ finite input source system, which finds wide applications in telephony [11].

Where: M_1 is the Exponential inter-arrival distribution, M_2 is the Exponential service time distribution, M is the number of channels or circuits, N is the system capacity (maximum number of calls allowed in the system), O is the permissible queue lay.

The corresponding state transition diagram as described using discrete-time Markov chains is as shown in fig 2.1 for $M_1/M_2/m/N/O$ system.

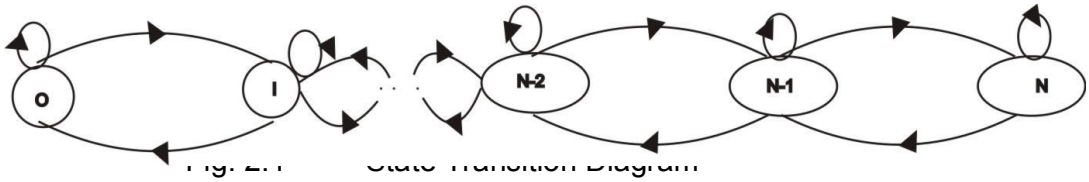


Fig. 2.1 State Transition Diagram

N is the number of calls in the system and δ is the function of the transition probabilities.

From the state transition diagram it is possible to derive a set of equations that can be solved for the equilibrium state occupancy probabilities (the probability that a call is in the system) upon arrival and after a departure. The probability of an arrival during infinitesimal interval Δt is assumed to be:

$\Delta t = \lambda_o \Delta t + o(\Delta t)$ ……. 2.8

where $o(\Delta t)$ is the following, $\lim_{t \to 0} \frac{o(\Delta t)}{\Delta t} = 0$

The probability, p of arrival of a call as a whole during t, when I out of N input sources are already in the system or generating traffic is:

$P = (N-i) \lambda_o \Delta t + o(\Delta t)$ …….…… 2.9

and the relationship between λ and λ_o is therefore

$\lim (N-i) \lambda_o = \lambda$ ..…… 2.10

as N approaches infinity and λ_o approaches zero.

The solution of statistical equilibrium for this case is:

$$P(i) = \frac{\begin{bmatrix} N \\ i \end{bmatrix} \left[\frac{\lambda_o}{\mu} \right]^i}{\sum_{u'=0}^{m} \begin{bmatrix} N \\ u' \end{bmatrix} \left[\frac{\lambda_o}{\mu} \right]^{u'}}$$ …….…… 2.11

for N>m

When N=m, no blocking occurs and the solution is given by the following Bernoulli distribution [12].

$$P(i) = \begin{bmatrix} N \\ i \end{bmatrix} \left[\frac{\lambda_o}{\lambda_o + \mu} \right]^i \left[\frac{\mu}{\lambda_o + \mu} \right]^{N-1}$$ …….…… 2.12

The probability that all servers/circuit are occupied will be given by:

$$P(m) = B_T = \frac{\left[\begin{matrix} N \\ m \end{matrix}\right]\left[\frac{\lambda_o}{\mu}\right]^m}{\sum_{u'=0}^{m}\left[\begin{matrix} N \\ u' \end{matrix}\right]\left[\frac{\lambda_o}{\mu}\right]^{u'}} \qquad \text{..... 2.13}$$

This is the time congestion probability or the percentage of time all server/circuits are busy. The probability that all servers are occupied when an incoming call arrives in the case of a finite input source is different owing to its arrival rate expression and is given by the conditional probability.

$$B_C = \frac{(N-m)\lambda_o p(m)}{\sum_{u'=0}^{m}(N-u')\lambda_o p(u')}$$

$$= \frac{\left[\frac{N-1}{i}\right]\left[\frac{\lambda_o}{\mu}\right]^m}{\sum_{u'=0}^{m}\left[\frac{N-1}{u'}\right]\left[\frac{\lambda_o}{\mu_o}\right]^{u'}} \qquad \text{..... 2.14}$$

This is the call congestion probability or the blocking probability and is called the Engset formula. The probabilities B_T and B_C are equal in the case where N approaches infinity; otherwise B_T is greater than B_C always. This is because the arrival rate decreases as the number of busy sources increases [12].

Employing Erlangs distribution, the probability of i servers being busy may be given as:

$$P_i = \frac{p_{m \geq i}(t) - p_{m \geq i+i}(t)}{1 - p_{m \geq u'+1}(t)} \qquad \text{..... 2.15}$$

Where $p_{m\geq}(t) = \sum_{m=t}^{\infty}\frac{(\lambda t)^m}{m!}\ell^{-\lambda t}$

Holding Times Distribution: The two most commonly assumed holding time distributions are the constant holding times and exponential holding times.

The former are valid for transmission times in fixed length packet networks. When constant time messages are in effect, it is straightforward to use equation 2.2 to determine the probability distribution of active channels. The probability that n channels are busy at any particular time is merely the probability that n arrivals occurred in the time interval of length t_m. The average number of active circuits over all time is called the traffic intensity:

$$A = \lambda t_m \qquad \text{..... 2.16}$$

The probability of n circuits being busy may be found from equation 2.15. Its value depends on the value of equation 2.16, where:

$$P_n(\lambda t_m) = P_n(A) = \frac{A^n}{n!}\ell^{-A} \qquad \text{..... 2.17}$$

The later is the most commonly assumed holding time distribution for the telephone, i.e.

$$P(\lambda t_m) = \ell^{-1/tm} \qquad \text{..... 2.18}$$

Equation 2.18 specifies the probability that a holding time exceeds a value. This distribution has the property that the probability of a termination is independent of how long a call has been in progress i.e. the exponential holding time represent the most random process possible [3].

The probabilistic characteristics of the holding time t_m may be given by the following expressions: where M and D are probability constants [3].

$$Mt_m = \int_0^\infty t^2 p(t)dt$$

$$= \int_0^\infty t\lambda\, \ell^{-\lambda t}\, dt$$

$$= 1/\lambda \qquad \text{..... 2.19}$$

$$Dt_m = \int_0^\infty t^2 p(t)dt - M^2 t_m$$

$$= \int_0^\infty t^2 \lambda \, \ell^{-\lambda t} \, dt - 1/\lambda^2$$

$$= 1/\lambda^2 \qquad \ldots\ldots\ldots 2.20$$

$$6t_m = \sqrt{Dt_m}$$

$$= 1/\lambda \qquad \ldots\ldots\ldots 2.21$$

2.5 Multi-Switching Network Traffic

In the preceding sections, basic techniques of congestion and fault theories are presented to determine the performance of individual switching centre route group. Here, techniques of calculating end-to-end blocking probabilities of a network, with multiple routes between end points are considered.

End-to-end blocking probabilities: Connections through large networks involve series of transmission links, each one of which is selected from set of alternatives. Thus, an end-to-end blocking probability analysis usually involves a composite of series and parallel probabilities.

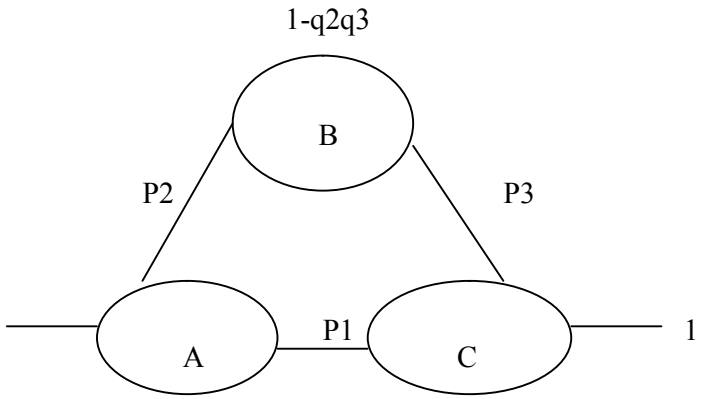


Fig. 2.2 End-to-end Network

In the blocking probability equation of the network shown in Fig. 2.2, the blocking probability (matching loss) of the switching centres is not included. In a digital time division switch, matching loss can be low enough

that it is easily eliminated from the analysis. When necessary, switch blocking is included in the analysis by considering it as a source of blocking in series with the associated trunk groups. When more than one route through the same switch, as in mode C of Fig 2.2 is considered, proper treatment of correlation between matching losses is an additional complication. Assuming the matching losses are independent, then they may be considered to be in series with the common link. Fig. 2.3 depicts these two approaches for including the matching loss of switch C into the end-to-end blocking equation. In this case the link from C-D is the common link [3].

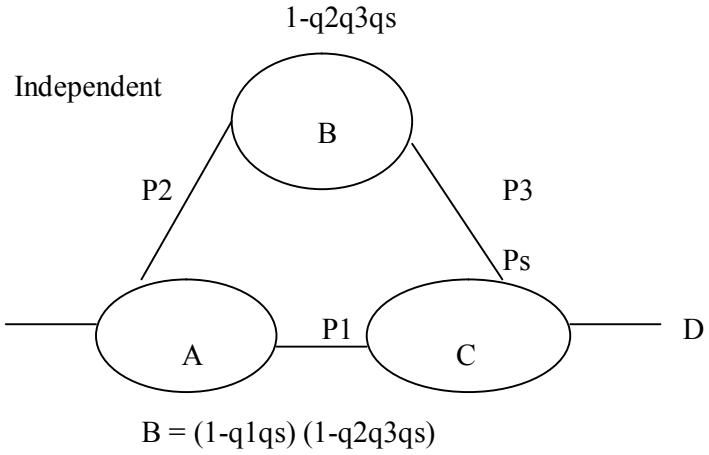


Fig. 2.3 Matching Loss

Traffic Matrix: if the traffic from a group of subscribers in one switching centre i to a group of subscribers in switching centre j is a a_{ij}, the traffic between subscribers in n different switching centres may be summarized in a matrix as follows:

$$a = [a_{ij}] = \begin{bmatrix} a_{11}a_{12}.....a_{1n} \\ a_{21}a_{22}.....a_{2n} \\ .a_{21}a_{22}.....a_{2n} \\ a_{n1}a_{n2}.....a_{nn} \end{bmatrix} \qquad \text{..... 2.22}$$

Such matrix is called a traffic matrix. Each row represents the outgoing traffic of switching centre and each column represents its incoming traffic. The principal diagonal represents the 'within group' traffic for each of the switching centres. The matrix then represents the junction traffic between pairs of switching centres in a multi-switching centre network as shown in fig. 2.2. In general, the outgoing traffic a_{ij} from a switching centre is not equal to the traffic incoming to the switching centre a_{ij}. If however, the originating and terminating traffic are equal, ($a_{ij} = a_{ji}$) then the matrix is symmetrical and $a = a^1$, where matrix a^1 is the transpose of matrix of matrix a.

If the number of subscribers in switching centres i and j are N_i and N_j, respectively the total traffic originating in exchange i is:

$$A_i = N_i \sum_{j=1}^{n} a_{ij}N_j \qquad \text{..... 2.23}$$

Which can be written as a matrix product

$$A_i = N_i[a_{i1}, a_{i2},\ldots a_{in}] \begin{bmatrix} N_1 \\ N_2 \\ . \\ N_n \end{bmatrix} \qquad \text{..... 2.24}$$

The total traffic originating within the network is:

$$A = \sum_{j=1}^{n} A_i \sum_{j=1}^{n} N_i a_{ij} N_j$$

$$A = [N_1, N_2, \ldots N_n] \begin{bmatrix} a_{11} \ldots a_{in} \\ a_{21} \ldots a_{2n} \\ \ldots\ldots\ldots a_{2n} \\ a_{ni} \ldots a_{nn} \end{bmatrix} \begin{bmatrix} N_1 \\ N_2 \\ . \\ N_n \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots 2.25$$

Which can be written as: $A = N_a N^1$ 2.26

Thus, the outgoing traffic per group of subscribers in one switching centre (I,j,…..,n) can be read from the rows of the column vector (N) as:

$t = aN$ 2.27

The incoming traffic per group of subscribers can be read of from the columns of the row vector (N^1)[2].

$r = N^1 a$ 2.28

Tele-traffic forecasting: a model for forecasting the traffic between two switching centres following a change in the number of subscribers may be obtained as follows: the total both way traffic between the area (P and Q) at some future time is given by:

$$A_{pq} = N_{pt} N_{qt} a_{qp}$$

$$= A_o \frac{N_{pt} N_{qt} (N_{po} + N_{qo})}{N_{po} N_{qo} (N_{pt} + N_{qt})} \quad \ldots\ldots\ldots\ldots\ldots 2.29$$

Where A_{pq} is the community of interest factor/affinity; Ao is the present total both way traffic between P and Q; N_{po} is the present number of subscribers in switching centre P; N_{qo} is the present number of subscribers in switching centre Q; N_{pt} is the future numbers of subscribers in switching centre P; N_{qt} is the future number of subscribers in switching centre Q.

In general, a new switching centre may be created from parts of two or more existing areas and more than one switching centre may be introduced

and other boundary changes may be made at the same time. The traffic a_{ij} between two switching centres i and j, after such a rearrangement of a muiti-exchange centre is given by:

$$A_{ij} = \sum_{k=1}^{s} N_i^{(K)} aLKN_j^{(L)} \qquad \text{..... 2.30}$$

Where K, L = 1,2, …s, and s is the present number of switching centres; I, j = 1,2, ……. r, and r is the number of switching centres after the alteration in number and sizes of switching centres.

$aKL = \frac{A_{KL}}{N_K N_L}$ is the community of interest factor between existing areas K and L. $N_i^{(K)}$ is the number of subscribers in new area I who were previously contained in area k.

When there is no existing direct route between two switching centres areas, it is more difficult to make any adequate forecast of future traffic between them. An approximate estimate can sometimes be made, by using a simple gravity model as follows:

$$A_{KL} = \frac{aN_K N_L}{d^2} \qquad \text{..... 2.31}$$

Where A_{KL} is the traffic between areas K and L, N_K;N_L are the numbers of subscribers in the two areas, d is the distance between the centres of two areas and a is the coefficient of affinity.

The constant a can be estimated by substituting into equation (2.31), data for two areas whose inter-switching centre traffic is known. Transformation equation (2.31) will result in:

$$\text{Log}\left[\frac{A}{N_K N_L}\right] = \log a - 2\log d \qquad \text{..... 2.32}$$

Which enables the value of a to be determined by simple linear regression analysis [2].

2.6 Dimensioning Circuit-Switched Networks

A mathematical model is required for predicting network performance in order to determine how many circuits a network will need in order to meet traffic demand or control the proportion of blocked calls. The model should comprise at least two parts:

- A statistical distribution, to represent the number of calls in progress at any given time.
- A forecast of the overall volume of traffic.

The probability density function used for the calculation is termed the 'Erlang distribution'. The Erlang formula, which is a related and complex interactive mathematical formula, can be manipulated into a number of different forms, the most common form is used to calculate the required number of circuits (or circuit group size) to carry a given traffic volume between two switching centres under the constraint of having to meet a given grade of service (GOS). Thus, circuits required = e(a, GOS). Where E represents the appropriate form of Erlang formula, A is the route busy hour traffic and GOS is the target grade of service.

The dimensioning of circuit switched networks (i.e. telephone, circuit-switched data) is based upon the 'Erlang lost-call formula'

$$\text{E (N,A) or B (N,A)} = \frac{(A^N / N!)}{1 + A + (A^2 / 2!) + ...(A^N / N!)} \quad \text{..... 2.33}$$

Where E (N, A) is the proportion of lost calls, and probability of blocking, A is the offered traffic intensity and N is the available number of

circuits.

A commonly used grade of service for inter-switching centres traffic routes is 0.01 or one percent blocking. For overflow circuit groups (outside the scope of this research work), a slight modification of the Erlang formula called the Wilkinson-rapp route dimensioning method is used [1].

