Addis Ababa University

Addis Ababa Institute of Technology

School of Electrical and Computer Engineering

Spatiotemporal Modeling of Short Message Service Traffic Distribution

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Declaration

I declare that the work contained is my own, has not been summited for a degree in any other university or professional qualification, and all sources of materials used for the thesis have been fully acknowledged.

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Abstract

Short Message Service (SMS) is a widely used text messaging service on mobile devices. Business owners and companies look forward to new ways of promoting their services and products to reach and attract the intended users. However, SMS distribution is not investigated in Ethio Telecom with time and location. The current way of selecting customers to send bulk SMS is very costly and resource wastage.

The concern of the thesis is to understand the SMS distribution and develop a spatiotemporal model of SMS traffic using city of Addis Ababa, Ethiopia as a case study. The dataset is extracted from SMS traffic of Ethio Telecom network system. The model selection is performed in time and space domain using Fourier Transform methods. By applying Fourier Transform, five major frequency components are identified with different magnitude of coefficients and phases. Then, the coefficient and phase values are transformed from spatial to spectral-domain by applying Two Dimensional Discrete Cosine Transform. The tools used are Matlab for traffic modeling, MapInfo to map geographical location and SPSS for analysis.

Validation of the SMS traffic distribution model is done based on the R^2 coefficient of determination statistically. The accuracy of the proposed temporal model is evaluated with real SMS traffic data. The results show that these models can accurately describe the variation pattern of real SMS traffic. In the spatial model, the effect of the level of truncation on the frequency of transformed phase and coefficient on the model performance is evaluated. Finally, a mathematical model that captures the SMS traffic variation of any location in the city at any time of the day is developed. Furthermore, correlation analysis is done between outgoing and incoming SMS traffic. The general SMS usage trend of customers that respond to SMS advertisements was analyzed.

The distribution model helps the Company to know the SMS traffic distribution, which in a way helps to understand the behaviours of its customers thereby saving cost and reducing resource wastage, and plan its marketing strategy accordingly.

Key terms: *SMS Traffic, bulk SMS, Spatiotemporal Modeling, SMS Traffic Distribution.*

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List of Acronyms

2D-DCT	Two-Dimensional Discrete Cosine Transform
A2A	Application-to-Application
A2P	Application-to-Person
API	Application Interface
BS	Base Station
BSS	Base Station Subsystem
BSC	Base Station Controller
BTS	Base Transceiver Station
BST	Base Station Transceiver
CDR	Call Detail Records
CP	Content Provider
CP/SP	Content Provider and Service Provider
CRM	Customer Relation Management
CTFT	Continuous-Time Fourier Transform
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DIT	Decimation- In-Time
DTFT	Discrete-Time Fourier Transform
E2P	Email-to-Person
EDR	Event Detail Records
EIR	Equipment Identity Register
ESME	External Short Message Entity
FFT	Fast Fourier Transform
GSM	Global System for Mobile communications
HLR	Home Location Register

ITP	Internet Transfer Points
JPEG	Joint Photographic Expert Group
SMSC	Short Message Service Center and gateway
SMC	Short Message Center
SS7	Signaling System 7
SMEs	Short Message Entities
MML	Man-machine language
MMS	Multimedia Messaging Service
MMSC	Multimedia Messaging Service Center
MS	Mobile Station
MSC	Mobile Switching Center
MO	Mobile Originated
MS	Mobile Station
MT	Mobile Terminated
NMS	Network Management System
P2A	Person to Application
P2E	Person-to-Email
PHP	Hypertext Preprocessor Programming
R^2	R Squared Coefficient of Determination
SDP	Service Delivery Platform
SP	Service Provider
SPPP	Spatial Poison Point Process
SM	Short Message
SME	Short Message Entity
SMPP	Short Message Peer-to-Peer Protocol
SMS	Short Message Service

SMTP	Short Mail Transfer Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
VLR	Visitor Location Register
VAS	Value Added Service

Chapter I: Introduction

1.1 Overview

SMS is a messaging platform that is used to exchange text messages between mobile users. This platform will also be used as a gateway for other applications to integrate and push their service text messages to mobile subscribers. The uses of SMS messaging are continually evolving as a new business. The messaging service provides a cost-effective solution for managing communications with small or large contact groups. It used for information sharing, advertise, and promote products to targeted customers.

One of the SMS services is bulk SMS. This messaging service is a legacy description for application-to-person (A2P) SMS messaging services. It refers specifically to sending a message to a predetermined group of mobile phones in a short period of time [1].

SMS marketing is one of the most popular forms of mobile marketing. Marketers intend to utilize SMS advertising because it provides several advantages such as perceived ease of use, cost-effectiveness, ubiquity, immediacy, and niche targeted [2]. The fast reading of delivered message by customers encourages telecom service providers and other business groups to use the service for advertising their products than any other means. The major advantage of using SMS is its accessibility anywhere and anytime.

According to research reported in [3], there are nearly eight billion mobile devices worldwide. The majority of the devices support SMS service. Nearly 98% of SMS is successfully delivered within a minute and read within the first 10 minutes. These facts speak about how important SMS really is for advertisement purpose. The global headline report indicated that the A2P SMS revenue figure is conservatively estimated to be $45 billion and set to grow to over $60 billion by 2025 in the world [4]. This is a big number in terms of revenue.

Nowadays highly competitive markets, business owners and companies look forward to new ways of promoting their services and products to reach and attract the intended users. However, even today SMS service on mobile is pretty much the most frequently used features after calling or even more than calling [5].

In Ethiopian context, SMS promotion is one of the effective, easy and cheaper promotion means in Ethio Telecom as there are more than 42 million mobile subscribers. A study conducted by Ethio Telecom about an SMS product in June 2017 identifies benefits of customers from SMS products. Some of these benefits include empowering with information, entertainment, commerce, bank transactions, extended utility and social services [7]. Ethio Telecom encourages the Value Added Services (VAS) ecosystem to flourish by supporting Content Provider (CP) or Service Provider (SP) to engage and invest so as to benefit from the increase in revenue achieved by revenue-sharing activities. The marketing mix strategy allows CP/SP to send bulk SMS to customers. In a 2018 report, each month more than 100 million SMS non-premium shortcode and around 1 million premium SMS traffic is generated. SMS service is one of the revenue-generating business VAS platforms and one of the major advertising and promoting which is widely used in Ethio Telecom.

Therefore, Ethio Telecom conducts research to know the SMS traffic distribution with location and time. This helps to understand the behaviours of its customers and eventually formulate an effective way of using bulk SMS for advertising purposes.

1.2 Statement of the Problem

Ethio Telecom gains revenue from bulk SMS. The price of bulk SMS is cheaper compared to the normal SMS price. Therefore, the third party CP/SP mostly utilize the system for advertisement purpose. In addition to that, the company gives the service to governmental institutions for the purpose of official announcements, holiday greeting, and other advertisement issues.

The nature of the bulk SMS service has yet to be fully understood; some of the customers do not respond the SMS advertising. Studies need to be performed to gain insight on how to utilize it in the best possible manner. One of the investigations is to understand the distribution of SMS traffic (both incoming and outgoing) in time and space domains, possibly at the base stations site level. Knowledge of this distribution will help to target customer’s thereby saving cost and reducing resource wastage.

In Ethio Telecom SMS distribution is not investigated with time and location. Moreover, the Company selects customers randomly to send bulk SMS. The current way of randomly selecting customers is very costly and resource wastage. Lack of information on what time customers use SMS more frequently means that SMS advertisements are likely to be sent to customers at the wrong time. Thus, SMS advertisements may get far less response than expected. The other area of concern in improving the effectiveness of SMS advertisements is the location that SMS advertisement campaigns choose to send their advertisements. In general, further investigation on where and when SMS service traffic is high helps both Ethio Telecom and third party CP/SP to gain an insight on how to improve SMS advertising.

The concern of this research is to develop a spatiotemporal model by using SMS traffic distribution of Addis Ababa, Ethiopia. The model helps the company to know the SMS traffic distribution, which in a way helps to understand the behaviours of its customers and plan its marketing strategy accordingly. In addition to that, shows correlation analysis between outgoing and incoming SMS, to investigate the magnitude of incoming SMS also results in the increment of outgoing SMS and vice versa. Analyze, the general SMS usage trend of customers that respond to SMS advertisements.

1.3 Objective

1.3.1 General Objective

With the intention of understanding SMS customers' behaviour, the main objective of this research is to model, both in space and time, SMS traffic distribution in the city of Addis Ababa.

1.3.2 Specific Objectives

The specific objectives of the research are:

- Review literature about spatial and temporal traffic modeling approaches and SMS technology;
- To collect SMS traffic data;
- Develop a mathematical model using Fourier Transform, that capture SMS traffic distribution in space and time;
- Validate the SMS traffic distribution model;
- Discussion and analysis of incoming and outgoing SMS correlation;

1.4 Literature Review

In cellular networks, understanding the distribution dynamics of traffic and the base station level in time and geographical location, literature have used different approaches. In [6] author studied SMS traffic distribution based on a statistical Gaussian process by two day's data. The main objective of the study is to analyze the message length distribution, message arrival distribution, delay distribution based on the timestamps from SMS Call Detail Record (CDR). The distribution analysis results mention that more than half percent of the messages are exchanged within the same Mobile Switching Center (MSC). Due to traffic conjunction and more traffic is contributed by application-to-person service as a result of this have spurious destinations. Because of that, there is a waste of processing and computing resources. The author recommended that an extra Home Location Register (HLR) lookup before sending the message may do trick and minimizes the spurious A2P traffic. In addition to that, to minimize the conjunction at SMSC center the service provider can use SMSC proxy to reduce the traffic load. The researcher's study based on a few MSC, and for a specific time interval. The paper does not consider geographical location distribution.

The paper presented in [7], has an objective to know message-level characteristics such as the distribution of the message among users, the distribution of message size, and the distribution of messages at different locations. The research uses a different statistical distribution like cumulative distribution, probability distribution, Weibull and Lognormal towards understanding SMS traffic. But the study did not consider a deterministic way of distribution.

To the best of our knowledge, similar studies have not been presented in the research community before in both in space and time SMS traffic distribution. The spatiotemporal traffic distribution model based on the Fourier transform method captures real traffic and visualize the traffic with space and time.

This section intends to review key papers that are done in the area of traffic distribution of the data service based on the Fourier Transform. The paper in [8], [9] and [10], the traffic modeling is performed in space and time dimension where the data traffic variation pattern at the base station level in a real cellular network is modelled.

The paper presented in [8], build a temporal and spatial model to describe the mobile data traffic variation pattern for multiple base stations in real cellular networks. The researcher firstly proposed a sinusoid superposition model for describing the temporal traffic variation of multiple base stations based on real data in a cellular network. Based on the frequency domain, three main frequency components are identified to know related user behaviour. For the spatial-temporal model, the lognormal distribution of real traffic data was used to compute the probability density function (pdf) of the traffic volume. The spatial-temporal traffic distributions analyzed by computing the parameter mean value and standard deviation of a lognormal variable associated with normal distribution in different regions. However, the author uses a lognormal model for spatial that can not visualize the traffic.

In [9], the data traffic of real data from a mobile operator in the large city of China has been analyzed to obtain a spatial distribution model. The major contributions of the research are that it used a truncated Two-dimensional Discrete Cosine Transformation (DCT) traffic spatial distribution model that is proposed based on real cellular network data. The spatial model contains the information of exact locations and sector information of the network. However, the study did not incorporate the temporal model.

According to [10] spatial-temporal model was studied and developed to show the geographical and time variation of the data traffic of the Universal Mobile

Telecommunications System (UMTS) network. The study is modeling traffic variation in different locations and time. It is applicable for energy efficient network planning, understanding customer's data traffic usage behaviour and dynamic resource allocation based on the Fourier Transform method.