CHAPTER THREE

GSM NETWORK DATA

3.1 General

Traffic in communication network refers to the aggregate of all users' requests being serviced by the network. A call initiated is referred to as an originating access, whereas one received is referred to as a terminating access. When both the originating access and the terminating access are of the same mobile switching, the call is referred to as a local call. When the originating access is a local subscriber and the dialed number resulted in a trunk and the terminating access is a local subscriber the call is defined as an incoming call, whereas if the originating access is a trunk and the terminating access is a trunk, the call is defined as a transit call [13]. Another important aspect of traffic in GSM communications include calls initiated by users to the Network Management Facilities or vise versa (customer services).

3.2 Measurement of Traffic

Measurements of traffic levels in various parts of mobile switching centre and networks are related to the occurrence of what are expected to be rare events, call failure due to ratio of initiated calls to available facilities, and the conversation time (holding time), the total number of data characters or calls etc. These are essential information in determining network performance. An important distinction to be made in networks is the difference between the offered traffic and the carried traffic, as in practice, a small percentage of the offered traffic typically experiences network delay [3].

The capacity of the network or system is determined by the volume of traffic it can carry over a period of time. Traffic volume is essentially the sum

of all holding times carried during the interval. In practice, telecommunication networks are found to have a ‘busy period’, which is a time of the day when traffic intensity is at its peak as in Fig. 3.1, where MN signifies minimum.

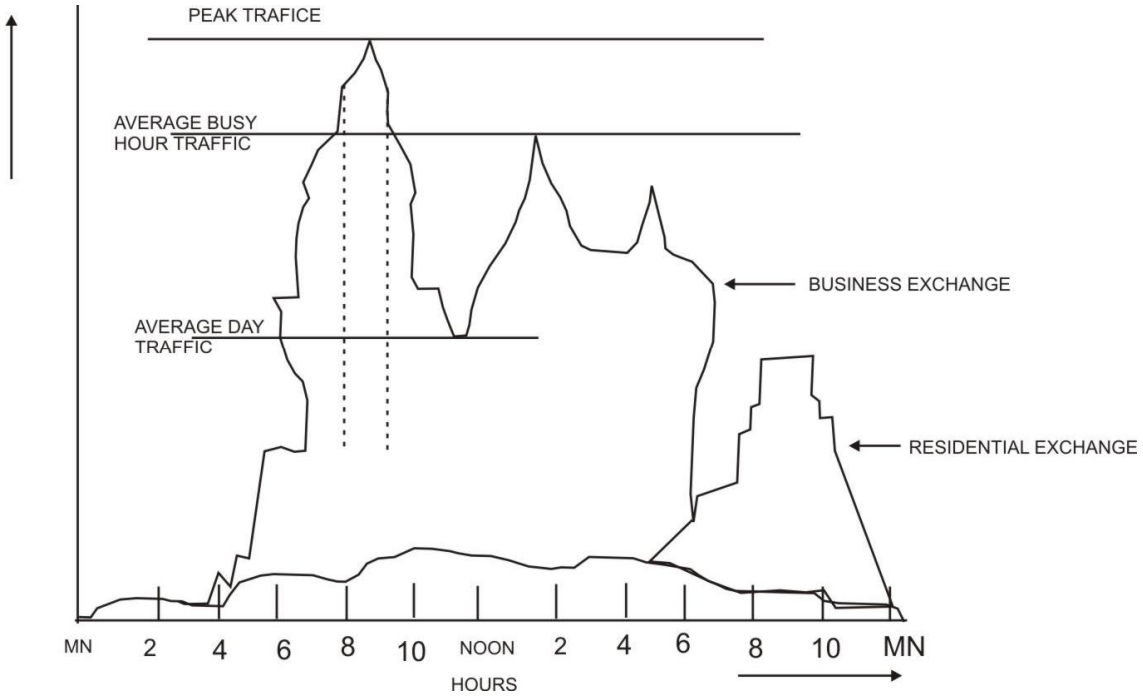


Fig 3.1 Daily Fluctuations in Telephone Traffic

A more useful measure of traffic is the traffic intensity, which is a division of the traffic volume by the length of time during which it is measured. Traditionally measurements of traffic intensity have been made over a full 3600 seconds at the busy period of the day [14].

In practice, the ‘traffic intensity’ on a given route may be measured using one of two main methods, either by sampling or by an absolute measurement. Historically, however, electro-mechanical exchanges did not lend themselves to easy calculation of absolute value of the total holding time. Instead it was common practice to use a sampling technique. In modern stored program controlled switching centres, the absolute measurement of call holding times are made relatively easy and which produce traffic intensity

measurements that are exact [1].

The traffic intensity represents the average activity during the given period and is expressed in units of Erlang. It is given by the expression:

$A = \lambda t_m$ 3.1

Where λ is the arrival rate and t_m is the average holding time.

This is the average number of active circuits over the period. If the average activity of a subscriber assuming no traffic is lost is designated as ρ, the offered load λt_m can be determined as:

$A' = \lambda' t_m$

$$= \frac{\rho}{1 + \rho(1 - Bc)} \quad \text{..... 3.2}$$

where Bc is the blocking probability.

If the total offered load is considered to be Nρ, then the carried traffic intensity is:

$$Ac = \frac{N\rho(1 - Bc)}{1 + \rho(1 - Bc)} \quad \text{..... 3.3}$$

The output utilization or traffic carried by each circuit is given by:

$$P = \frac{(1 - Bc)A}{n} \quad \text{..... 3.4}$$

where *n* is the number of circuits [2].

The probability that i circuits are busy using Erlangs distribution may be given by:

$$P_I = \frac{p_{n \geq i}(t) - p_{n \geq I+1}(t)}{p_{n \geq v+1}(t)} \quad \text{.....3.5}$$

Where $p_{n\geq}(t) = \sum_{n=1}^{\infty} \left(\frac{\lambda t}{n!}\right)^n e^{-\lambda t}$

and the carried traffic under this condition is given by:

$$Ac = A (1 - P(n)) \quad \text{..... 3.6}$$

Busy period traffic measurements indicate that an individual residential telephone is typically in use between five to ten percent of the busy period. Thus each telephone presents a traffic load between 0.05 and 0.10 Erlangs. The average holding time is between three and four minutes, indicating that a typical busy period telephone usually produce loading patterns different from residential telephone as illustrated in figure 3.1 [15].

3.3 Call Handling Systems

Traffic and network performance information usually are displayed on computers. The main hardware areas involved in call handling are:

a) Access Modules:

- Analog Subscriber Accesses
- ISDN Subscriber Basic Accesses
- Trunk Accesses (via PCM)
- X.25 and X.75 Packet Switching Accesses
- Remote Subscriber Accesses from Remote Subscriber Units (via PCM links)

b) Auxiliary Control Elements (ACE)

c) Service Circuit Modules (SCM)

d) Digital Switching Network (DSN)

The main software used for controlling call handling include:

a) Call Handling and Facilities Software

b) Call Services Software

c) Signaling Handling Software

d) Telephone Device and Signaling Adaptation Software

Telephone events (e.g. subscriber on/off-hook, dialed and digits, digital signaling messages etc) indicated by electric signals arriving at the exchange accesses are detected by the hardware in the access module. These electrical signals are translated by software into logical signals for use by the call handling process, similarly logical signals generated by software, are translated to enable the terminal hardware to apply the correct electrical signals (e.g. busy tone, ringing tone etc) to the exchange accesses [13].

3.4 Network Data

The switching exchanges are the most invisible to the subscriber yet represent the most important element in a communications network in terms of available service offerings. The basic function of any switch is to set-up and release connections between transmission circuits on an 'as-needed basis'. The number of Celtel MSC in Lagos area at present is as indicated in the Table 3.1. However, due to rapid development in GSM infrastructure in the country, the management has planned several installations of such new MSC in a number of locations within the Lagos area.

At present, the Celtel network has nine mobile switching centres in Lagos. The individual mobile switching centre are grouped and each of the groups of mobile switching centres are seen as a unit in a particular location.

The data collected for this research work were based on these locations, namely; Victoria Island, Lagos Mainland and Other Areas. The content of these data for the stated locations include the followings:

- Number of trunks provided
- Number of trunks available
- Number of trunks occupied

- Number of attempted calls
- Number of seizures
- Number of Answer calls
- Number of busy reply
- Number of no reply

The data were collected between 10am to 11am at random from Mondays to Fridays for the period of six months.

The collected data for each location were averaged on weekly basis for a period of one month. Table 3.2 to Table 3.7 indicated the collected data on weekly basis for months of January to June.

It is the weekly data about the listed items that were used to compute the selected parameters which were eventually used to analyse the efficiency of mobile switching centres in the designated locations as in chapter four.

The original bulk data was given by the Celtel technical unit/educational material section, thus, its reliability was not in doubt.

Table 3.1 Number of MSC Installed in Lagos area

S/N	**LOCATION**	***NUMBER INSTALLED***
1	Victoria Island	2
2	Lagos Main Land	4
3	Other Areas	3
	TOTAL	**9**

Table 3.2 Traffic Data of Lagos Area (Average) [JAN] 10am to 11am.

Location	Tks(P)	Tks(A)	OCC	Attem	Seiz	Ans	Busy	NR
			2-6/01/06					
VI	3000	2850	1160	46721	46111	17494	11527	17090
LMI	10800	10800	4126	200100	200010	75005	50002	64003
OA	10800	10800	4112	201100	201000	86005	50250	63075
			9-13/01/06					
VI	3000	2850	1201	32775	31210	12405	7802	11003
LMI	10800	10800	4188	201262	200412	90155	50103	60154
OA	10800	10800	4201	211561	204121	93046	51030	60045
			16-20/01/06					
VI	3000	2850	1102	29216	28661	11449	7165	10047
LMI	10800	10800	4086	204231	203501	92316	50875	60310
OA	10800	10800	4127	206110	201126	85424	50281	65421
			23-27/01/06					
VI	3000	2850	1199	22464	22134	10392	5533	6209
LMI	10800	10800	4027	206162	201234	85866	50308	65060
OA	10800	10800	4285	211321	210462	96925	52615	60922
			30/01/06-03/02/06					
VI	3000	2825	1191	41120	40035	20015	10008	10012
LMI	10800	10800	4019	206316	203332	92290	50833	60209
OA	10800	10800	4223	201116	200028	85011	50007	65010

Table 3.3 Traffic Data of Lagos Area (Average) [FEB] 10am to 11am.

Location	Tks(P)	Tks(A)	OCC	Attem	Seiz	Ans	Busy	NR
			6-10/02/06					
VI	3000	2850	1201	56724	56700	34752	11340	10608
LMI	10800	10800	4220	221100	220100	125854	44020	50226
OA	10800	10800	4070	212712	212700	119604	42540	50556
			13-17/02/06					
VI	3000	2850	1271	45933	45916	26714	9183	10019
LMI	10800	10800	4072	210063	210050	117427	42010	50613
OA	10800	10800	4120	206866	206810	114542	41362	50906
			20-24/02/06					
VI	3000	2850	1101	35660	35609	20443	7121	8045
LMI	10800	10800	3718	202520	202010	109586	40402	52022
OA	10800	10800	3848	204311	201100	110572	40220	50308
			27/02/06-3/03/06					
VI	3000	2850	1169	48017	48000	27380	9600	11020
LMI	10800	10800	4069	216046	215011	121107	43002	50902
OA	10800	10800	3919	221420	221058	116752	44211	60095

Table 3.4 Traffic Data of Lagos Area (Average) [MAR] 10am to 11am.

Location	Tks(P)	Tks(A)	OCC	Attem	Seiz	Ans	Busy	NR
			06-10/03/06					
VI	3000	2850	1130	71024	71000	50123	11300	9577
LMI	10800	10800	4220	215990	215900	126734	64770	24396
OA	10800	10800	4040	220616	220523	131245	68362	20916
			13-17/03/06					
VI	3000	2850	1225	70012	70010	49672	11003	9335
LMI	10800	10800	4218	230134	230100	140721	61331	28048
OA	10800	10800	4203	220901	220900	138672	59600	22628
			20-24/03/06					
VI	3000	2850	1260	50124	50120	35611	9002	5507
LMI	10800	10800	4041	210544	210541	132334	55612	22595
OA	10800	10800	4150	209986	209972	128679	52013	29280
			27-31/03/06					
VI	3000	2850	1230	51670	51660	31667	10002	9991
LMI	10800	10800	3992	226712	226701	137689	54234	34778
OA	10800	10800	3980	219906	219876	141375	58073	20428

Table 3.5 Traffic Data of Lagos Area (Average) [APR] 10am to 11am.

Location	Tks(P)	Tks(A)	OCC	Attem	Seiz	Ans	Busy	NR
			3-7/04/06					
VI	3000	2850	1240	76540	76030	44458	12671	18901
LMI	10800	10800	4215	230116	230001	136646	38333	55022
OA	10800	10800	4069	201673	201002	119435	33500	48067
			10-14/04/06					
VI	3000	2850	1273	71012	71000	42264	11833	16903
LMI	10800	10800	4070	240631	240241	141188	40040	59013
OA	10800	10800	4100	207634	207011	122379	34501	50131
			17-21/04/06					
VI	3000	2850	1201	75067	75001	44501	12500	18000
LMI	10800	10800	3898	210367	210222	124153	35037	51032
OA	10800	10800	3996	207198	207108	122519	34518	50071
			24-28/04/06					
VI	3000	2850	1180	76374	76371	44642	12728	19001
LMI	10800	10800	4169	230578	230570	140542	38428	51600
OA	10800	10800	3976	209370	209351	122360	34891	52100

Table 3.6 Traffic Data of Lagos Area (Average) [MAY] 10am to 11am.

Location	Tks(P)	Tks(A)	OCC	Attem	Seiz	Ans	Busy	NR
			1-5/05/06					
VI	3000	2850	1250	75925	75600	20125	10300	45175
LMI	10800	10800	4225	234900	230925	80075	70550	80300
OA	10800	10800	4075	223800	220400	79675	65050	75675
			8-12/05/06					
VI	3000	2850	1275	68975	68700	20875	9325	38500
LMI	10800	10800	4075	231375	226825	77850	67025	81950
OA	10800	10800	4125	222975	218150	78775	66875	72500
			15-19/05/06					
VI	3000	2850	1100	50225	50125	17725	10350	22050
LMI	10800	10800	3725	209675	206700	75525	61575	69600
OA	10800	10800	3850	207750	204225	72675	59675	71875
			22-26/05/06					
VI	3000	2850	1175	51375	51250	1750	8325	41175
LMI	10800	10800	4075	234275	229425	78525	67400	83500
OA	10800	10800	3925	225550	220600	73500	69225	77875
			29/05/06-2/06/06					
VI	3000	2825	1125	77750	77750	1750	12350	63650
LMI	10800	10800	3750	242725	238975	73950	71550	93475
OA	10800	10800	4050	208250	204400	86275	53300	64825

Table 3.7 Traffic Data of Lagos Area (Average) [JUN] 10am to 11am.

Location	Tks(P)	Tks(A)	OCC	Attem	Seiz	Ans	Busy	NR
			5-9/06/06					
VI	3000	2850	1206	80211	80001	54517	11428	14056
LMI	10800	10800	4116	251922	251901	169216	35985	46700
OA	10800	10800	4015	241012	241002	162568	34428	44006
			12-16/06/06					
VI	3000	2850	1272	79346	79009	54178	11287	13544
LMI	10800	10800	4062	246392	246308	166090	35186	45032
OA	10800	10800	4125	243161	241998	166022	34571	41405
			19-23/06/06					
VI	3000	2850	1109	69937	69017	47135	9859	12023
LMI	10800	10800	3825	229673	228948	154126	32706	42116
OA	10800	10800	3830	216346	216016	149137	30859	36020
			26-30/06/06					
VI	3000	2850	1175	70024	70006	47943	10000	12063
LMI	10800	10800	4025	223998	223043	149949	31863	41231
OA	10800	10800	3975	209761	209706	141725	29958	38023

CHAPTER FOUR

TRAFFIC ANALYSIS

4.1 General

Basic techniques of traffic theory were presented in chapter two and used in determining the blocking probabilities of individual switching centres. From the collation of information relating to all current and very recent calls, a true picture of the current network status may be calculated. These information include circuit occupancy, number of calls attempted, number of seizures, number of calls completed etc. in the Lagos area.

4.2 Circuit Occupancy

This is the average number of calls in progress on a given circuit or the average number of circuits in use on a given route group for a certain period. It represents the intensity of the traffic 'carried' on the trunk group and is equal to the number of active or busy circuits A =λt_m measured in Erlangs. The traffic per circuit is given by:

$$\text{Traffic/Circuit} = \frac{Occupancy}{Available\ Trunks} \qquad \ldots\ldots\ldots\ldots 4.1$$

4.3 Attempted Calls

The total number of calls attempted is the measure of unconstrained customer demand. At a time of network congestion, the busy hour call attempt (BHCA) count may continue to increase. It is also a good means of spotting suppressed traffic within the network. The busy hour traffic is:

$$\text{BHT} = \frac{no.\ of\ calls\ attempted\ \ X\ \ average\ holding\ time}{60} \qquad \ldots\ldots\ldots\ldots\ldots 4.2$$

A normal holding time is usually between three to four minutes, the choice was four minutes.

4.4 Completed Calls

The number of calls completed (i.e. reaching ringing tone), when compared with the calls attempted, gives another measure of the state of network performance. The proportion of busy hour calls completed, should equal the design grade of service (GOS).

$$\text{GOS} = \frac{no.of\ busyhour\ calls\ attempted - no.of\ busyhour\ calls\ completed}{no.of\ busyhour\ calls\ attempted} \text{ X } 100\% \quad \ldots\ldots\ldots 4.3$$

4.5 Network Performance Parameters

Other important parameters useful in the analysis of network performance include the call completion ratio (CCR), answer bid ratio (ABR) and answer seizure ratio (ASR). They are defined as follows:

$$\text{CCR} = \frac{Answered\ calls + No\ reply\ calls}{Attempted\ calls} \text{ X } 100\% \quad \ldots\ldots\ldots\ldots 4.4$$

$$\text{ABR} = \frac{Number\ of\ Answered\ calls}{Attempted\ calls} \text{ X } 100\% \quad \ldots\ldots\ldots\ldots 4.5$$

$$\text{ASR} = \frac{Number\ of\ Answered\ calls}{Number\ of\ Seizures} \text{ X } 100\% \quad \ldots\ldots\ldots\ldots 4.6$$

ABR and ASR statistics are used as tools for “switching network performance analysis”. These and other parameters are calculated using equations 4.1 to 4.6 utilizing data in Table 3.2 and the results presented in Table 4.1.

Table 4.1 Lagos Area Network Traffic [JAN]

Location	TFC/CCT	BHT	CCR	ABR	ASR	GOS
		2-6/01/06				
VI	0.4070	3114.73	74.02	37.44	37.94	62.56
LMI	0.3820	13340.00	69.47	32.48	37.50	62.52
OA	0.3807	13406.67	74.13	42.77	42.79	57.23
		9-13/01/06				
VI	0.4214	2185.00	71.42	37.85	39.75	62.15
LMI	0.3878	13417.67	74.68	44.79	44.98	55.21
OA	0.3890	14104.07	72.36	43.98	45.58	56.02
		16-20/01/06				
VI	0.3867	1947.73	73.58	39.19	39.95	60.81
LMI	0.3783	13615.40	74.73	45.20	45.36	54.80
OA	0.3821	13740.67	73.19	41.44	42.47	58.55
		23-27/01/06				
VI	0.4207	1497.60	73.90	46.26	46.95	53.74
LMI	0.3729	13744.13	73.21	41.65	42.67	58.35
OA	0.3968	14088.07	74.70	45.87	46.05	54.13
		30/01/06-03/02/06				
VI	0.4178	2741.33	73.02	48.67	49.99	51.33
LMI	0.3721	13754.40	73.92	44.73	45.39	55.27
OA	0.3910	13407.73	74.60	42.27	42.49	57.73

Table 4.2 Lagos Area Network Traffic [FEB]

Location	TFC/CCT	BHT	CCR	ABR	ASR	GOS
		6-10/02/06				
VI	0.4214	3781.60	79.97	61.27	61.29	38.73
LMI	0.3907	14740.00	79.64	56.92	57.18	43.08
OA	0.3769	14180.80	80.00	56.23	56.23	43.77
		13-17/02/06				
VI	0.4460	3062.20	79.97	58.16	58.18	41.84
LMI	0.3770	14004.20	80.00	55.90	55.90	44.10
OA	0.3815	13791.10	79.98	55.37	55.39	44.63
		20-24/02/06				
VI	0.3863	2377.30	79.89	57.33	57.41	42.67
LMI	0.3443	13501.30	79.80	54.11	54.25	45.89
OA	0.3563	13620.70	78.74	54.12	54.98	45.88
		27/02/06-3/03/06				
VI	0.4102	3201.10	79.97	57.02	57.04	42.98
LMI	0.3768	14403.10	79.62	56.06	56.33	43.94
OA	0.3629	14761.30	79.87	52.73	52.82	47.27

Table 4.3 Lagos Area Network Traffic [MAR]

Location	TFC/CCT	BHT	CCR	ABR	ASR	GOS
		6-10/03/06				
VI	0.3965	4734.93	84.06	70.57	70.60	29.43
LMI	0.3907	14399.33	69.97	58.66	58.70	41.32
OA	0.3741	14707.73	68.97	59.49	59.52	40.51
		13-17/03/06				
VI	0.4298	4667.47	84.28	70.95	70.95	29.05
LMI	0.3906	15342.27	73.34	61.15	61.16	38.85
OA	0.3892	14726.73	73.02	62.78	62.78	37.22
		20-24/03/06				
VI	0.4421	3341.60	82.03	71.05	71.05	28.95
LMI	0.3742	14036.27	73.59	62.85	62.85	37.15
OA	0.3843	13999.07	75.22	61.28	61.28	38.72
		27-31/03/06				
VI	0.4316	3444.67	80.62	61.29	61.30	38.71
LMI	0.3696	15114.13	76.07	60.73	60.74	39.27
OA	0.3685	14660.40	73.58	64.29	64.30	35.71

Table 4.4 Lagos Area Network Traffic [APR]

Location	TFC/CCT	BHT	CCR	ABR	ASR	GOS
		3-7/04/06				
VI	0.4351	5102.67	82.78	58.08	58.85	41.92
LMI	0.3903	15341.07	83.29	59.38	59.41	40.62
OA	0.3768	13444.87	83.06	59.22	59.42	40.78
		10-14/04/06				
VI	0.4467	4734.13	83.32	59.52	59.53	40.48
LMI	0.3769	16042.07	83.20	58.67	58.77	41.33
OA	0.3796	13842.27	83.09	58.94	59.12	41.06
		17-21/04/06				
VI	0.4214	5004.47	83.26	59.28	59.33	40.72
LMI	0.3609	14024.47	83.28	59.02	59.06	40.98
OA	0.3700	13813.20	83.30	59.13	59.16	40.87
		24-28/04/06				
VI	0.4140	5091.60	83.33	58.45	58.45	41.55
LMI	0.3860	15371.87	83.33	60.95	60.95	39.05
OA	0.3681	13958.00	83.33	58.44	58.45	41.56

Table 4.5 Lagos Area Network Traffic [MAY]

Location	TFC/CCT	BHT	CCR	ABR	ASR	GOS
		1-5/05/06				
VI	0.4386	5061.67	86.00	26.51	26.62	73.49
LMI	0.3912	15660	68.27	34.09	34.68	65.91
OA	0.3773	14920	69.41	35.60	36.15	64.40
		8-12/05/06				
VI	0.4474	4598.33	86.08	30.26	30.39	69.74
LMI	0.3773	15425	69.07	33.65	34.32	66.35
OA	0.3819	14865	67.84	35.33	36.11	64.67
		15-19/05/06				
VI	0.3860	3348.33	79.19	35.29	35.36	64.71
LMI	0.3449	13978.33	69.21	36.02	36.54	63.98
OA	0.3565	13850	69.58	34.98	35.59	65.02
		22-26/05/06				
VI	0.4123	3425	83.55	3.41	3.41	96.59
LMI	0.3773	15618.33	69.16	33.52	34.23	66.48
OA	0.3634	15036.67	67.11	32.59	33.32	67.41
		29/05/06-2/06/06				
VI	0.3982	5183.33	84.12	2.25	2.25	97.75
LMI	0.3472	16181.67	68.98	30.47	30.94	69.53
OA	0.3750	13883.33	72.56	41.43	42.21	58.57

Table 4.6 Lagos Area Network Traffic [JUN]

Location	TFC/CCT	BHT	CCR	ABR	ASR	GOS
		5-9/06/06				
VI	0.4232	5347.40	85.49	67.97	68.15	32.03
LMI	0.3811	16794.80	85.71	67.17	67.18	32.83
OA	0.3718	16067.47	85.71	67.45	67.46	32.55
		12-16/06/06				
VI	0.4463	5289.73	85.35	68.28	68.57	31.72
LMI	0.3761	16426.13	85.69	67.41	67.43	32.59
OA	0.3819	16210.73	85.30	68.28	68.60	31.72
		19-23/06/06				
VI	0.3891	4662.47	84.59	67.40	68.29	32.60
LMI	0.3542	15311.53	85.44	67.11	67.32	32.89
OA	0.3546	14423.07	85.58	68.93	69.04	31.07
		26-30/06/06				
VI	0.4123	4668.27	85.69	68.47	68.48	31.53
LMI	0.3727	14933.20	85.35	66.94	67.23	33.06
OA	0.3681	13984.07	85.69	67.56	67.58	32.44

4.6 Analysis of Results

From the data obtained and presented in chapter Three, and subsequent computations in chapter Four as Tables 4.2 – 4.6, the network performance is as follows:

Fig. 4.1 of Appendix B illustrated the behaviour of the network throughout the month of January. In all the three centres, the worse cases are in the first and third weeks, while the second and fourth up to the fifth week show some level of improvement. On each of the centres, Victoria Island and Lagos Mainland indicated faults and congestions for the first and third week while other areas witnessed a sharp drop in calls for second, third and fifth weeks. The circuit occupancy and hourly traffic is highest in the second, fourth and fifth weeks. This may not be unconnected with the low business activities in the first week of the month and high movement of people from the beginning of the second week.

Fig. 4.2 of Appendix B shows a relatively good network characteristics, however, the third week, especially in the case of other areas were quite abnormal. This may be as a result of a major fault within the week as second and fourth weeks showed better network performance.

Fig. 4.3 of Appendix B indicated that the network performance was relatively acceptable, but suddenly changed from the third week. Coincidently, this was the period in which another service provider company MTEL was having problems of striking workers. This has affected the network performance level of Celtel because of congestion.

Fig. 4.4 of Appendix B show network behaviour within the month of April, it is clear that there was only stability within the second and third weeks

in all the centres. Victoria Island had the worst cases which indicated a reasonable high level of fault.

Fig. 4.5 of Appendix B indicated very poor network performance especially during the third and fourth weeks. The case of Lagos Mainland is the worse affected and Victoria Island indicated a random grade of service. The performance was impressive during the first and second weeks but reached an all time low in the fourth week of the month.

Fig. 4.6 of Appendix B was a clear case of relative improvement in the network in all the centres. There was a steady occurrence of grade of service with a fairly constant busy hour call completion rate throughout the month.

Figs 4.7 to 4.12 show the network performance for the period of six months. Each of selected parameters were analysed as they affected the entire network in all the centres for the period under review.

Answer Seizure Ratio: This parameter is inversely proportional to the network congestion at a switching centre. The lower the ASR value, the higher is the congestion. From Table 4.1 to Table 4.6 and Fig. 4.8 it is clearly shown that ASR is relatively below its “nominal value” compared to Appendix C. In the case of Victoria Island, it is worse in the month of May while the months of January, February and May indicated a low value for the centres. ASR is usually measured at an originating witching centre on the basis of destination. It is an important tool for network performance analysis.

Call Completion Rate: This parameter shows the number of calls reaching ringing tone compared with the number of attempted calls. It is a measure of the quality of service. Table 4.1 to Table 4.6 and Fig 4.9 indicate that it is essentially normal for Lagos main Island, randomly varying for

Victoria Island and slightly stable for other areas throughout the period of six months. Its variation indicates that the fault or congestion levels are on the high side as seen in the case of Victoria Island.

Answer Bid Ratio: This is directly proportional to the call drop rate. The value must be kept low. It is relatively above its acceptable value when compared to Appendix C, which is due to inadequate channel availability resulting in handoff problems and coverage problems. As indicated by Fig. 4.10 this is more pronounced in the case of Victoria Island while the remaining two areas exhibit fairly uniform value. However, the months of March, April and June have worse cases. This may not be unconnected with traffic volume during these months.

The grade of service is essentially expected to maintain a constant value. This is likely the case within each month for the period under review for all the centres with slight differences for Victoria Island. However, between the six months for the same period under review, the situation is different as indicated by the fig 4.7. This is a clear case of faults and possible congestion on these centres exceeding their designed capacities but fairly managed within the months by the network operators.

The circuit occupancy and Busy hour traffic chart as indicated in Table 4.2 to 4.7 and Fig 4.5 to Fig 4.12 show a progressive traffic load for the period of six month with the consequence that unless more circuits are made available, the network capacity will be very inadequate for the ever increasing traffic load in the Lagos area of Celtel Network.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Introduction

The introduction of Global System for Mobile Communications (GSM) into the country has extensively expanded all telecommunication infrastructures in the country. The request for various services has lead to over-stretching of the existing capacities, which resulted into below average performance of the entire network.

The current trend of increasing traffic volume would definitely continue. Therefore, adequate and reliable tools for managing the entire network performance is essential so as to foretold congestions and faults by obtaining an appropriate analysis of the traffic information. This is crucial to the provisions of the quality and capacity of switching of switching centres, transmission equipment needed to match network capacity to users demand.

In this research work, traffic data were obtained on weekly basis for nine mobile switching centres located in three locations within Lagos. The computed data resulted in definite value for certain parameters. The values of these parameters form the basis of information on the current status of the Celtel network in Lagos and possibly how to reduce side effects stated under contribution.

5.2 Conclusions

The entire network status as indicated shows some level of faults and congestions, which is a clear indication of low level of network performance. In the interim, an improved restrictive control measures that acknowledge every subscriber and avoid ‘no reply’ calls is suggested. While the expansive

control measures that actually lead to the establishment of more Mobile Switching Centres especially in Victoria Island is the lasting solution to ensure reasonable improvement in network performance.

Finally, the management of Vmobile should make adequate provisions to take care of over traffic at certain period in particular places by using forecasted traffic data and by extension use the same idea in new areas. Without this, the essence of matching service demands to network capacity will ever remain elusion going by ever-increasing demand for telecommunication services in the country.