In [11] statistical model is used for the service of voice traffic and data traffic with longitude and latitude information. The paper presented spatial modeling that is used for the performance evaluation of network planning and resource management. The study used Lognormal, Lognormal mixture, Weibull and Gamma distribution for the comparison of the statistical model. The statistical distribution models were tested for the fitness of the traffic distribution and lognormal mixture was found to be the best fit than from all the other distribution models.

Additionally, different modeling methods are proposed for the spatial traffic distribution in cellular networks that can be used for energy-efficient network planning and resource management, such as log-normal distribution [12], SPPP [13] and [14], Weibull and Log-normal mixture [15].

To summarize, there are several existing traffic distribution models, approaches that reflect spatial traffic distributions are introduced. Such as Spatial Poison Point Process (SPPP) distribution model reflects the randomness of the distribution, Lognormal distribution model, an Exponential distribution model for analyzing traffic density, and 2-dimensional Gaussian distribution model for approximation of user distribution in cellular networks. The second category of models in the deterministic approach as the once based on Fourier transform. A 2D-DCT model is proposed to characterize the spatial traffic pattern more precisely to show the real traffic.

1.5 Methodology

The research methodology initially reviewed related literature about spatial-temporal traffic distribution modeling. Then, analysis of a dataset of Addis Ababa's SMS traffic, which is extracted from Ethio Telecom network performance system, called Smartcare, is conducted.

The model selection is performed in time and space domain using Fourier Transform methods. The Fourier Transform method transforms data from time or spatial domain into frequency domain. It used in a wide range of applications, such as image analysis, image filtering, image reconstruction and image compression. The method also has relevance to problem, modeling and simulation of visual functions.

In time domain, Fast Fourier Transform (FFT) is used to convert the time domain to the spectral domain. Based on the spectral domain, the temporal model is applied by Fourier Transform. Additionally, Two Dimensional Discrete Cosine Transform (2D-DCT) and the inverse of the spatial domain are used. Finally, a mathematical model that captures the SMS traffic of Addis Ababa city is developed.

The tools used are; Matlab for the traffic modeling in space and time, Excel for preprocessing, MapInfo to capture the geographical location of the base station by longitude and latitude and SPSS for correlation analysis. R^2 coefficient of determination is used for the model evaluation methods statistically.

1.6 Scope and Limitation

1.6.1 Scope of the Thesis

The scope of the research is developing models for SMS traffic distribution with time and location in Addis Ababa by using the Fourier Transform technique. The modeling is performed on SMS outgoing traffic and SMS incoming traffic separately.

1.6.2 Limitation of the Thesis

This research is limited to modeling SMS traffic distribution with space and time at a base station site level to capture real traffic. Spatiotemporal traffic variation at individual customer level and preferred advertisement type are not incorporated in this thesis.

1.6.3 Contribution

This research deals about studying SMS traffic distribution in a deterministic approach. The main contribution of this research is modeling SMS outgoing traffic and SMS incoming traffic to capture real traffic with space and time in Addis Ababa for UMTS and GSM networks at service level. Based on the knowledge of this traffic distribution advertisements can be sent at site level with location and time in an effective manner. The spatiotemporal model helps in improving the effectiveness of SMS advertisements. In addition to that, this SMS traffic model helps Ethio Telecom to understand the behaviours of its customers and plan its marketing strategy accordingly.

1.6.4 Thesis Layout

The research paper is organized as follows. Chapter II presents SMS network architecture, protocol, interface, and services. In addition to that, the Chapter discusses the bulk SMS system. In Chapter III, the basics of Fourier Analysis and Fourier Transform methods are presented. In Chapter IV, traffic distribution modeling approaches are presented. The SMS traffic distribution model, based on SMS data collected from the mobile network in the city of Addis Ababa, Ethiopia, is presented. Chapter V, includes results, discussion, analysis of incoming and outgoing SMS correlation and customer responding to the advertisement. Finally, conclusions and recommendations are included in Chapter VI.

Chapter II: SMS and Bulk SMS system

This chapter has two main sections. The first section deals with the SMS system that includes an overview of network architecture, protocol, and service. The second section describes the bulk SMS service.

2.1 Overview of the SMS System

SMS has started since 1980 by GSM communication. Short messages have features like timely delivery, interoperability, and ubiquity which enable the service to keep its popularity till today [16]. SMS service uses standardized communication protocols to enable mobile devices to exchange short text messages.

2.1.1 SMS Network Architecture

The SMS network architecture of GSM is shown in Figure 2-1. The figures indicate that Short messages sent from a mobile device flow through the originating mobile network operator MSC. Then, the SMSC receives the short message from the MSC and forwards it to the appropriate mobile device. The Signal Transfer Point (STP) helps the SMSC to communicate with the Home Location Register (HLR) and MSC of the terminating mobile network operator.

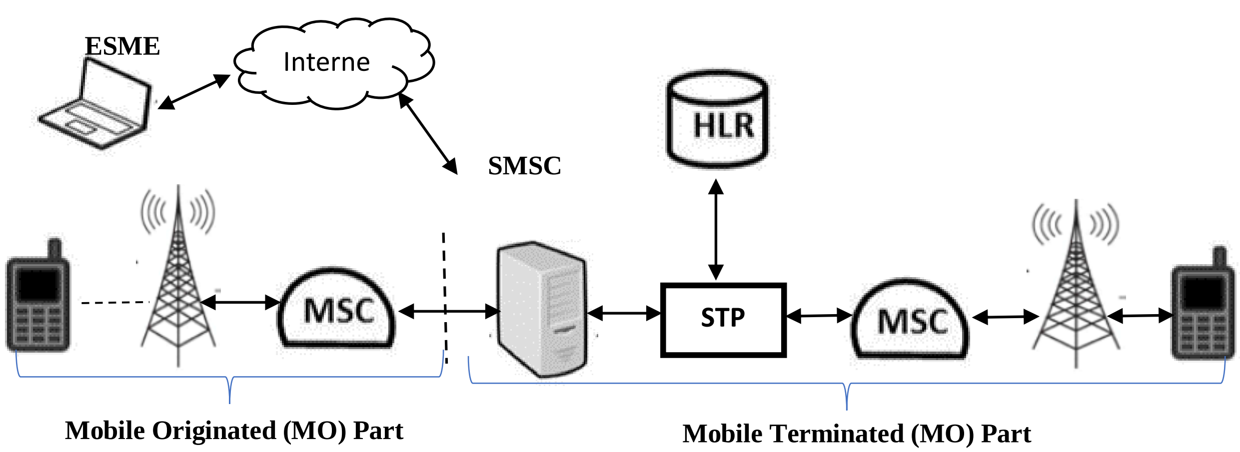

Figure 2- 1 SMS network architecture of GSM [17].

2.1.2 SMS Components

The SMS architecture has different components such as SMSC, MSC, HLR, Visitor Location Register (VLR) [18]. The component is described below.

SMSC is an important element in the SMS network. It is a combination of hardware and software that's responsible for the relaying, storing and forwarding of a short message between Short Message Entity (SME) and mobile device. It has a configurable time limit for how long it will store the message.

The MSC used for switching functions of the system and control messages to and from another telephone. It has to receive access subscriber's information from the VLR to service visiting subscribers based on queries. The MSCs are connected to the two STPs. The STPs are connected to Internet Transfer Points (ITP) based on mesh topology through SS7 links. The function of ITPs, the total traffic equally divided between the ITPs. They balance incoming traffic load onto outgoing links to the SMSC.

HLR is a database used for permanent storage and management of subscriptions and service profiles. HLR provides the routing information for the indicated subscriber based on request of SMSC. Whereas, the VLR is a database that contains temporary information about subscribers. This information is needed by the MSC in order to service visiting subscribers.

2.1.3 SMS Protocols

There are different types of protocols used for SMSC. One of the protocols is Short Message Peer-to-Peer Protocol (SMPP). This protocol used for exchanging short messages between peer-entities and integrate with third parties like CP/SP. There is a different version of SMPP protocols such as SMPP 3.3, SMPP 3.4 and SMPP 5.0. The other

SMS protocol is the Short Mail Transfer Protocol (SMTP). This protocol used for sending an email from SMS service and delivered to MS in text format from the email system [19].

Besides to SMPP and SMTP, there are different types of protocols that connect other systems as an interface. The SMPP+ protocol is used for Anti-spamming connect to SMSC. The other protocol is the Man-machine language (MML) interface protocol. The main use of this protocol is to connect the SMSC with the Network Management System (NMS). This NMS is responsible for SMSC monitoring, maintenance, and management. The FTP/SFTP protocol is to connect the SMSC with the billing system for charging and statistical report'. Furthermore, SMS Application Interface (API) supports Parlay X 2.1/3.0 to connect and integrate for Service Delivery Platform (SDP).

2.1.4 SMS Services

There are different types of SMS messaging services like Person-to-Person (P2P), Application-to-Person (A2P), Person-to-Application (P2A), Application-to-Application (A2A), Person-to-Email (P2E) and Email-to-Person (E2P).

P2P messaging service is the process of exchanging short messages between one mobile device to another via a valid mobile network. A2P messaging service it has delivered the message to a mobile device from the web portal. The flow of A2P is, SMSC receives the short message (SM) from the Application and implements the storing and forwarding. Then, the SMSC delivers the SM to the destination mobile station (MS). The messaging service of P2A sends from mobile device to a software or application. The MS subscriber can submit the SM to the application. On the other side, A2A works from application A to application B. This type of service is configurable by System Admin (on/off) per External Short Message Entity (ESME).

SMS services support P2E and E2P. The SMSC supports the standard SMPP protocol for Email gateway. The Email gateway can send the message from the email server to subscriber via the interface, or receive the message from SMSC via the interface and then forward to an email server.

SMS system includes several service elements relevant to the submission and reception of short messages like validity-period, service-center-time-stamp, protocol-identifier, more-messages-to-send, priority, messages-waiting and alert-SC. The validity period indicates how long the SMS shall guarantee to keep in the storage of SMSC before delivery to the intended recipient. The priority is an element of information provided by an SME to indicate the priority message.

The charging flow of the SMS service has two records that are logged in the trace for billing purposes. The mobile originates charging data record (MO-CDR) for the mobile originating part of the communication. That means, of the originating mobile device to the SMSC. The second CDR is the mobile terminate (MT-CDR) from the mobile terminating segment, from the SMSC to the destination handset. Each record logs information such as mobile identification numbers of the sender and the receiver, the time stamp of the event, the address of the MSC with the sender and receiver device, the result of the delivery attempt, the message size, and a reference value mobile originates and mobile terminates [20].

In the case of Ethio telecom, the same network architecture is used. But it integrated with the SDP platform to provide sent SMS and receiving SMS interface via the protocol. The company SMS system, it supports all services like P2P, A2P, P2A, A2A, P2E, and E2P. But P2E and E2P are not commercialized.

2.2 Bulk SMS

Bulk SMS is one of the most popular and effective marketing tools and big revolution in the mobile industry in the world adopted by the Enterprise and advertising industry [21]. The service is the most popular and widely used, dissemination of a large number of SMS messages for delivery to mobile phone terminals. The service is delivered mostly from CP/SP to large groups of mobile users.

The use of bulk SMS services due to the efficiencies of the services they contribute a large factor to many successful businesses. It enables the business to engage with customers in a simple, fast delivery, time-saving, instant, user-friendly and cost-effective way. There are many advantages through the service like; it encourages users to express themselves concisely, texts use little memory which keeps costs down and no extra technological training is required. It enables the advertisement on a phone without an internet connection and can be targeted based on location. P2P SMS volume sometimes declines globally by over-the-top service as channels such as WhatsApp and Viber [3] and [4]. However, A2P SMS volumes are increasing rapidly. Based on this and above reason bulk SMS are supporting the customer and business partners to advertise the products and services.