5.3 Contributions

From the analysis of the results presented in tables and figures, it is clear that the mobile switching centres located in Victoria Island (three in number) do experienced congestions and dropped calls especially on the high business days (i.e. Mondays, Thursdays and Fridays) largely due to their limited capacity. The monitoring of other parameters such as CCR, ABR, ASR and GOS which allows the network manager to evaluate overall network status and take appropriate corrective measures in good time has worse cases during the months of February, March and April. However, the months of May and June have shown considerable improvements.

It is the duty of network managers to ensure the followings by embarking on either expansive or restrictive control actions.

- The use of all available equipment to complete calls or determine data packets.
- To give priority to calls or packets most likely to be completed.
- To represent switching status and its spread.

- To recognize to give priority to calls or data packets that require limited number of links.

In the case of expansive control action, the manager either create a redundant route as a standby to bear the load of any failed route or allows all routes to operate at a very much lower capacity so as to be able to bear the extra load resulting from the failed route. However, in stored program control switching like the ones in Vmobile a temporary alternative routing method can be used. In this method, the controlling software can detect faulty route and re-direct traffic via other routes based on their current carried load capacities.

The restrictive control action is normally used when all network resources are in-use. In this case all new calls are rejected at the originating switching centre and a message is sent to the subscriber may be 'network busy'. This action is referred to as call gapping.

5.4 Limitations

The detail of the data made available by the services operator about the status of the Lagos Area Network is not comprehensive enough for detailed Network Performance Analysis. Information regarding Base Transceivers Station (BTS) status, hand-off, frequency and channel assignments, intra-switching centre traffic, trunk selection traffic, intra-network, which could aid other important performance analysis such as end-to-end blocking probabilities, tele-traffic forecasting, group route dimensioning are completely impossible from the available data.

GSM Services Providers in most cases are reluctant to give any data regarding their network status. It should however be made clear to them by the appropriate bodies on the importance of educational data needed for

proper research works.

5.5 Area of Further work

in order to enhance the work, the following are suggested for further work.

(i) Very important network information not available for this research work (as under limitations) should be obtained. Parameters relating to the individual mobile switching centres in a particular location, those relating to the intra-Mobile Switching Centre and inter-Mobile Switching Centre should be analysed to enhance performance.

(ii) The Mobile Switching Centres located within Victoria Island need to be properly dimensioned and expanded so as to take care of the ever-increasing traffic volume of the area.

(iii) Similar research work could be carried out on the network of MTN, Global com, MTEL and others so as to see and possibly compare the efficiency of these individual service providers.

(iv) A research work on different products/models of Mobile Switching Centres within a particular service provider who uses different types of products is suggested to ascertain the efficiency of one product/model over others.

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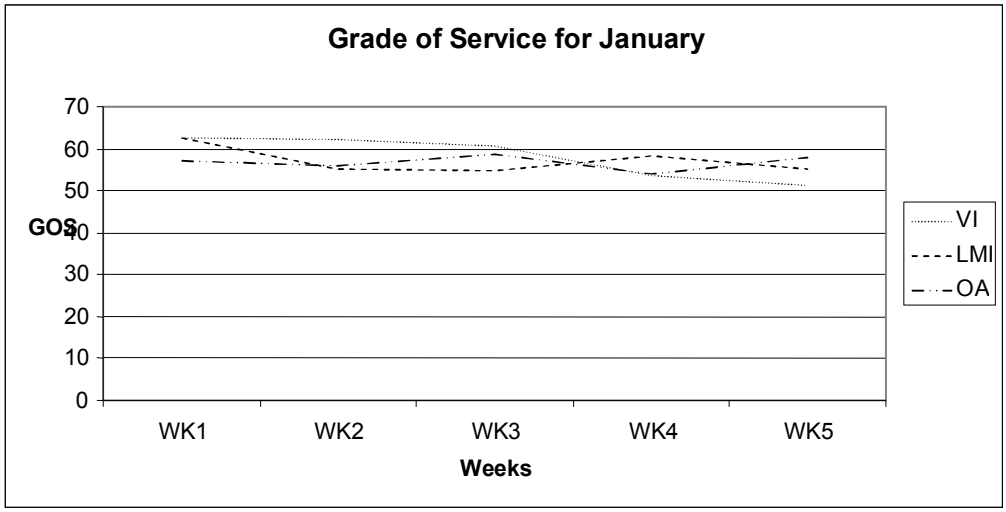
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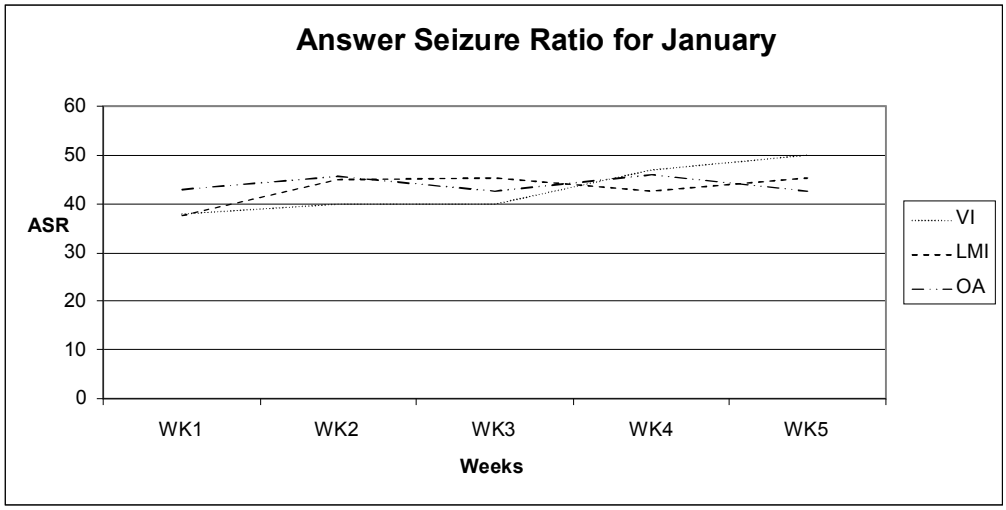
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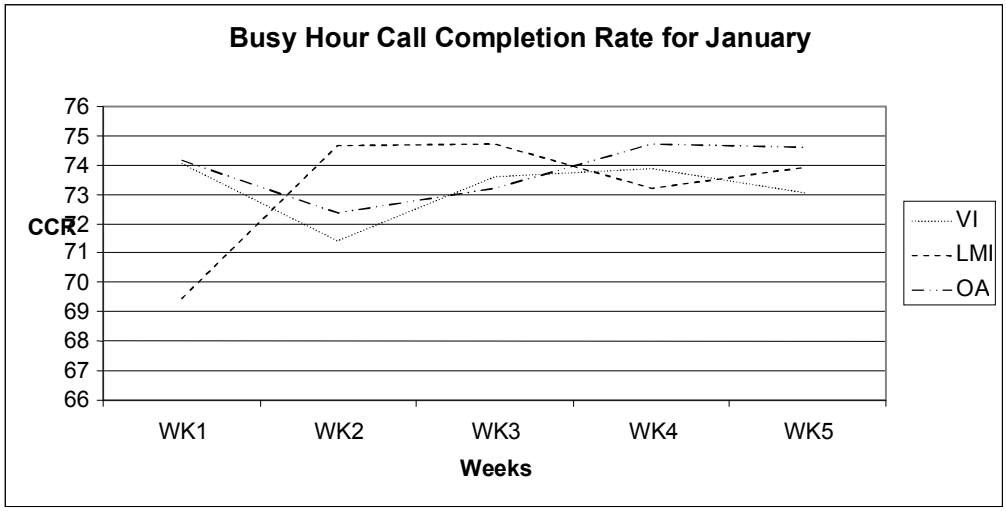
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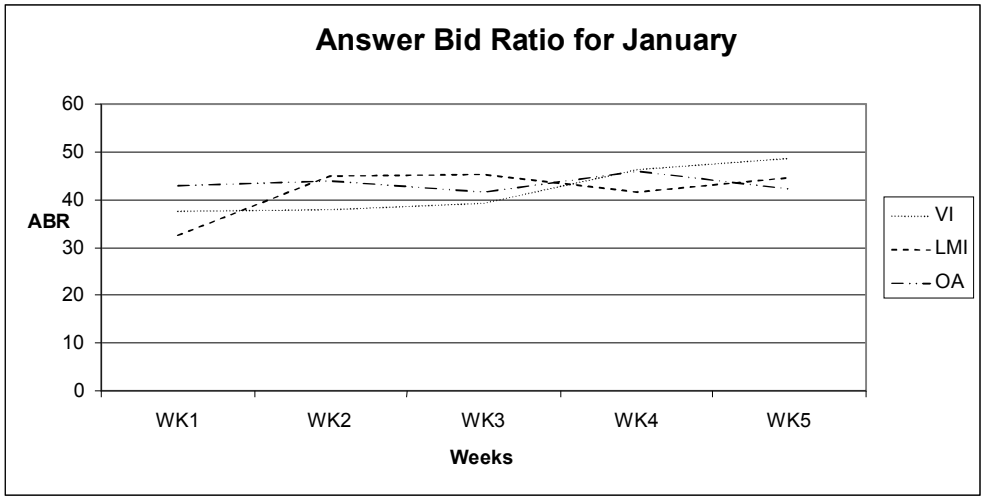
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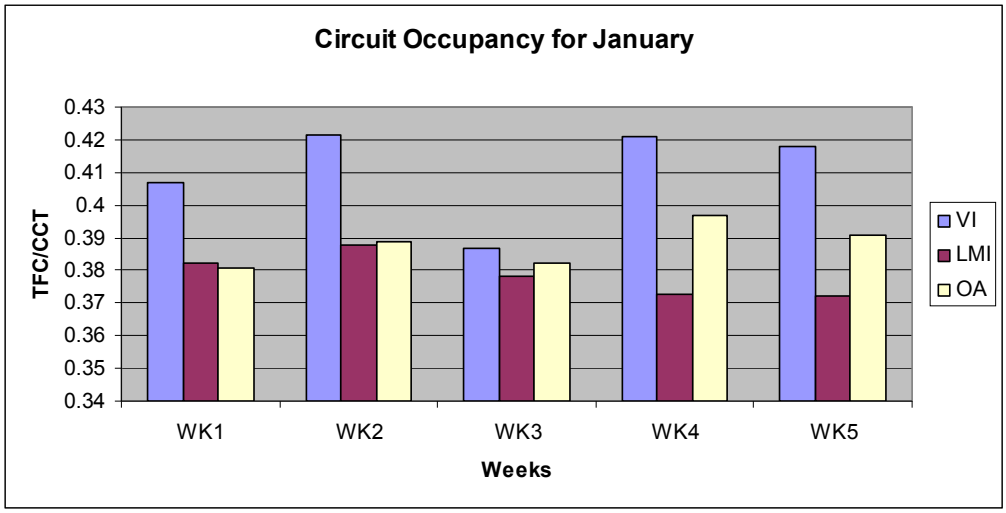
APPENDIX A


Grade of Service for January
70
60
50
40
30
20
10
0
GOS
WK1
WK2
WK3
WK4
WK5
Weeks
VI
LMI
OA


Answer Seizure Ratio for January
60
50
40
30
20
10
0
ASR
WK1
WK2
WK3
WK4
WK5
Weeks
VI
LMI
OA


Busy Hour Call Completion Rate for January
76
75
74
73
72
71
70
69
68
67
66
CCR
WK1
WK2
WK3
WK4
WK5
Weeks
VI
LMI
OA





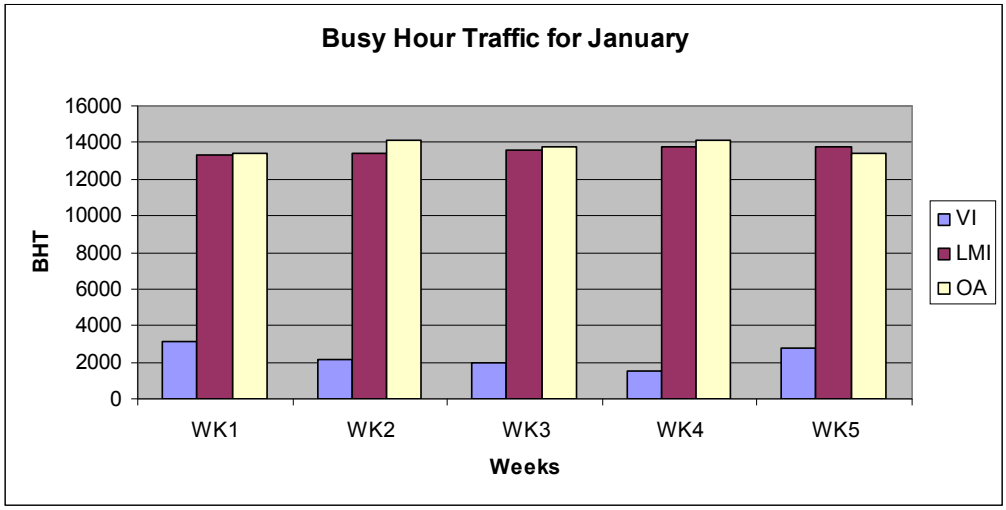
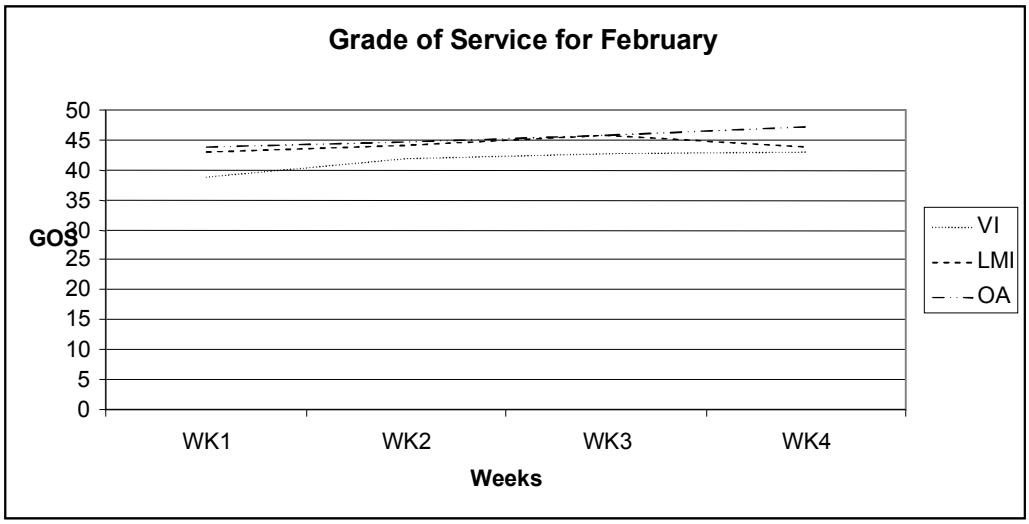
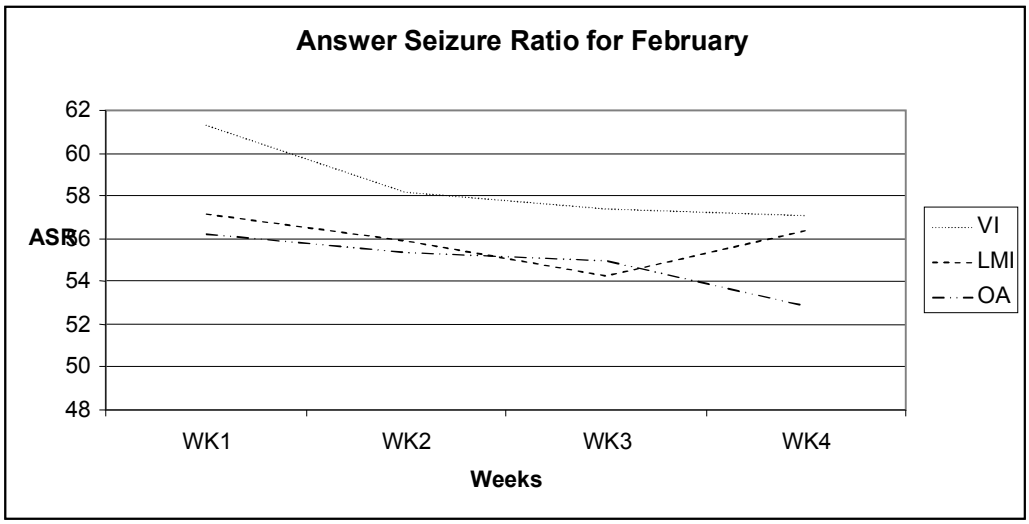
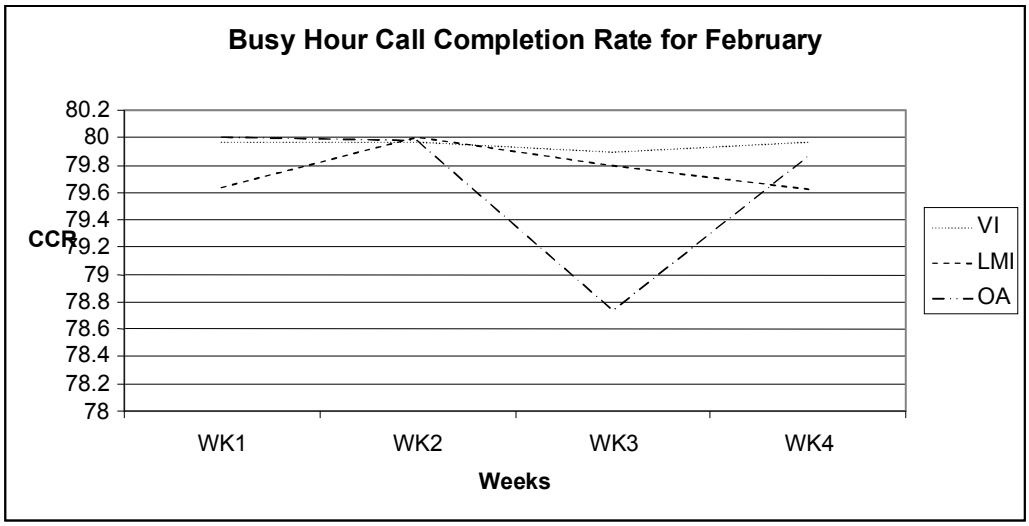
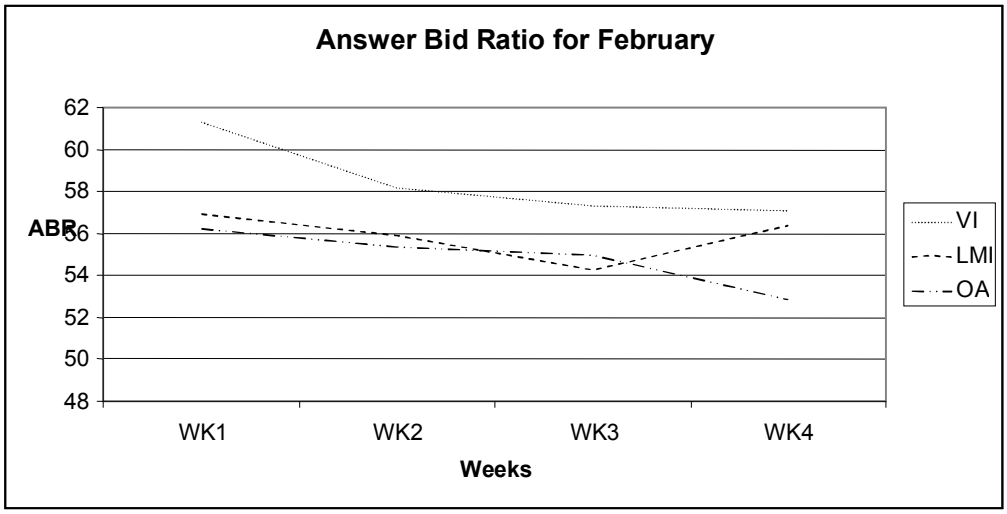