2.2.1 Architecture of Bulk SMS

Bulk SMS system architecture works as a middleman between the modern, fast internet connection technologies and the well-known cellular network. Figure 2-2 shows the network architecture of the Bulk Management System (BMS) in Ethio Telecom.

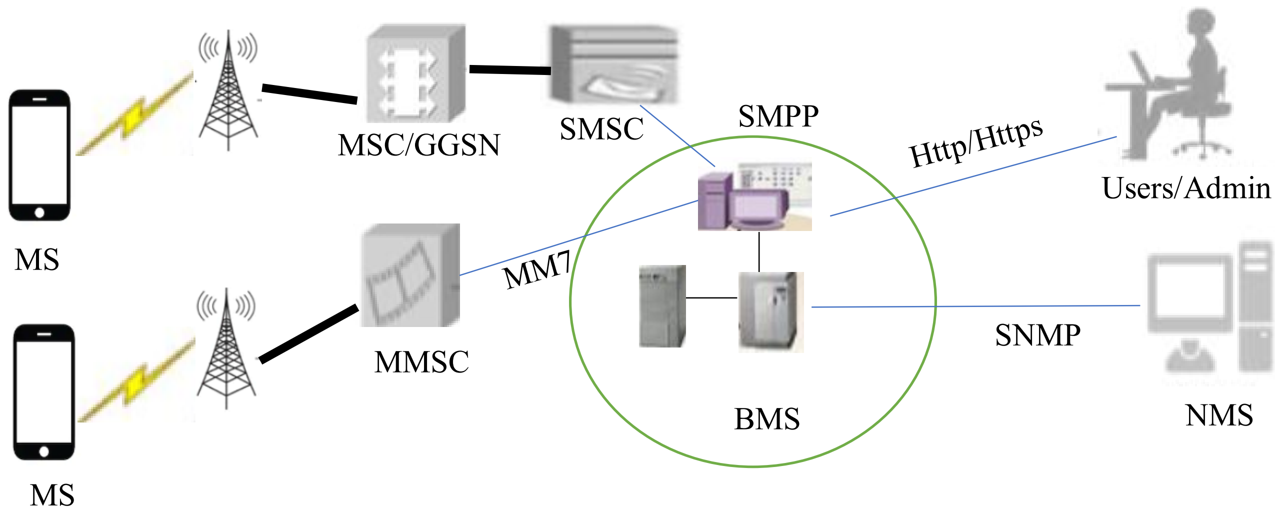

Figure 2- 2 Bulk SMS [22]

Bulk SMS provider provides the APIs for sending content in SMS. API is accessible via the internet from the SMS gateway of the service provider. The BMS supports multimedia service through Multi-Media Service Center (MMSC).

2.2.2 Bulk SMS Getaway Protocol

In Bulk SMS services, there are different types of standard protocol to connect API like email, File Transfer Protocol (FTP), Hypertext Transfer Protocol (HTTP) and SMPP. The first one is directly connecting to mobile operators via SS7 or SIGTRAN. For the service user, the application provides to send SMPP and HTTP protocol to bulk SMS APIs. The second one is to connect the SMSC of mobile operators through SMPP. The third option is using aggregators via SMPP or HTTP based on APIs.

Ethio Telecom is using the second and third options for bulk SMS integration with the third party. Which are the SMSC of mobile operators via SMPP and using an aggregator through SMPP or HTTP based on APIs. The API connects with the SMPP to the SMSC of mobile operators over SMPP 3.3/3.4 version.

Chapter III: Basics of Fourier Analysis

3.1 General Introduction

Fourier analysis is a method of decomposing periodic waveforms in terms of trigonometric function or exponential functions with definite frequencies. Using Fourier analysis signals are transformed from the time domain to the frequency domain and vice versa [23].

There are two types of Fourier analysis; namely, Fourier series and Fourier Transform. Fourier Series is for periodic signals, whereas the Fourier Transform is for non-periodic signals. Below mathematical basics about the two analysis techniques are presented.

3.1.1 Fourier Series

Fourier series is a way to represent a periodic waveform (or signal) as the sum of simple sine and cosine waves [24]. In addition to that, it is applicable to a function that is finite in length. The basics equation is summarized as follows:

Let a periodic function f(t) with a period of T is defined as given in Equation (3.1).

$$f(t) = f(t+T) \qquad (3\text{-}1)$$

Fourier series representation of the function f(t) given in Equation (3.2).

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty}\left(a_n \cos\frac{2\pi nt}{T} + b_n \sin\frac{2\pi nt}{T}\right) \qquad (3\text{-}2)$$

The Fourier coefficients a_n and b_n in Equation (3-2) are computed as follows.

$$a_n = \frac{1}{T}\int_{to}^{t0+T} f(t)\cos\frac{2\pi nt}{T}\,dt \qquad (3\text{-}3)$$

$$b_n = \frac{1}{T}\int_{to}^{t0+T} f(t)\sin\frac{2\pi nt}{T}\,dt \qquad (3\text{-}4)$$

Fourier series can use complex exponentials instead of the sine and cosine functions because exponentials are simpler for mathematical operations, e.g., to perform integration and differentiation. The exponential form of the Fourier series and the coefficients are given in Equations (3-5) and (3-6), respectively.

$$Fn = \frac{1}{T}\int_{t0}^{t0+T} f(t)e^{-iwnt}\ dt \tag{3-5}$$

$$Where\ w = \frac{2\pi}{T}$$

$$f(t) = \sum_{n=-\infty}^{\infty} Fn\ e^{iwnt} \tag{3-6}$$

For discrete function (series) x[n] with N number of elements, its Fourier series representation and its coefficients are given in Equations (3-7) and (3-8), respectively.

$$Xt = \frac{1}{N}\sum_{t=0}^{N-1} x[n]e^{-iwnt} \tag{3-7}$$

$$x[n] = \sum_{t=0}^{N-1} x[n]\ Xt\ e^{-iwnt} \tag{3-8}$$

3.1.2 Fourier Transform

Fourier transform is used to represent non-periodic functions as a continuous superposition of complex exponentials. It converts a signal from the time domain to the frequency domain or spectrum. Whereas an inverse Fourier Transform converts the frequency domain components back into the original time-domain signal [25].

For continues function f(t), its Fourier transform and inverse Fourier Transform are given in Equations (3-9) and (3-10) respectively.

$$F(w) = \int_{-\infty}^{+\infty} f(t)e^{-jwt}\ dt \tag{3-9}$$

$$f(t) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} F(w)e^{jwt}dw \tag{3-10}$$

Discrete Fourier Transform (DFT) and inverse for a discrete function x[n] with N number of elements are given in Equations (3-11) and (3-12), respectively.

$$X[k] = \sum_{n=0}^{N-1} x[n]e^{-2\pi jnk/N} \qquad (3\text{-}11)$$

$$x[n] = \frac{1}{N}\sum_{k=0}^{N-1} X[k]e^{2\pi jnk/N} \quad \ldots . n = 0,1,2,\ldots\ldots, N-1 \qquad (3\text{-}12)$$

The DFT of the signal is a sequence X[k] for k=0,1, 2, ..., N-1 number of elements.

There is an upgrade version of DFT, called Fast Fourier Transform (FFT), which is computationally efficient when compared to DFT. It is discussed in Section 3.1.3 below.

3.1.3 Fast Fourier Transform

The FFT is an important digital signal processing technique to analyze the phase and frequency components of a time-domain signal. It is a fast computation algorithm, a numerically efficient method to calculate the DFT and also an upgrade of DFT which reduces the required computational step [26]. In practice, the computation time can be reduced by several orders of magnitude. For example, if N=1000 samples are used for DFT the required computational steps will be ($N^2 = 10^6$), whereas for FFT the result will be ($Nlog_2^N = 10^4$).

The DFT is impractical as it has a slow computation and complicated when the length of the sequence increases whereas FFT, which is a numerically efficient method to calculate DFT [27] and [28].

Generally, DFT needs N^2 complex multiplication and N(N-1) complex additions, whereas the FFT takes only (N/2) ($\log_2 N$) complex multiplications and $N\log_2 N$ complex additions. The computation between DFT and FFT for the same N is proportional to ($2N/\log_2 N$). Therefore, the FFT algorithm reduces the number of complex multiplication and addition operation and computation time required to compute the DFT.

As a sample, the flow graph of the dissemination-in-time (DIT) decomposition N=8 is presented in Figures 3-1 and 3-2 respectively.

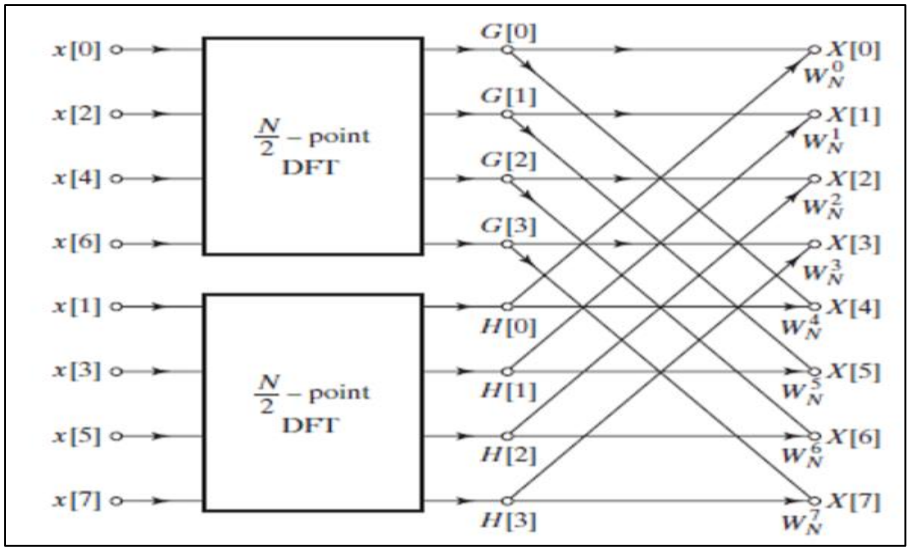

Figure 3- 1 Flow graph of the DIT of an N-point DFT computation into two (N/2)-point DFT [29]

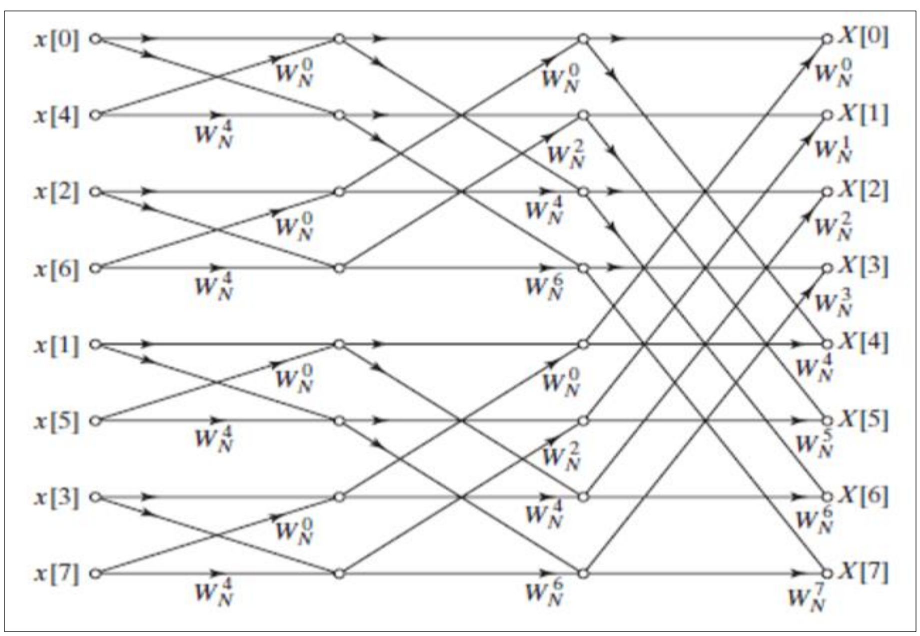

Figure 3- 2 Flow graph of complete DIT decomposition of an 8-point DFT computation [29]

In DIT, the input sequence is divided into subsequences, i.e. even and ordinary sequences.