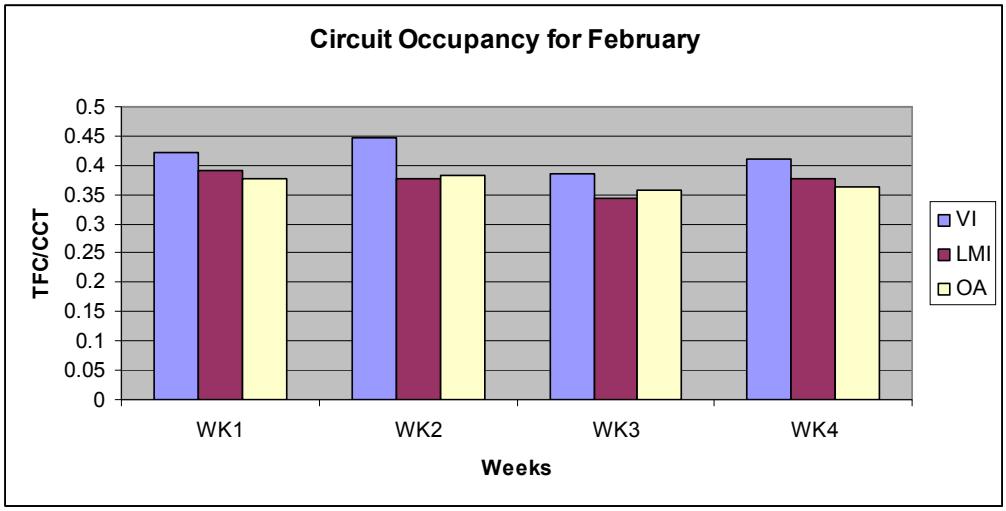
Fig. 4.1 January Parameters


Grade of Service for February
50
45
40
35
30
25
20
15
10
5
0
GOS
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Answer Seizure Ratio for February
62
60
58
56
54
52
50
48
ASR
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Busy Hour Call Completion Rate for February
80.2
80
79.8
79.6
79.4
79.2
79
78.8
78.6
78.4
78.2
78
CCR
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA





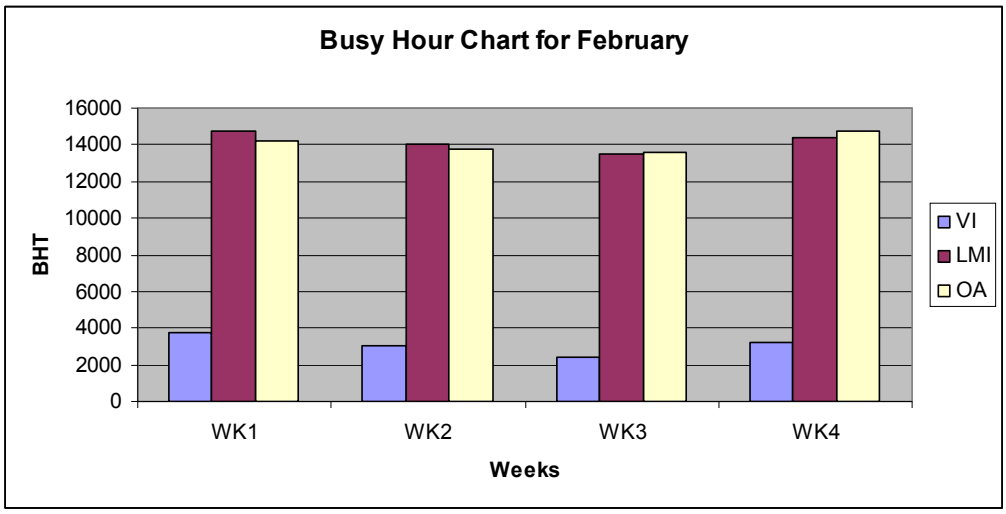
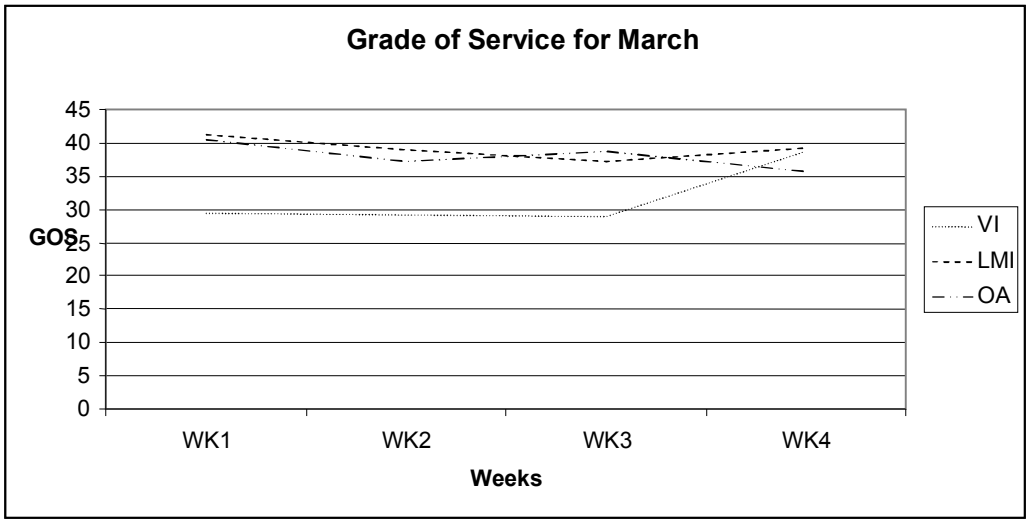
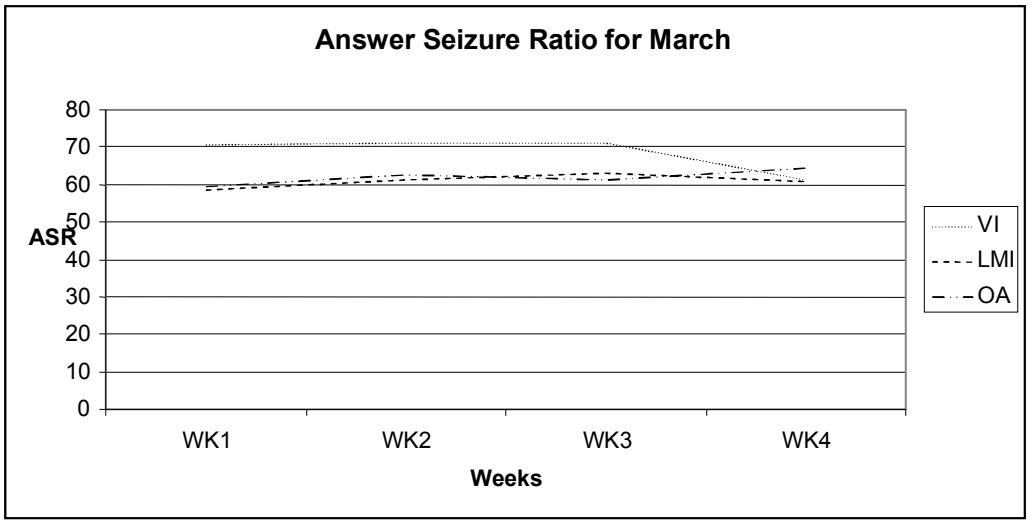
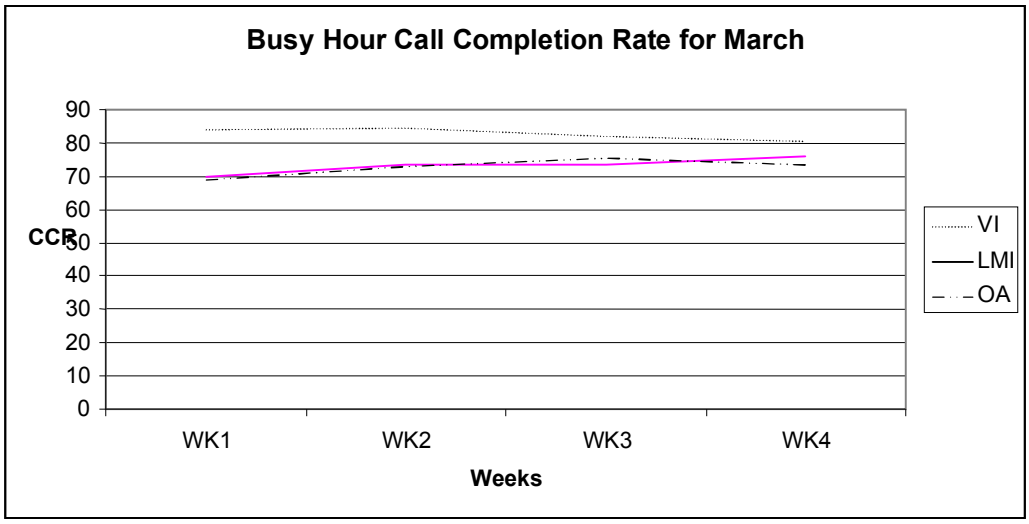


Fig. 4.2 February Parameters


Grade of Service for March
45
40
35
30
25
20
15
10
5
0
GOS
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Answer Seizure Ratio for March
80
70
60
50
40
30
20
10
0
ASR
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Busy Hour Call Completion Rate for March
90
80
70
60
50
40
30
20
10
0
CCR
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA

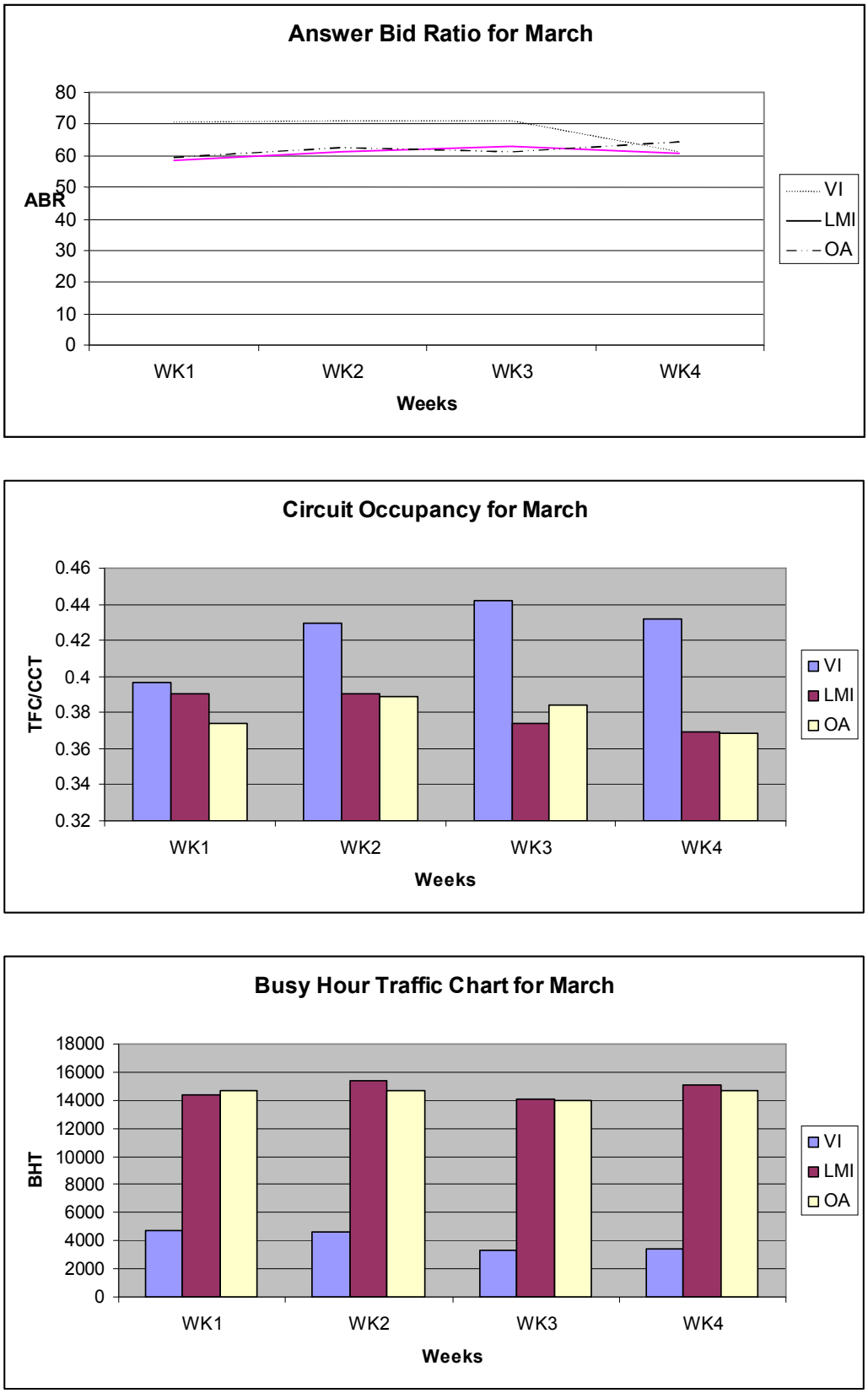
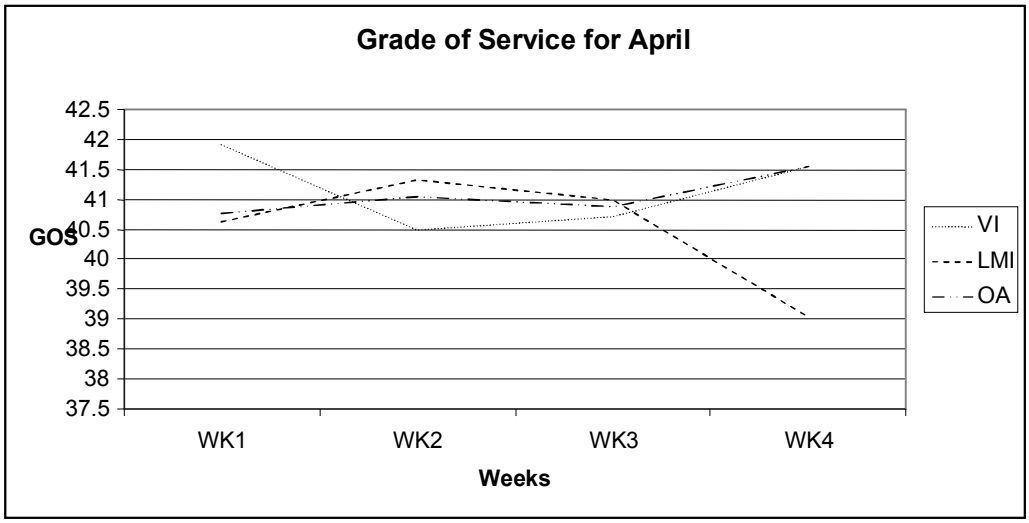
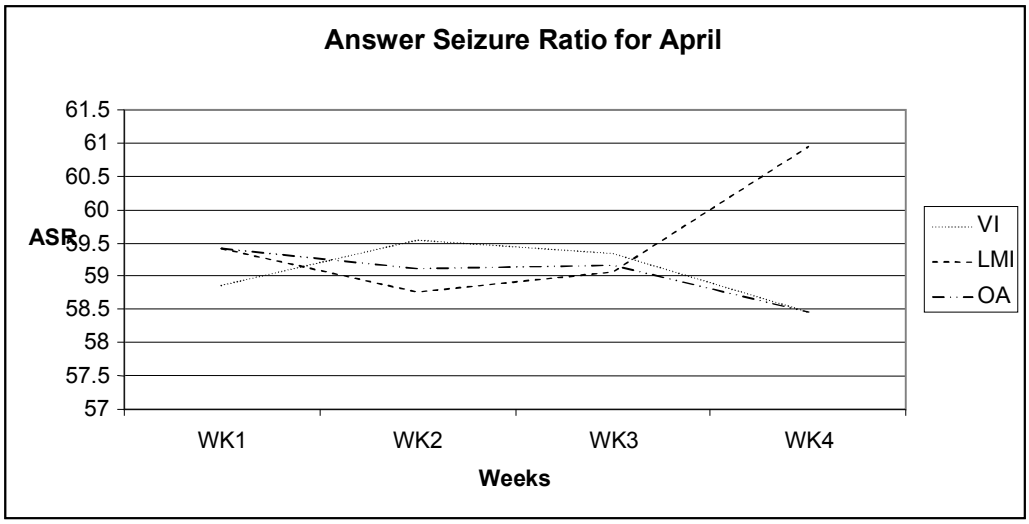
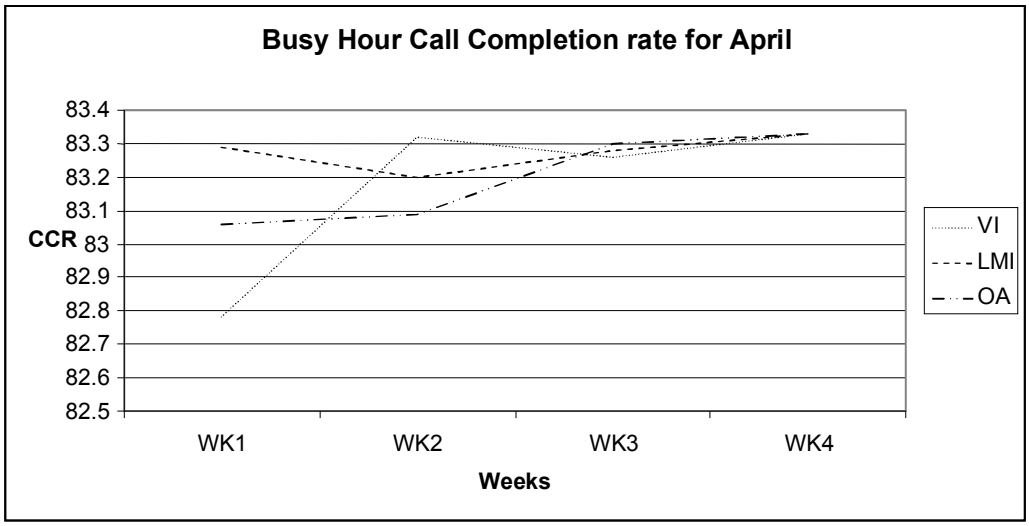
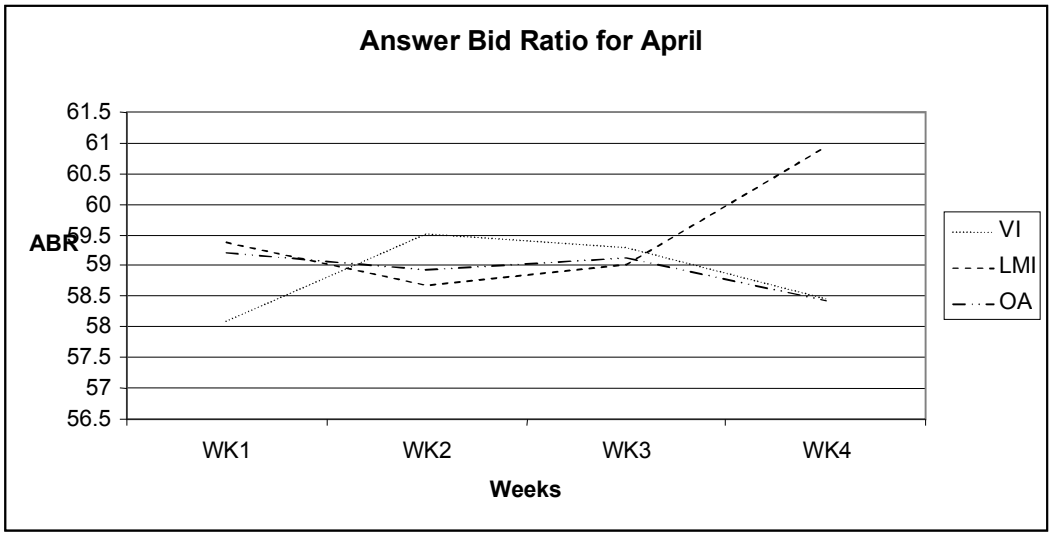


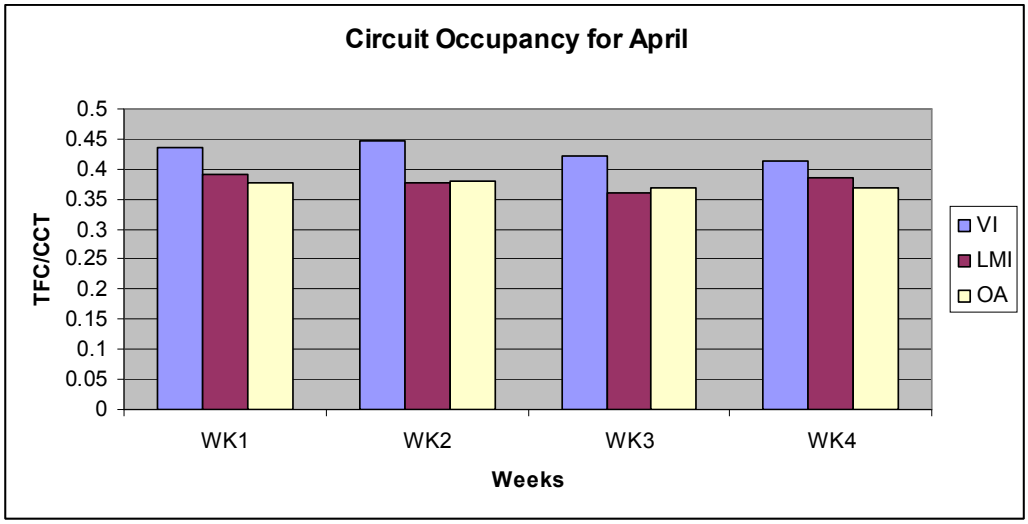
Fig. 4.3 March Parameters


Grade of Service for April
42.5
42
41.5
41
40.5
40
39.5
39
38.5
38
37.5
GOS
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Answer Seizure Ratio for April
61.5
61
60.5
60
59.5
59
58.5
58
57.5
57
ASR
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Busy Hour Call Completion rate for April
83.4
83.3
83.2
83.1
83
82.9
82.8
82.7
82.6
82.5
CCR
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA





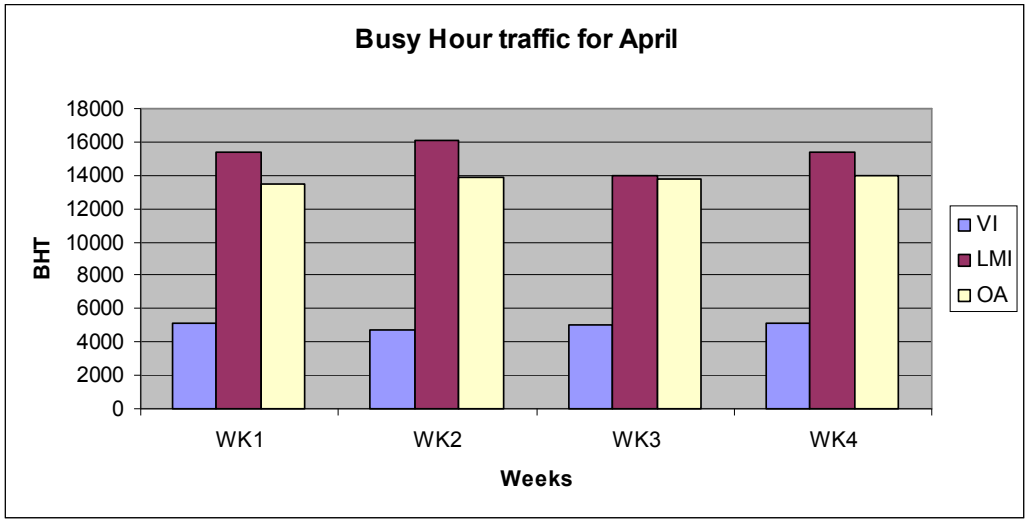
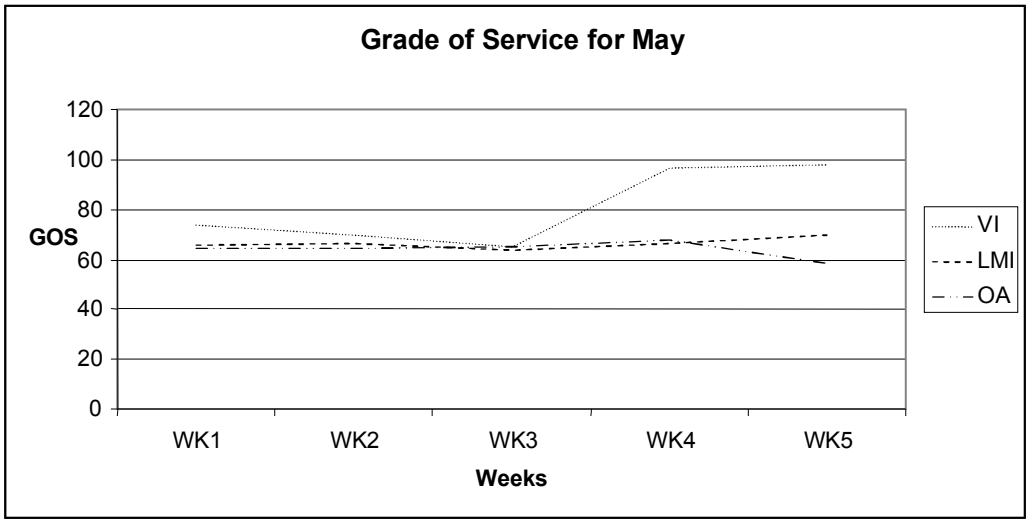
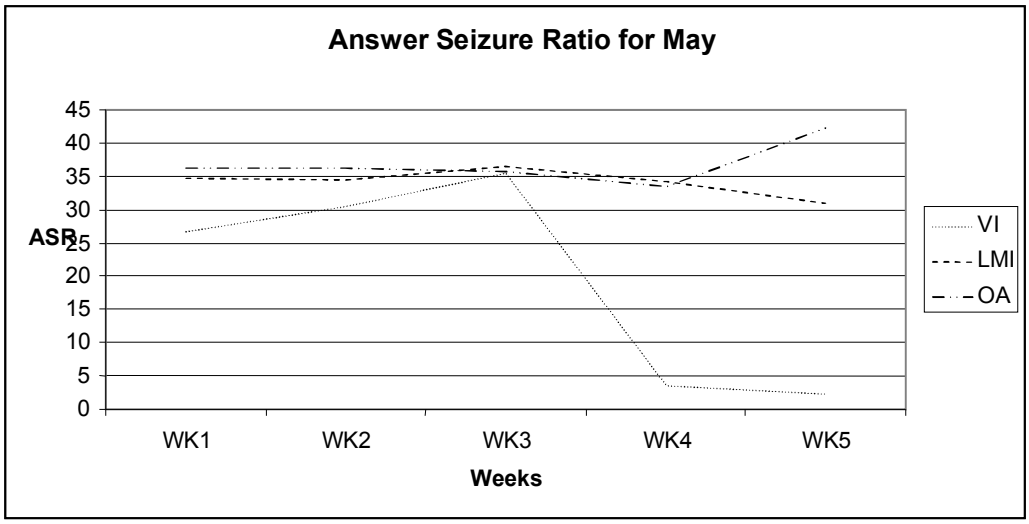
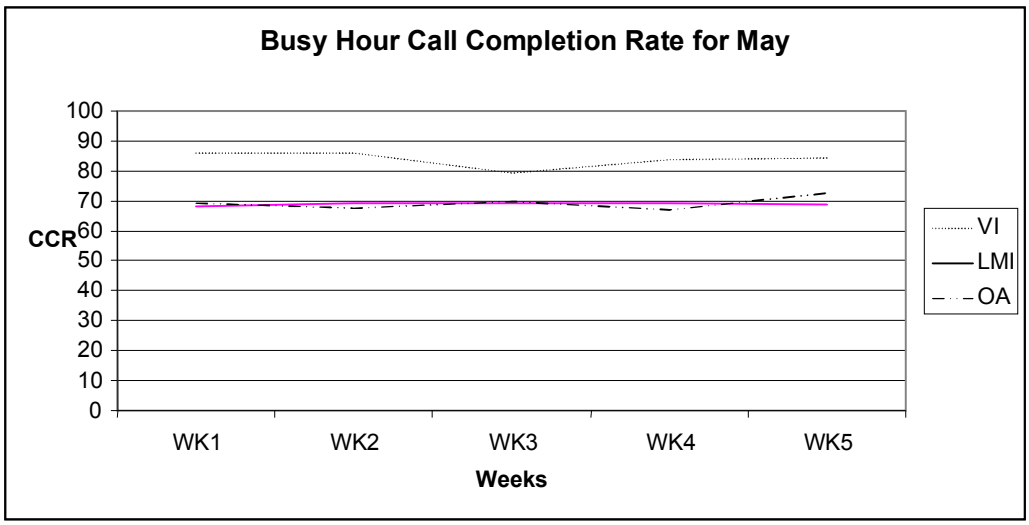
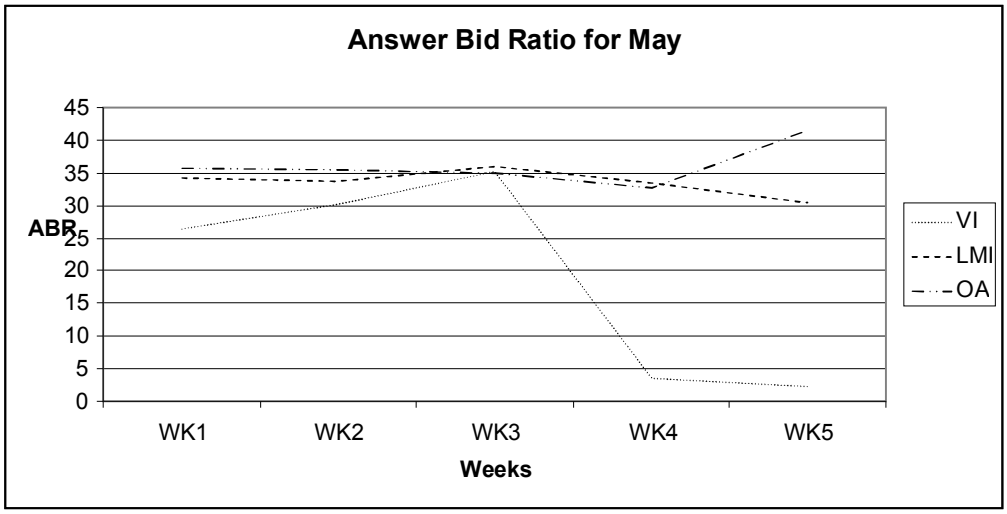