3.1.4 Discrete Cosine Transform

Discrete Cosine Transform (DCT) is a widely used method in image compression that transforms a signal or image from the spatial domain to the frequency domain. DCT is one of the most popular lossy image compression techniques used today in video compression schemes for most applications [30]. In lossy compression, the image in the decompressed image is very close, but not the same as, that of the original [31] and [32]. Since an image is represented in two dimensional (2D) array, 2D Discrete Cosine Transform (2D-DCT) is used to transform an image.

The 2D version of the transform NxN block forward and reverse equation of 2D-DCT has shown in Equation (3-13) below.

$$F(u,v) = \frac{2}{N} C(u)C(v) \sum_{y=0}^{N-1} \sum_{x=0}^{N-1} f(x,y) \cos\left[\frac{(2x+1)u\pi}{2N}\right] \cos\left[\frac{(2x+1)v\pi}{2N}\right] \qquad \textit{(3-13)}$$

The compressed data, when IDCT is taken from the decompressed image. The 2D-IDCT (2D-IDCT) is given by Equation (3-14).

$$f(x,y) = \frac{2}{N} \sum_{y=0}^{N-1} \sum_{x=0}^{N-1} C(u)C(v)F(u,v) \cos\left[\frac{(2x+1)u\pi}{2N}\right] \cos\left[\frac{(2x+1)v\pi}{2N}\right] \qquad \textit{(3-14)}$$

In particular, the 2D-DCT is often used in signal and image processing, especially for lossy compression, because it has a strong energy compaction property. In typical applications, most of the signal information tends to be concentrated in a few low-frequency components of the DCT. Based on using the inverse 2D-DCT frequency components with low energy content are truncated.

The DCT coefficients carry the information about the pixels in the image. In the top left corner carries the maximum information and the remaining coefficients, arranged in a zigzag manner in the decreasing order. Therefore, to achieve compression, the coefficients starting from the end can be dropped depending on the quality required for the decompressed image.

Chapter IV: SMS Traffic Modeling

4.1 Basics of Modeling

A model is a simplified representation of a system at some particular point in time or space projected to promote an understanding of the real system [33]. Modeling of any system can either be statistical or deterministic [34].

In this research, a deterministic modeling approach is followed and as a result, a mathematical model that can determine the SMS traffic distribution value in space and time is developed. As the modeling is performed in both space and time, the basics of time series and spatial modeling are discussed in the below sections.

4.2 Time Series Modeling

A time series is a sequential set of data points, measured over successive times. A time-series can be univariate or multivariate. The univariate recorded sequence is for a single observation whereas multivariate is for multiple sets of observation. A time-series can be continuous or discrete. In continuous-time, series observations are measured at every instance of time. On the other hand, the discrete-time series contains observations measured at discrete points of time [35].

There are a number of approaches to modeling time series [36]. The most common approaches are presented as follows.

- Frequency Based Approach: It is commonly used in scientific and engineering applications for analyzing the series in frequency domain.

- Autoregressive (AR) Models: A common approach for modeling univariate time series. The model is used for forecasting future behaviour based on past behaviour. The output variable depends linearly on its own previous value.
- Moving Average (MA) Models: Prediction based on the current value of the series against the previous (observed) white noise error terms.
- Box-Jenkins approach: It is popularized approach that combines the moving average and the autoregressive approaches.

From the above mentioned modeling types, frequency based approach is used for time modeling because it can change time-series data to spectral domain.

4.3 Spatial Modeling

Spatial Modeling is a study that provides a unique set of techniques and methods for analyzing events that are located in geographical space [37]. In mobile network technology, most of the spatial modeling studies concentrate on the statistical distribution of users, base stations and traffic. Spatial modeling approaches are presented below.

- SPPP model: Used to model the random fluctuations of the total traffic. It is a simple and widely used distribution model for modeling the locations of base stations and users' in a heterogeneous network. The model can reflect the randomness of distribution and generate a uniform distribution.
- The Lognormal distribution model: It uses a probability distribution of real data and fitting data at different times for spatial traffic model.
- Gaussian distribution model: A normal distribution used for the approximation of the user distribution in cellular networks. This model can generate various user

distributions such as uniform distribution by adapting parameters. These parameters are mean values and standard deviations using N-dimensions.

- Exponential distribution: One of the widely used continuous distributions. It used for traffic density by analyzing the traffic data the time elapsed between events.

4.4 Model Development

The research is a case study of the SMS traffic distribution in Addis Ababa within 34km by 34km coverage. The city has 739 base stations. The distribution of base stations in the city can be seen in Figure 4-1.

Figure 4- 1 Addis Ababa Base Stations

The SMS traffic dataset is collected from the Ethio Telecom network performance system. The data recorded is outgoing and incoming SMS traffic counts for a week in an hourly interval separately at the base station level. The location information (in degrees) is obtained from longitude, latitude and sited id found from the network.

The modeling process is done through the following steps

1. Firstly, as shown in Figure 4-2, rectangular areas that can fit all the boundaries of the city is selected. The dimension of the city is 34km by 34km in the square of the same dimension.
2. Each side of the square is equally divided into N parts and creating a matrix of N by N.
3. To reduce the space domain by a factor of $1/N^2$ and also the average number of sites in each cell by the same factor.
4. Base Station at site level located in the same cell of the matrix is grouped together and every hourly is summed up an outgoing and incoming SMS separately. Each pixel represented with a single traffic profile.

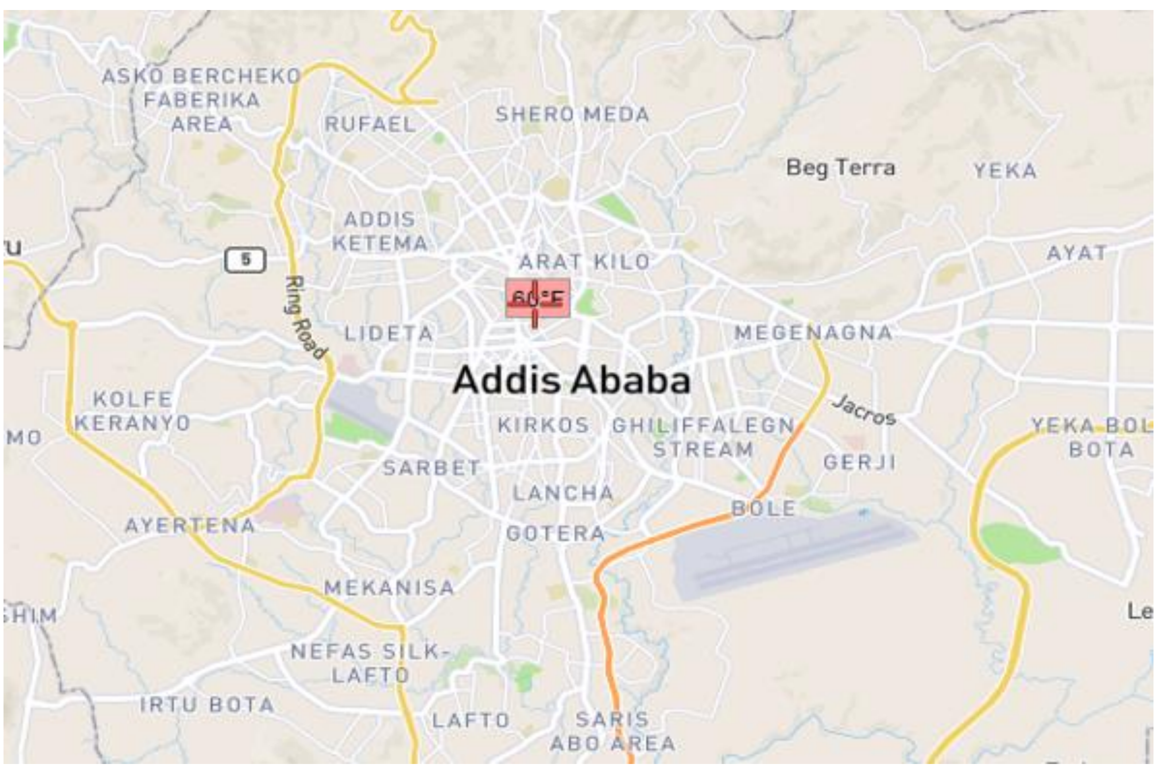

Figure 4- 2 Map of the city

4.5 Traffic Model in Time

In this paper, the term SMS outgoing means mobile user sending SMS within that specific place. SMS incoming means mobile user receiving SMS within that specific place.

The research uses time-series data, by applying FFT each group's SMS traffic count is transformed from time to spectral-domain where major frequency components are extracted.

After applying FFT, it used the Fourier inverse transform, the transformed spectral frequency domain is transformed from spectral to time in order to develop a temporal model. Fourier inverse transform that used for developing the temporal model is shown in Equation (4-1).

$$V(t) = a_0 + \sum_{i=1}^{5} (a_i \sin(2\pi f_i t + \alpha_i)) \qquad (4\text{-}1)$$

Where V(t) is the total traffic count of all base stations in the selected area, a_o is average traffic count during a period of time, f_i is frequency components of traffic variation, a_i and α_i are the amplitudes and phases corresponding to the major frequency components, i is the number of major frequency components.

The Fourier transform uses three parameters to model the time and space domain. These parameters are frequency, coefficient, and phase. The frequency determines the hidden pattern of the customer's SMS traffic usage behaviour in the day. The coefficients determine the SMS traffic count on a corresponding pattern. Whereas, the phase gives information about the position of the starting point of the pattern a day. The amplitude or power spectra of the signals gives information how the frequency content of signal changes with time. Four sample areas are selected with the three parameters.

The following figures, Figures 4-3 and 4-4, shown the SMS traffic of sample area in frequency component for outgoing SMS and incoming SMS respectively.

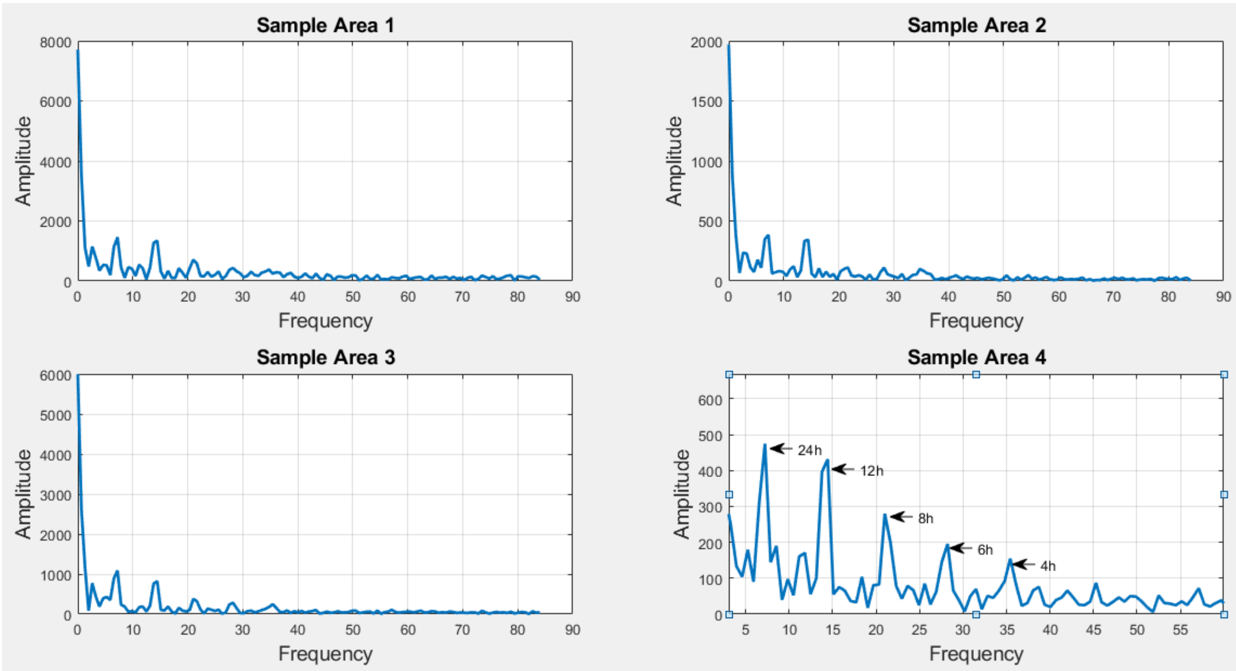

Figure 4- 3 Outgoing SMS traffic in spectral domain

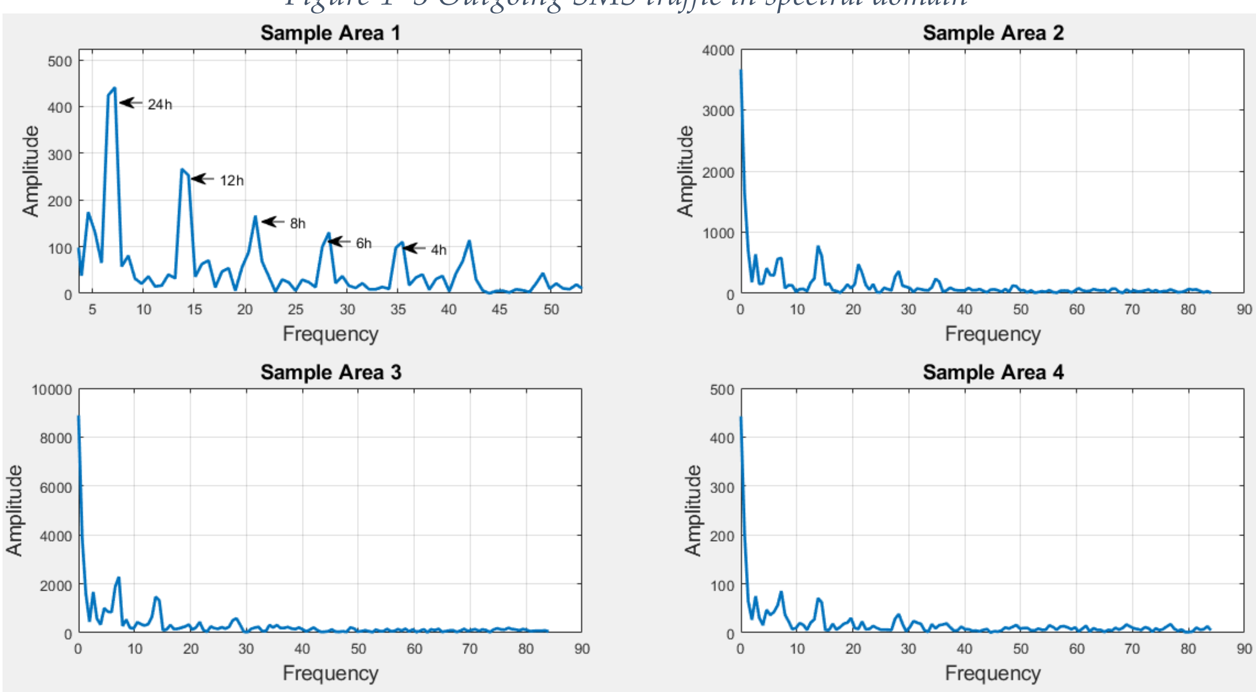

Figure 4- 4 Incoming SMS traffic in Spectral domain

There are five major SMS traffic usage patterns in the city that contribute to the daily traffic variation. These are f_1=1/24 or (T=24), f_2=1/12 or (T=12), f_3=1/8 or (T=8), f_4=1/6 or (T=6) and f_5=1/4 or (T=4). This phenomenon is related to the user behaviour of mobile users who tend to have repetitive behaviours in periods of one day. This dominant pattern which corresponds to f_1 repeats itself within 24 hours whereas, the others have an impact in decreasing order of f_2, f_3, f_4, and f_5.

The temporal model of real data and the proposed model of outgoing and incoming SMS are plotted based on the major frequency component on Equation (4-1). The temporal model of outgoing and incoming SMS is presented in Figures 4-5 and 4-6 respectively.

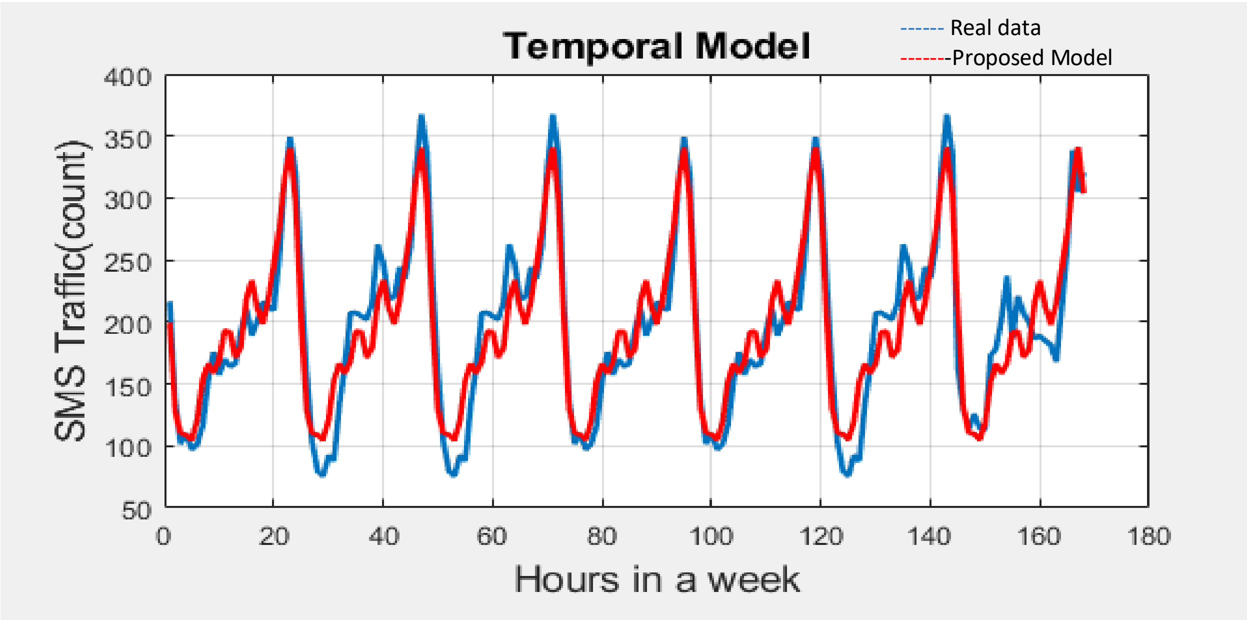

Figure 4- 5 Outgoing SMS

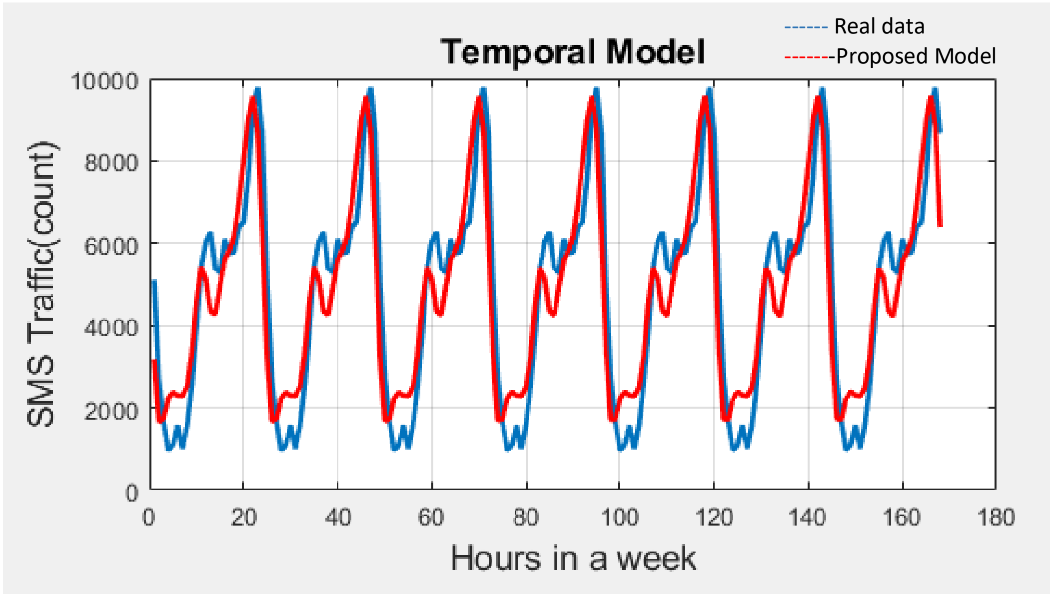

Figure 4- 6 Incoming SMS

The temporal model captured the daily SMS traffic in the city of Addis Ababa. From the model observed that the daily traffic changes the traffic pattern five times within a day.

4.6 Traffic Model in Space

In order to incorporate the space domain in the temporal model, it used three parameters in equation analyzed and identified that is frequency, coefficient and phase. In the space domain, the coefficient, and phase vary within the location while frequency is constant within different locations. Based on the coefficient and phase, we can extract the matrix of SMS traffic of each spatial parameter for outgoing SMS and incoming SMS separately.

By applying 2D-DCT on each of the matrices, all are transformed from spatial to spectral domain. To describe the 2D-DCT, in the spectral domain the majority of the energy is concentrated in the low-frequency part. The high-frequency components use less energy. As a result, frequency components with low energy content are truncated. The remaining components are using inverse 2D-DCT based on Equation (4-2). The following Figure 4-7 are presented energy content of the spatial parameter in the spectrum.

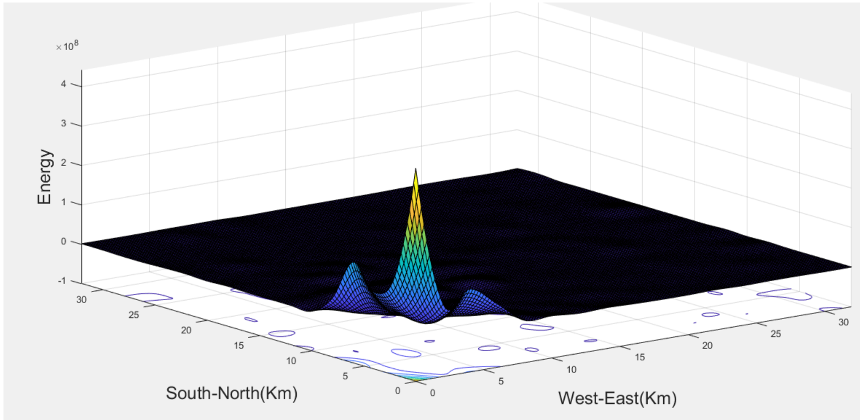

Figure 4- 7 Energy content of the spatial parameter in the spectrum

The Fourier coefficient that used for the formulating matrix of average traffic coefficient and phase in outgoing and incoming SMS is shown in Equation (4-2) below.

$$a_n(x,y) = \frac{2}{N}\sum_{n=0}^{N-1}\sum_{m=0}^{N-1} C(n)C(m)A(n,m)\cos(W_n x + \theta_n)\cos(W_m y + \theta_m) \ldots.. \qquad (4\text{- }2)$$

$$where\ C(n), C(m) = \begin{cases} \frac{1}{\sqrt{2}}, for\ n,m = 0 \\ 1,\ \ otherwise \end{cases}$$

$$W_n = \frac{(N-1)n\pi}{N.X}, \qquad W_m = \frac{(N-1)m\pi}{N.Y}, \quad \theta_n = \frac{\pi n}{2N} \quad and\ \theta_m = \frac{\pi m}{2N}$$

The function of the a_n is represent the spatial parameters i.e. coefficient and phase with location coordinate (x, y), A is the spectral domain content after truncating frequencies with less energy value. N has represented the size of the block that the DCT is done on. The X and Y are the city's width and length respectively, while x and y are the local distances.