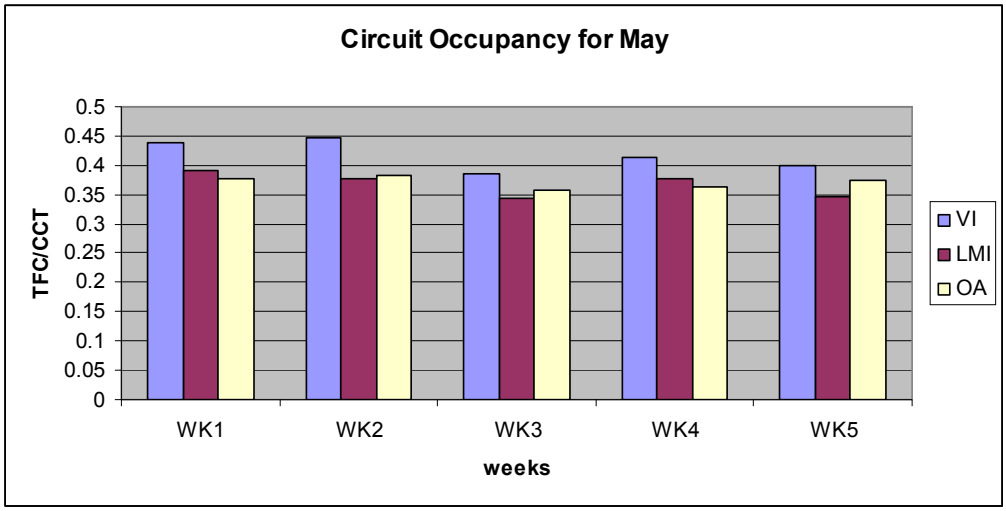
Fig. 4.4 March Parameters


Grade of Service for May
120
100
80
60
40
20
0
GOS
WK1
WK2
WK3
WK4
WK5
Weeks
VI
LMI
OA


Answer Seizure Ratio for May
45
40
35
30
25
20
15
10
5
0
ASR
WK1
WK2
WK3
WK4
WK5
Weeks
VI
LMI
OA


Busy Hour Call Completion Rate for May
100
90
80
70
60
50
40
30
20
10
0
CCR
WK1
WK2
WK3
WK4
WK5
Weeks
VI
LMI
OA





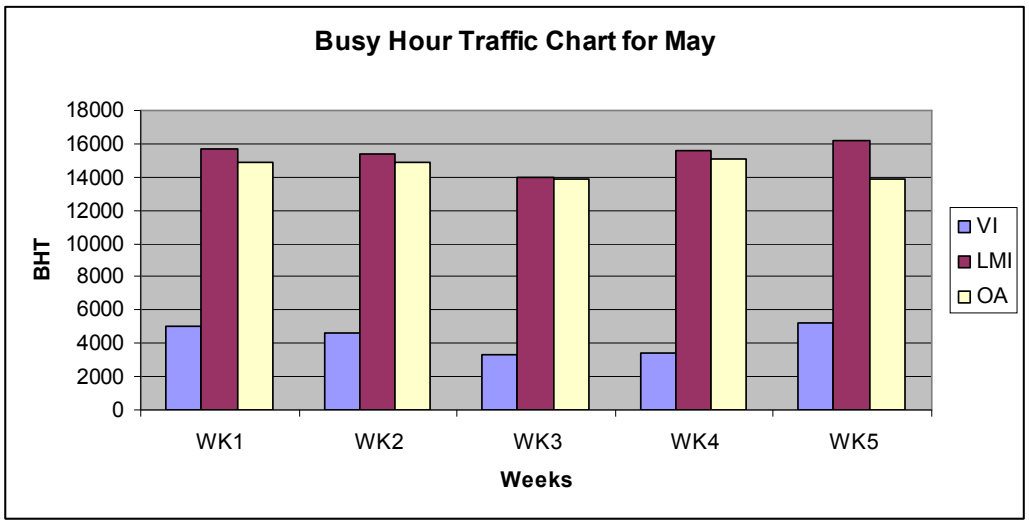
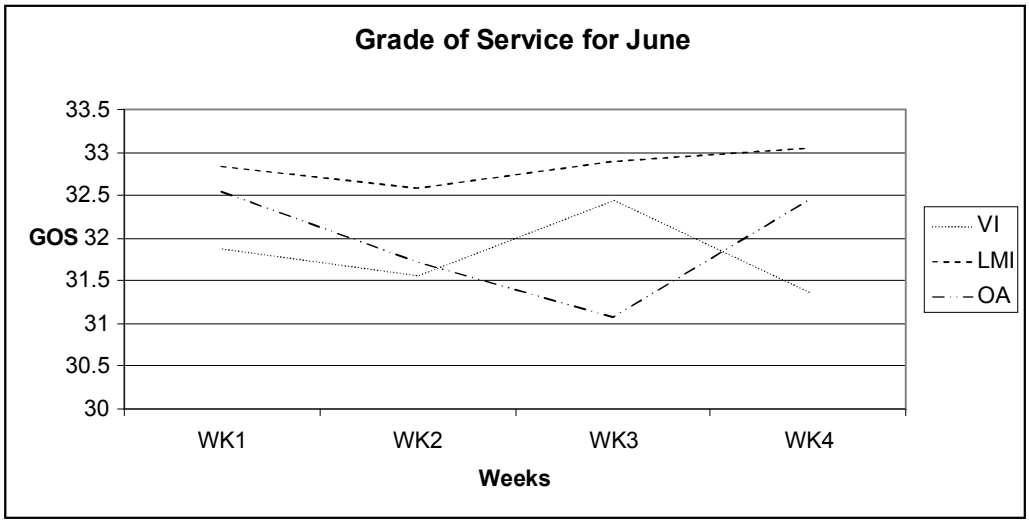
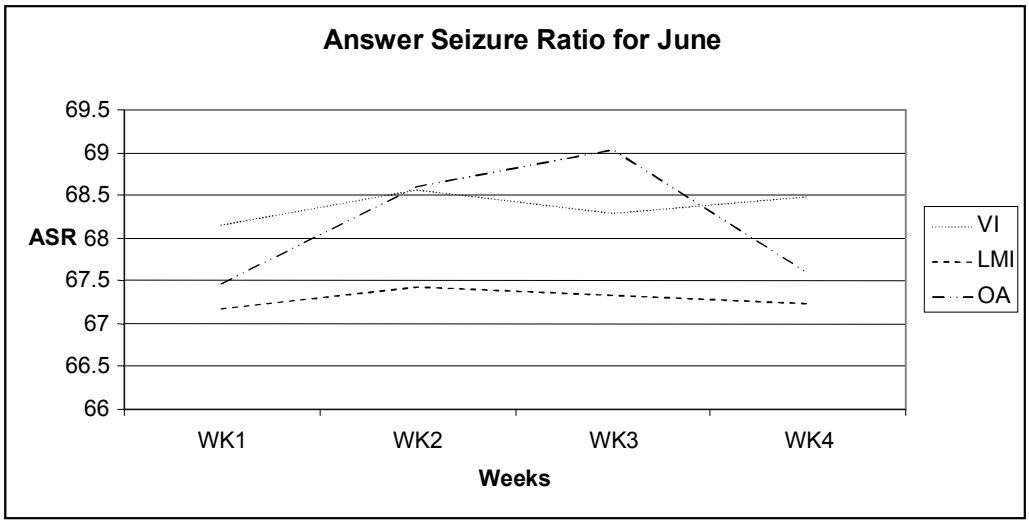
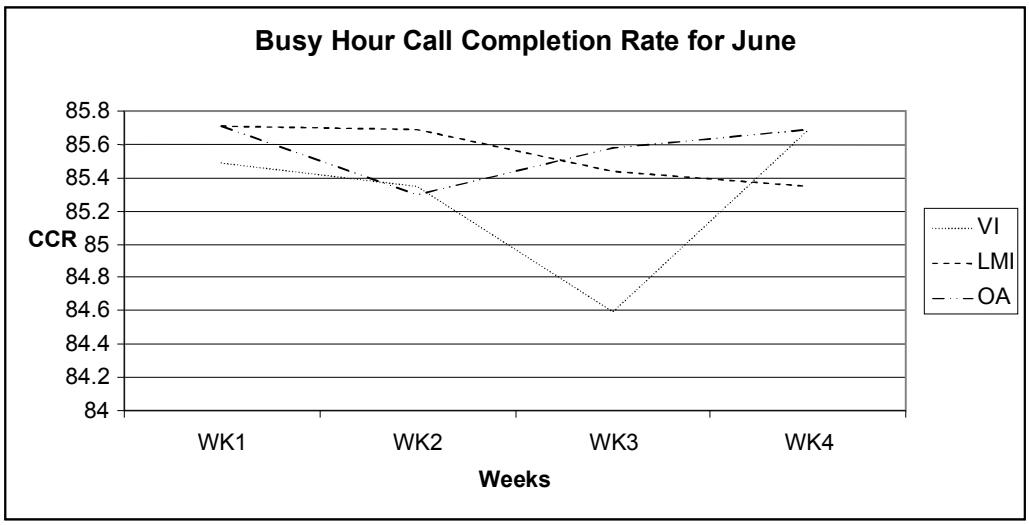
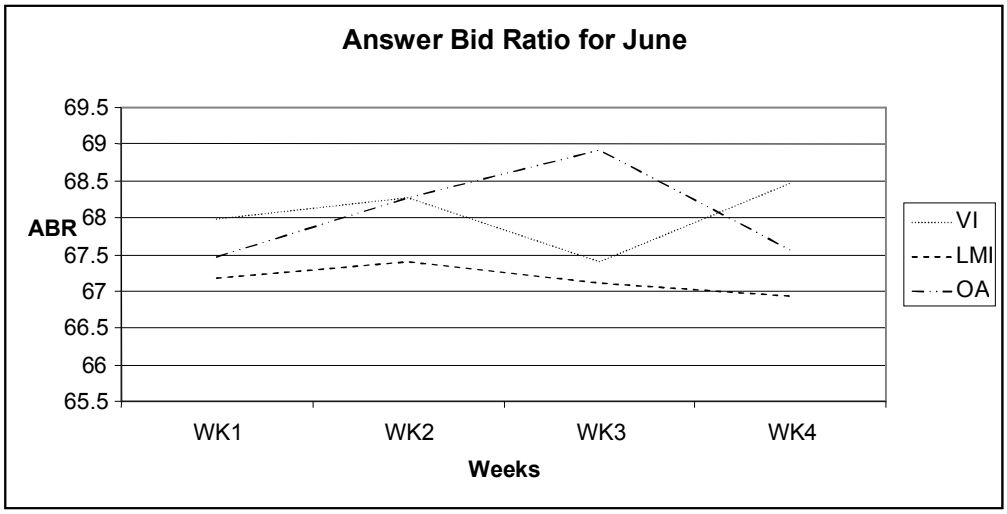