As a result of coefficient and phase value are extracted, eleven matrixes table (six are related to coefficient and five are related to phase) corresponding to the spatial parameter are prepared for each outgoing and incoming SMS traffic. As a sample, the average matrixes of coefficient and phase of outgoing and incoming SMS are shown in Table 4-1, 4-2, 4-3 and 4-4 below. The remaining others are attached in the Appendix section.

The matrices match the geographical area in the city. The bottom left corner of the table corresponds to the south-west of the city whereas the upper right corner refers to north-east.

Table 4- 1 SMS outgoing, Matrix of average traffic coefficient(C0)

0	13	0	5	174	0	84	0	77	0	0	0	0	0	0	0	0
791	1786	1175	2	145	6	280	7	38	0	0	160	0	754	0	0	0
527	2970	2690	3099	4317	3276	5979	2857	1228	47	385	97	1143	2181	648	0	0
0	717	1699	5597	5671	9114	5720	3557	685	1501	2189	2772	3837	224	0	38	0
876	312	1845	2409	9881	11217	7880	7235	6237	1481	2113	3309	2352	1955	95	31	44
0	889	4694	3857	3229	8905	6675	8009	6362	6154	5019	5026	1833	1140	1033	0	8
0	3013	3507	3639	3431	5392	7626	6931	6447	6106	3986	866	1958	300	629	20	5
399	893	5341	1897	3836	4393	3548	4257	596	0	728	1164	944	998	98	2	0
12	3623	2309	984	6518	3558	6200	3614	1685	375	188	46	0	465	0	0	0
678	1017	1681	1614	3333	3290	2708	2458	43	0	123	9	18	0	0	0	0
679	1866	16	371	0	2808	589	629	0	346	77	1	0	43	0	0	0
217	48	0	0	0	439	1880	2999	410	80	0	19	0	0	0	0	0
0	0	33	0	0	0	532	4079	1611	425	0	243	0	0	0	0	0
0	0	0	0	50	0	72	1463	1268	1053	1003	0	0	0	0	0	0
0	0	0	0	0	0	0	86	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0

Table 4- 2 SMS outgoing, Matrix of Phase in rad (P0)

0.0	-2.6	0.0	3.1	3.5	0.0	1.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9	1.6	0.9	6.1	1.2	2.7	1.6	1.1	3.8	0.0	0.0	2.3	0.0	1.6	0.0	0.0	0.0
0.1	0.8	1.1	1.2	0.8	1.4	1.0	0.9	0.3	1.6	5.2	1.1	1.0	1.3	0.9	0.0	0.0
0.0	0.3	-6.2	0.3	3.0	1.2	3.3	1.0	0.5	0.4	1.2	0.8	1.2	-5.3	0.0	1.4	0.0
1.5	-5.2	-5.8	0.5	0.8	1.6	0.7	1.3	1.6	1.4	3.5	1.4	1.4	1.3	3.4	3.9	3.1
0.0	0.6	0.2	0.8	2.9	2.0	2.0	1.8	3.6	4.9	0.9	1.2	1.2	1.3	1.2	0.0	0.9
0.0	-0.1	0.7	1.0	4.3	3.4	1.5	1.6	2.0	-4.7	0.8	0.8	0.9	-4.4	1.1	2.9	1.3
-6.0	-5.9	0.9	1.1	1.0	1.3	1.5	1.1	-4.6	0.0	0.7	3.4	1.3	1.0	0.9	2.8	0.0
1.1	0.8	0.7	1.1	1.3	1.3	1.4	1.0	0.8	1.1	2.7	1.1	0.0	4.3	0.0	0.0	0.0
0.8	1.2	0.4	0.6	0.9	1.5	1.5	1.0	2.0	0.0	2.3	2.5	6.8	0.0	0.0	0.0	0.0
1.2	1.0	3.2	0.7	0.0	0.8	1.4	4.2	0.0	1.2	1.6	2.9	0.0	3.0	0.0	0.0	0.0
1.5	-5.8	0.0	0.0	0.0	2.2	1.1	1.4	0.7	-5.7	0.0	0.4	0.0	0.0	0.0	0.0	0.0
0.0	0.0	6.8	0.0	0.0	0.0	1.1	1.1	1.2	1.9	0.0	3.6	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.4	0.0	1.8	0.7	1.4	1.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4- 3 SMS Incoming, Matrix of average traffic coefficient (C0)

0	93	0	38	433	0	370	0	184	0	0	0	0	0	0	0	0
2525	5294	3552	15	567	41	1272	37	162	0	0	589	0	2884	0	0	0
1489	9238	8797	9000	12546	11489	18142	7455	3014	247	1395	388	4106	8394	4555	0	0
0	2272	4156	16137	20184	29695	19335	10305	2046	4113	7305	7771	12647	859	0	254	0
3404	1035	5256	6969	32335	49429	28343	19831	22072	4937	7613	10518	7196	5260	171	181	213
0	2930	14354	12019	9902	32481	21380	24964	20837	19840	13219	15074	4572	3114	3168	0	46
0	9882	10638	12407	8422	14854	24396	17995	16909	17685	13690	2407	5786	1088	1579	101	18
1686	2564	17171	7191	11427	15778	11855	14521	1831	0	1719	3009	2793	4463	485	12	0
73	10812	7692	3574	19582	12053	20569	10936	4519	1247	497	225	0	2013	0	0	0
2325	3731	4402	4443	10405	10779	7480	7262	191	0	323	60	93	0	0	0	0
2290	6648	90	1137	0	7988	2153	2212	0	980	430	6	0	131	0	0	0
793	221	0	0	0	865	5415	10630	1567	0	477	122	0	0	0	0	0
0	0	185	0	0	0	1805	13509	5192	1678	0	998	0	0	0	0	0
0	0	0	0	177	0	240	4373	4719	3798	3355	0	0	0	0	0	0
0	0	0	0	0	0	0	363	0	0	0	0	0	0	0	0	0

Table 4- 4 SMS incoming, Matrix of Phase in rad (P0)

0.0	4.7	0.0	3.3	2.4	0.0	4.1	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	4.3	1.2	-2.5	1.6	3.2	4.3	2.0	2.3	0.0	0.0	1.7	0.0	3.9	0.0	0.0	0.0
1.4	3.4	2.6	2.7	-3.6	2.4	2.6	2.6	1.8	2.2	4.6	1.6	-0.1	1.6	2.2	0.0	0.0
0.0	3.6	-4.4	-2.9	1.0	-3.4	0.2	2.5	2.4	1.7	1.9	3.7	2.4	-3.6	0.0	2.3	0.0
1.6	4.4	-4.9	-3.7	-3.5	2.8	2.0	2.7	1.9	0.0	2.7	2.2	0.0	3.3	1.8	2.3	2.9
0.0	2.5	-3.6	-3.5	1.5	2.0	2.2	0.3	1.3	1.9	2.6	2.3	2.2	1.5	2.7	0.0	2.3
0.0	-3.5	2.5	2.6	0.1	0.8	1.8	0.2	1.9	0.0	2.5	2.8	2.7	2.4	4.0	2.6	1.9
-3.6	2.8	2.6	2.7	2.7	-0.1	0.3	-1.1	1.9	0.0	1.7	2.0	2.7	5.0	4.8	2.2	0.0
1.8	2.6	-3.5	-0.1	-0.1	-0.1	-0.1	2.6	3.4	4.0	2.2	2.8	0.0	1.1	0.0	0.0	0.0
2.5	1.0	-2.7	3.4	2.7	0.0	1.6	2.6	2.6	0.0	2.5	3.1	2.7	0.0	0.0	0.0	0.0
2.5	1.5	-5.8	3.1	0.0	2.7	2.1	1.6	0.0	2.6	2.0	2.9	0.0	1.8	0.0	0.0	0.0
3.4	-1.6	0.0	0.0	0.0	1.8	2.7	0.0	1.7	0.0	-1.2	2.7	0.0	0.0	0.0	0.0	0.0
0.0	0.0	2.3	0.0	0.0	0.0	0.1	2.6	0.0	2.1	0.0	4.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	3.5	0.0	2.2	3.5	0.2	3.5	4.2	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.7 Traffic Model in both Space and Time

The spatiotemporal model uses both the time and space domain. To obtain, the two models are combined that coefficient and phase from time modeling, and spatially by using 2D-DCT. The model is to be completed by inserting Equation (4-1) and (4-2) is given below in Equation (4-3) [10].

$$T(x,y,t) = a_0(x,y) + \sum_{n=1}^{5}(a_n\,(x,y)\sin(2\pi\, f_n t + \alpha_n(x,y))) \tag{4- 3}$$

Where $T(x,y,t)$ is the total SMS traffic count of the city of Addis Ababa.

In order to incorporate the spatiotemporal model, the model development has required transformation of the traffic from time and space to spectral domain followed by frequency truncation. In the temporal model, it used three parameters identified that is frequency, coefficient and phase. Additionally, five major SMS traffic usage patterns in the city that contribute to the daily traffic variation are identified.

In space domain coefficient and phase value are extracted corresponding to the spatial parameter. Because the coefficient and phase vary within the location while frequency is constant within different locations.

Finally, the traffic modeling in space and time can be done by any combination of the spatial and temporal model. The model captures the real SMS traffic within different space and time.

The spatiotemporal traffic distribution of the city from real data have been shown in Figure 4-8 and 4-9 at the time of 8 AM.

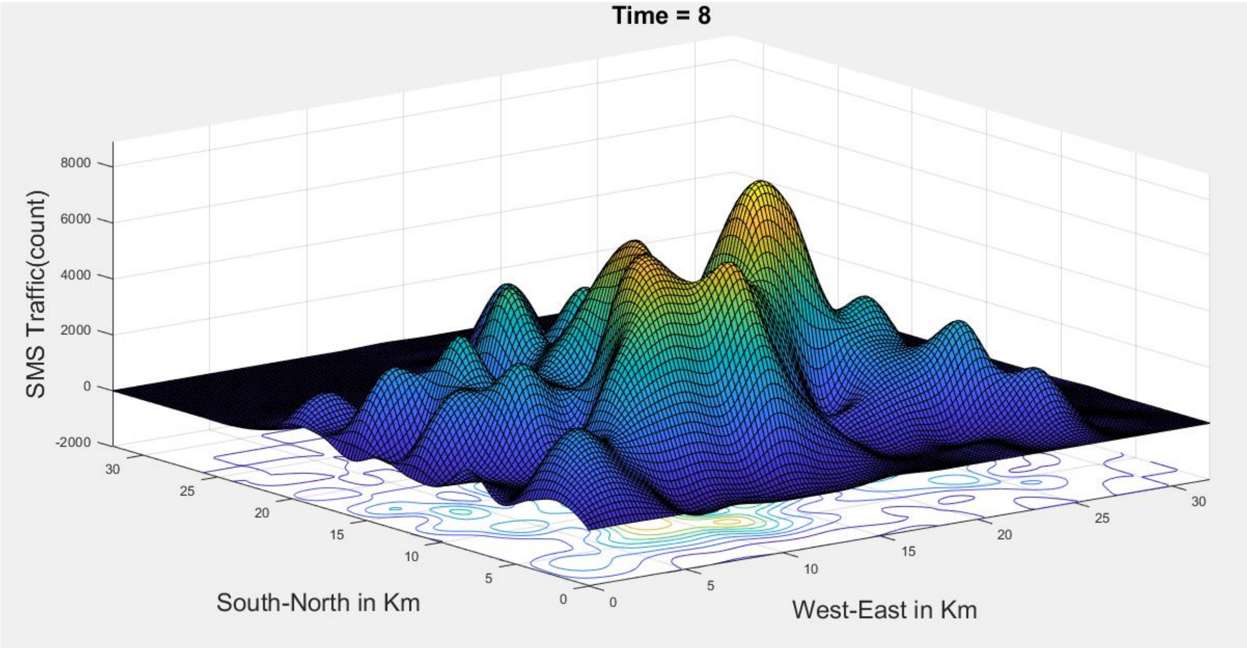

Figure 4- 8 Outgoing SMS at 8 AM

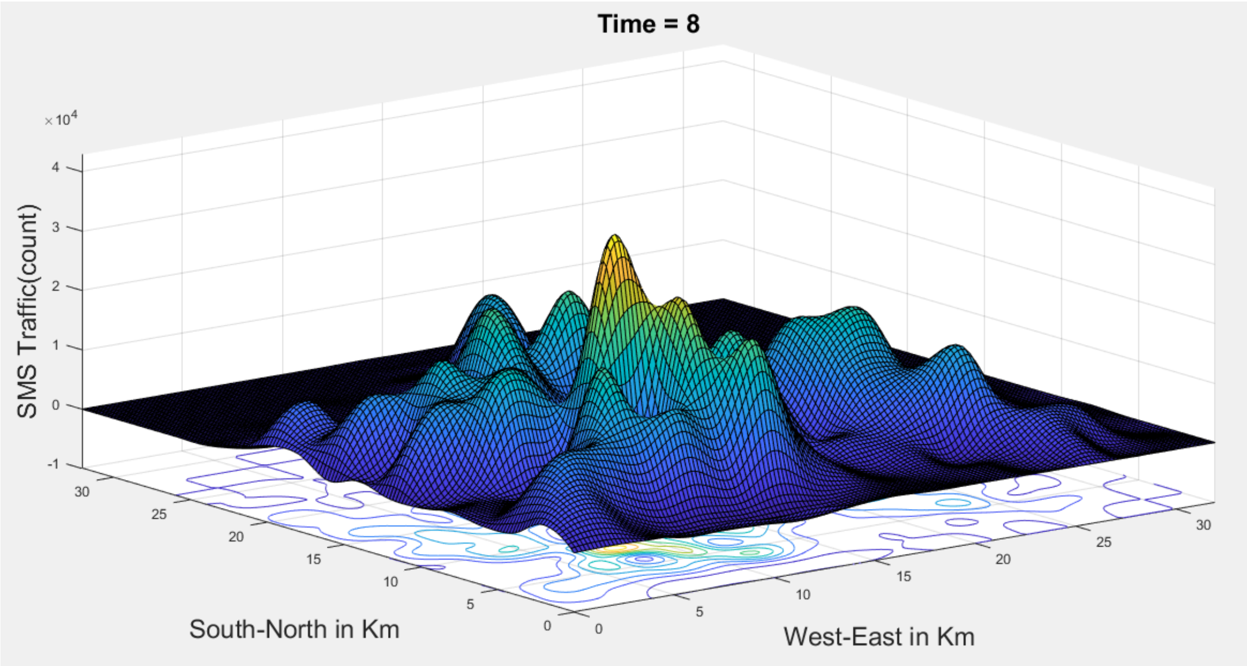

Figure 4- 9 Incoming SMS at 8 AM

Chapter V: Result and Discussion

5.1 Result

This research primarily focused on modeling SMS traffic distribution in space and time taking Addis Ababa city as a case study. The analysis is mainly on the relation between the level of frequency truncation in the spectral domain of the spatial parameters and temporal model in the model accuracy.

The sensitivity for the accuracy of the model is not similar in different applications. Planning, resource allocation, and energy-efficient design are more sensitive to the accuracy whereas applying the model for identifying customer usage behaviour and application dynamic pricing is less sensitive to the accuracy [10].

In this research, in order to do the performance evaluation of the model, the coefficient of determination (R^2) is selected. The R^2 is a statistical measure that is used to evaluate the goodness of fit for a model to measure the accuracy of the model. The R^2 is shown in Equation (5-1).

$$R^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \qquad \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \qquad (5\text{-}1)$$

Where x_i and y_i is i^{th} elements of fitting data of the model and the i^{th} element of the original data set respectively, and $\bar{y}$ is i^{th} elements of an average value of original data. The n value is the number of elements in the original data set.

R^2 as the metric of the accuracy of the proposed model, it indicates how well data fit a statistical model. The result of R^2 is closer to 1, the coefficient determination is the better fitting result between real and the model version [8].

It is observed that in the temporal model, all sampled area has the same major frequency components, there is only one truncation level.

As shown in Table 5-1, R^2 calculated the sum of error between the model version and the real data within 24 hours based on Equation (5-1).

Table 5- 1 The errors within 24 hours between the real and the model

Hour in a day	Outgoing SMS Temporal Model errors	Incoming SMS Temporal Model errors
1	0.00134423	0.00048980
2	0.00190549	0.00169899
3	0.00249345	0.00539610
4	0.00414314	0.00927610
5	0.00344234	0.01200399
6	0.00226136	0.01422745
7	0.00282279	0.00588145
8	0.00065929	0.00084584
9	0.00036035	0.00015504
10	0.00021621	0.00002423
11	0.00024914	0.00002294
12	0.00079926	0.00005784
13	0.00069644	0.00002688
14	0.00139540	0.00003493
15	0.00040690	0.00002498
16	0.00011263	0.00002330
17	0.00010518	0.00002716
18	0.00015447	0.00003548
19	0.00016260	0.00002911
20	0.00018799	0.00005199
21	0.00014810	0.00009088
22	0.00013716	0.00005015
23	0.00007731	0.00004496
24	0.00011503	0.00005749
Sum of errors	0.02439626	0.05057707
R^2	0.98	0.95

The accuracy of the proposed temporal model of outgoing SMS and incoming SMS is 0.98 and 0.95 respectively. Therefore, the model can fit the real data with great accuracy.

To evaluate the spatial model, we used the truncation level of estimation based on R^2 in Equation (5-1). In the time domain, as it is observed that it has the same major frequency components, there is only one truncation level whereas in the space domain there are many parameters. For each of the outgoing and incoming SMS traffic, there are six parameters related to coefficients and five parameters related to phases.

Truncation is chop low energy content from frequency components. In the spectral domain, the majority of the energy is concentrated in the low-frequency part. The high-frequency components use less energy. As a result, frequency components with low energy content are truncated. The remaining components are using for the model.

The level of truncation on the frequency of transformed phase and coefficient affects the model performance are analyzed as parameter level.

This study applied the truncation directly on the magnitude of frequencies amplitude. By applying the 2D-DCT approach for image compression and using the transforming matrix of colour values to the spectral domain. The coefficient represented as (C0, C1, C2, C3, C4 and C5) and phase represented as (P0, P1, P2, P3 and P4).

For outgoing SMS, the level of truncation on the frequency of the transformed coefficient and phase as in Figures 5-1 and 5-2, respectively.

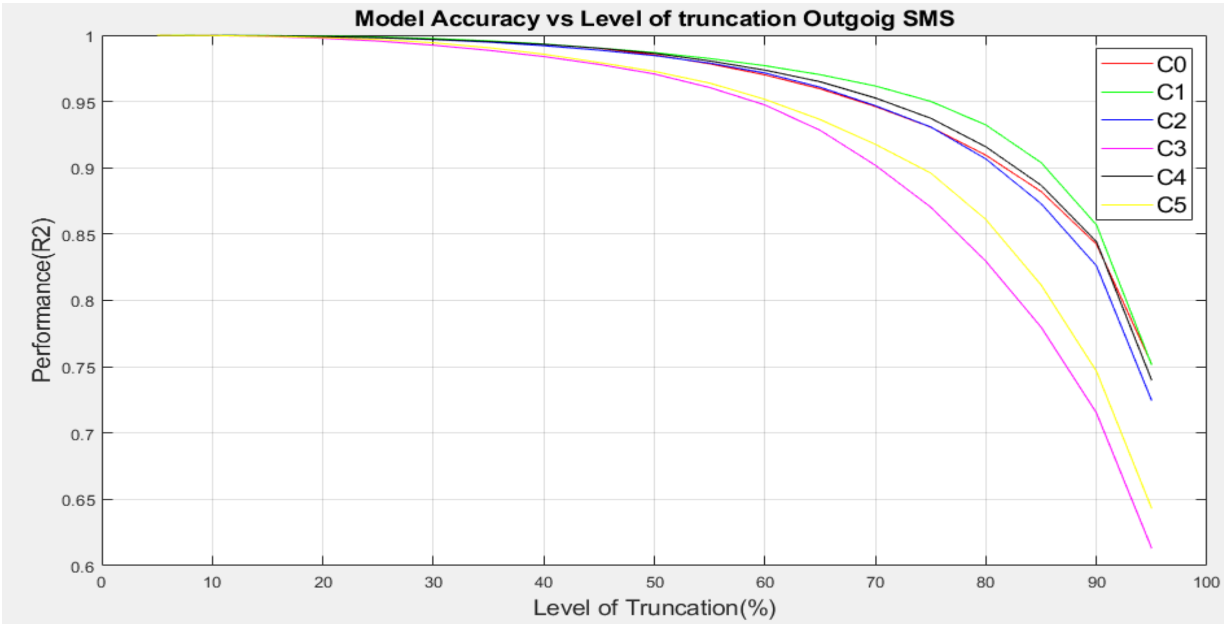

Figure 5- 1 Outgoing SMS Coefficient Evaluation

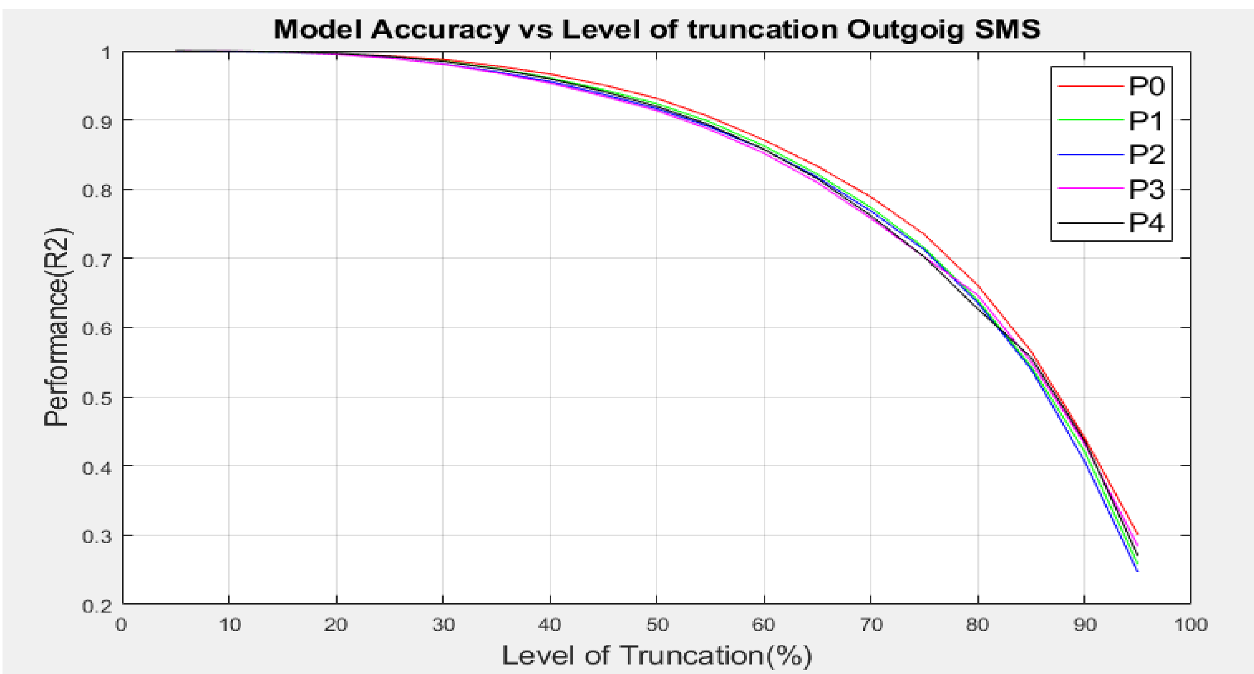

Figure 5- 2 Outgoing SMS Phase Evaluation

For incoming SMS, the level of truncation on the frequency of transformed coefficient and phase are as given in Figures 5-3 and 5-4, respectively.