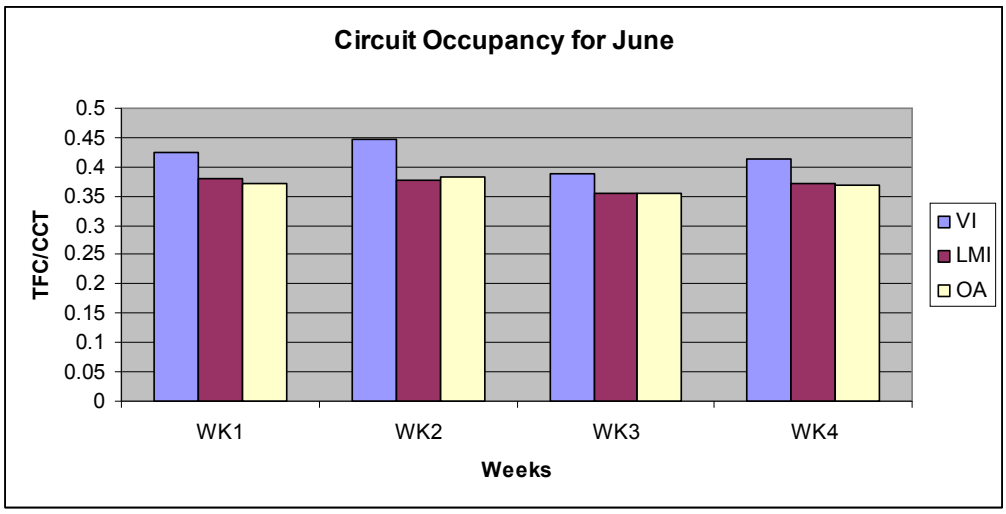
Fig. 4.5 May Parameters


Grade of Service for June
33.5
33
32.5
GOS 32
31.5
31
30.5
30
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Answer Seizure Ratio for June
69.5
69
68.5
ASR 68
67.5
67
66.5
66
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA


Busy Hour Call Completion Rate for June
85.8
85.6
85.4
85.2
CCR 85
84.8
84.6
84.4
84.2
84
WK1
WK2
WK3
WK4
Weeks
VI
LMI
OA





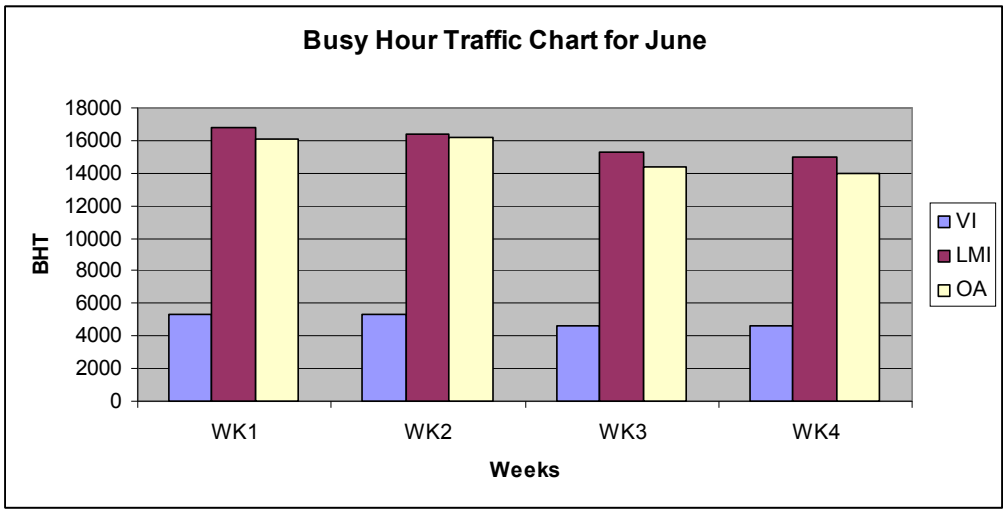


Fig. 4.6 June Parameters

APPENDIX B

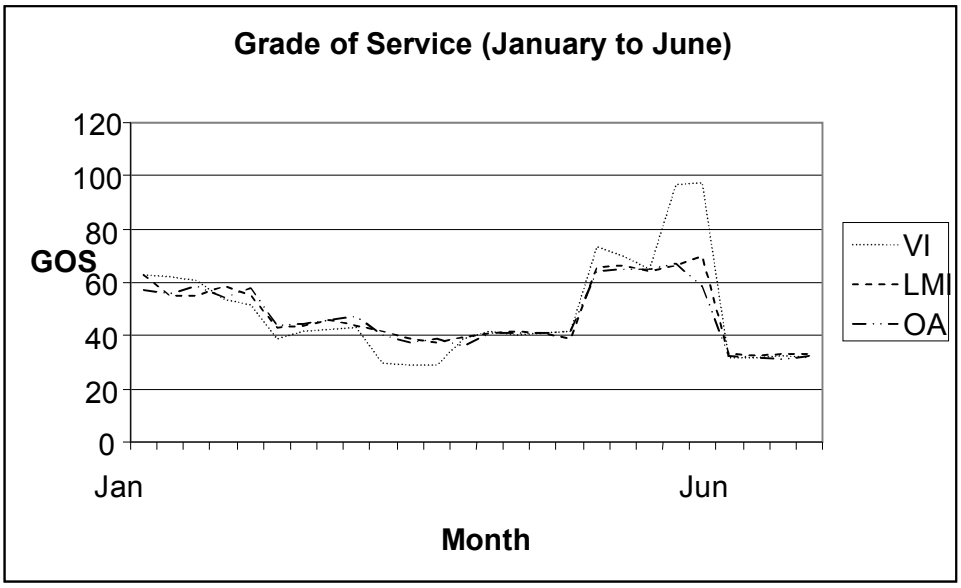


Fig. 4.7 Grade of Service

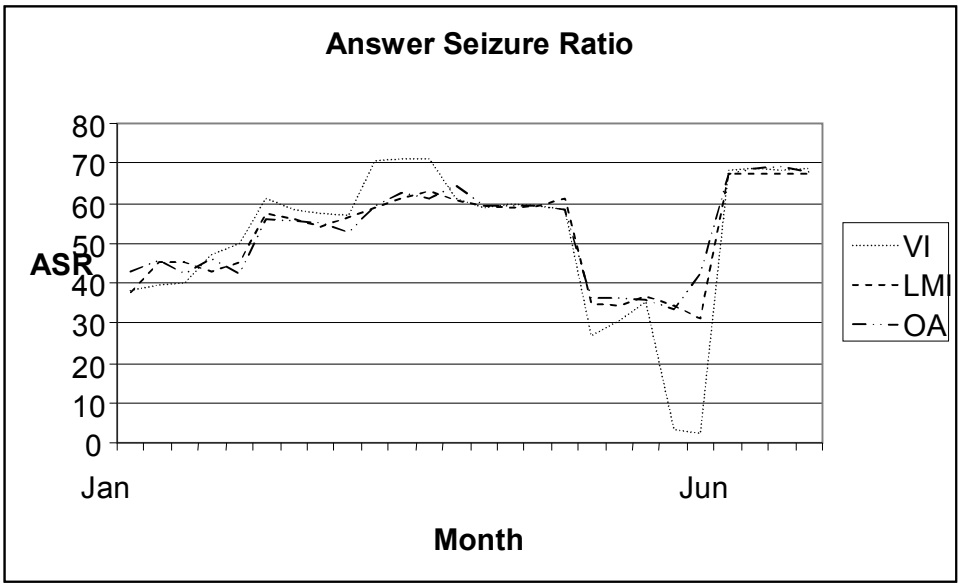


Fig. 4.8 Answer Seizure Ratio

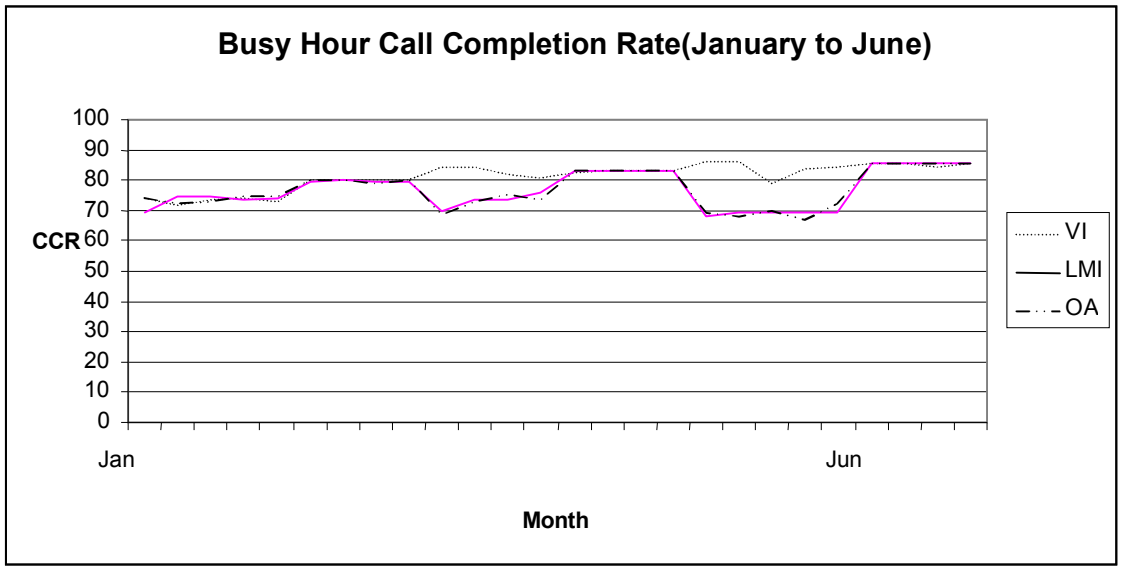


Fig. 4.9 Busy Hour Call Completion Rate

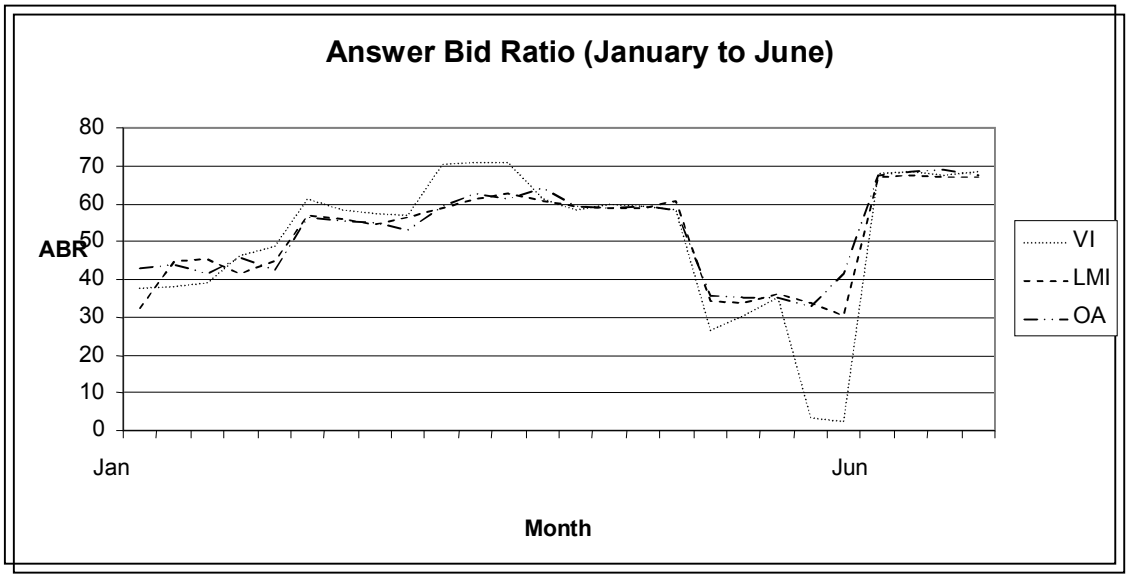


Fig. 4.10 Answer Bid Ratio

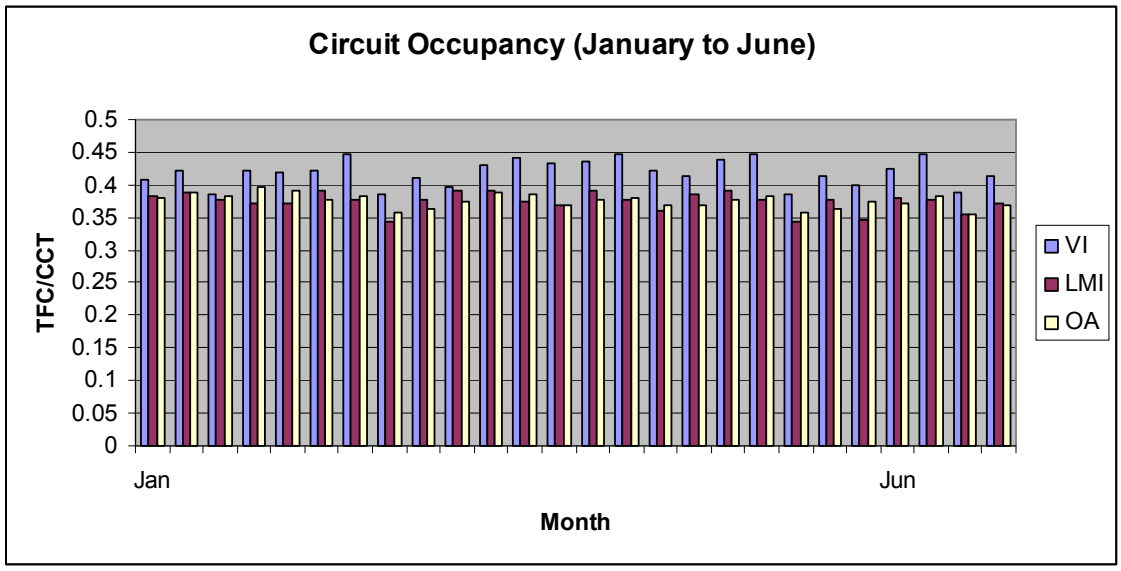


Fig. 4.11 Circuit Occupancy

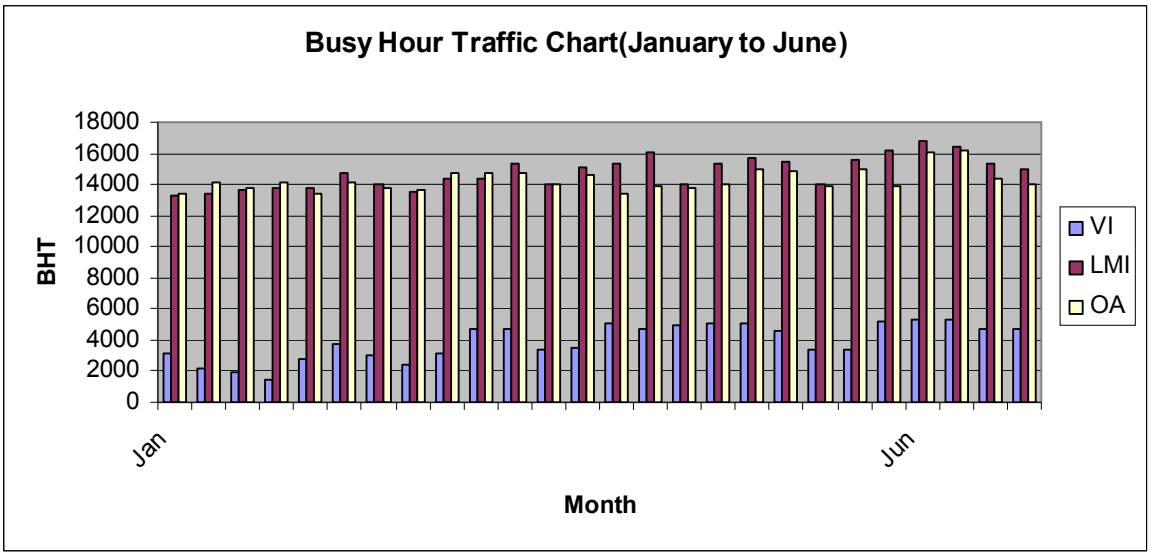


Fig. 4.12 Busy Hour Chart

APPENDIX C

***The standard value for the following parameters as used by Celtel Network is as follows:

PARAMETERS	VALUE	COMMENT
Grade of Service	0.01 – 0.03	Subjective
Answer Seizure Ratio	0.01 – 0.02	
Answer Bid Ratio	0.5	Maximum
Call Completion Ratio	0.01 – 0.02	
Traffic per Circuit	0.5	Minimum