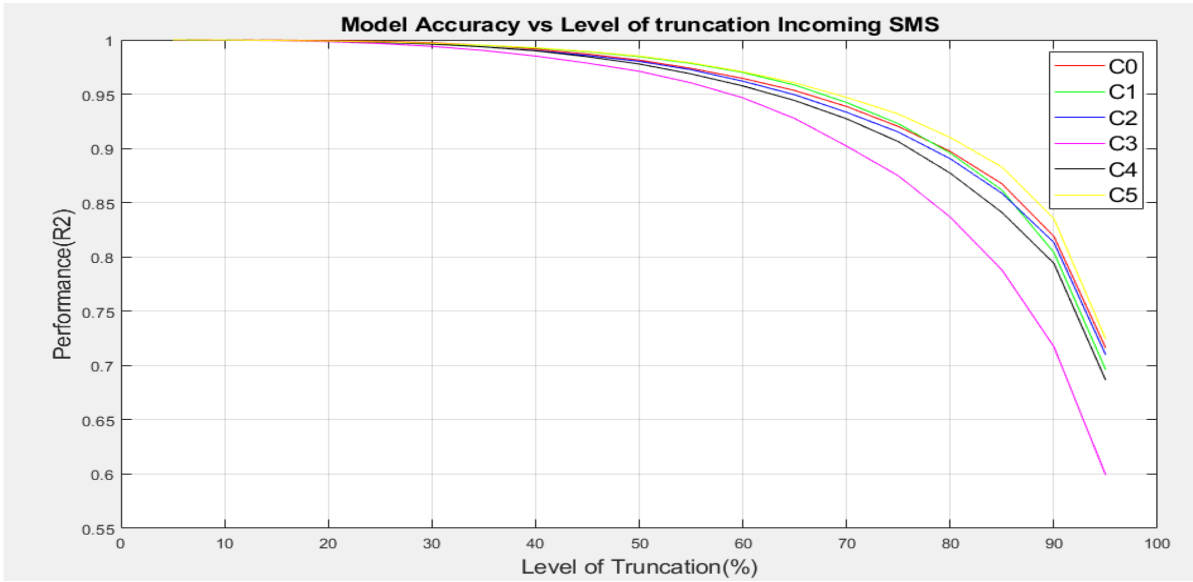

Figure 5- 3 Incoming SMS Coefficient Evaluation

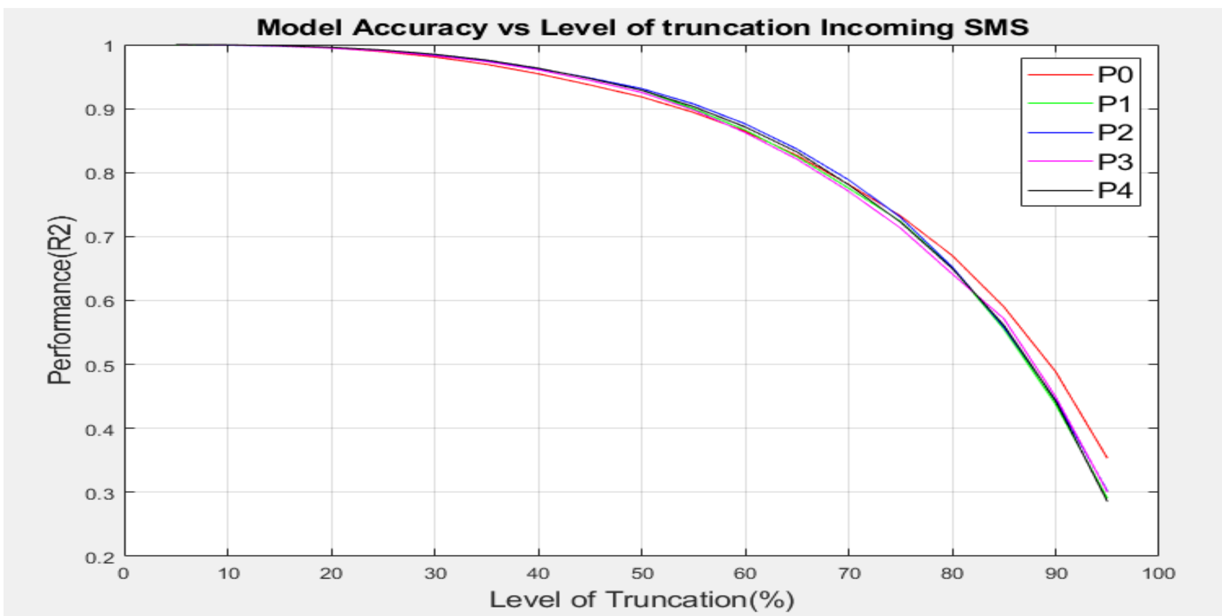

Figure 5- 4 Incoming SMS Phase Evaluation

The results show that the model performance of the corresponding coefficients and phases sensitive to the level of truncation for both incoming SMS and outgoing SMS. As it is shown in the above figure, the level of performance and level of truncation is inversely related.

Setting the coefficient of determination value to 0.95 as a target performance, the combination of truncation level for different parameters of the model for outgoing SMS and incoming SMS are presented in Tables 5-2 and 5-3, respectively. For example, the target performance R^2 set to be 0.95, the coefficient one (C1) parameter the level of truncation to be 75% and we use only 25%.

Table 5- 2 Outgoing SMS Truncation level

Coefficients	C0	C1	C2	C3	C4	C5	P0	P1	P2	P3	P4
Truncation Level in (%)	75	75	72	61	74	64	44	42	41	43	44

Table 5- 3 Incoming SMS Truncation level

Coefficients	C0	C1	C2	C3	C4	C5	P0	P1	P2	P3	P4
Truncation Level in (%)	72	70	71	60	69	72	49	45	45	44	47

5.2 Discussion

SMS distribution study in [6] and [7] used statistical distribution like cumulative distribution, probability distribution, Weibull and Lognormal to understand SMS traffic. Unlike the above researches, this research is done in a deterministic approach to study the traffic distribution in space and time based on Fourier Transform.

Knowing the SMS traffic distribution plays a great role in identifying the distribution of customers within specific time and place which in turn helps SMS advertising campaigns to target areas with high SMS service traffic to promote their advertisements in a more effective way. Therefore, the research first prepared a model of SMS traffic distribution to capture the real SMS traffic distribution. Then, the model helped in analyzing the customer's general SMS usage behaviour in time and space.

The distribution of SMS traffic based on time and location can be seen from the spatial-temporal model in Figure 5-5.

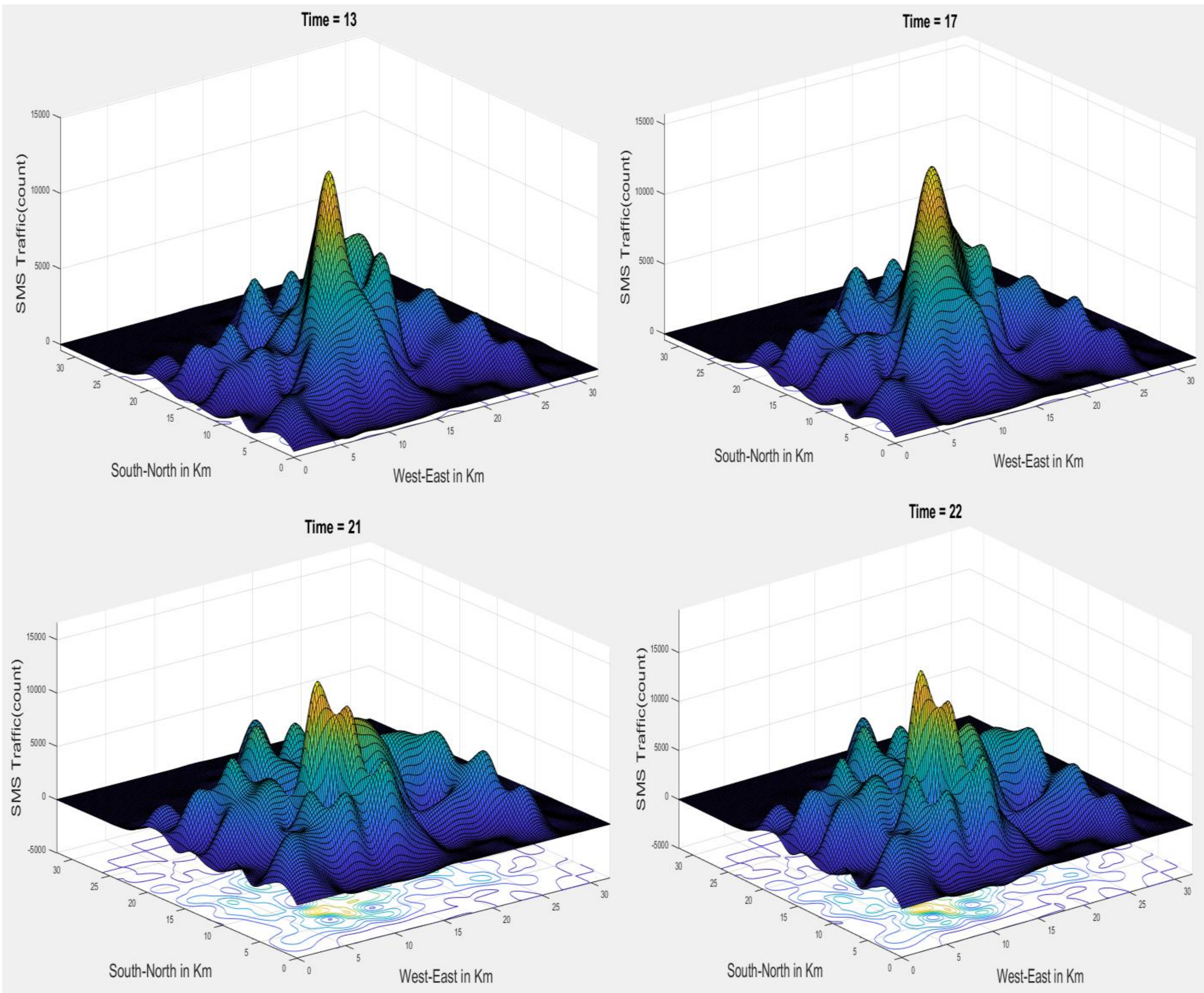

Figure 5- 5 SMS Outgoing model output at different time

From the above SMS traffic models, it is observed that central Addis Ababa city utilizes more SMS service than other areas in the city from 1 PM up to 5 PM. But all parts of the city have similar fashion of SMS traffic during night hours (9 PM and 10 PM).

Based on the traffic distribution, it is recommended that the company or business partner target central of the city to advertise their products and services during the day time.

In comparing incoming SMS and outgoing SMS at the same time and location, the utilization of the incoming SMS traffic is higher than the outgoing SMS. To visualize the outgoing and incoming SMS Figures 5-6 and 5-7, have shown respectively. The customer trends shown that more SMS receive from individual and advertising applications.

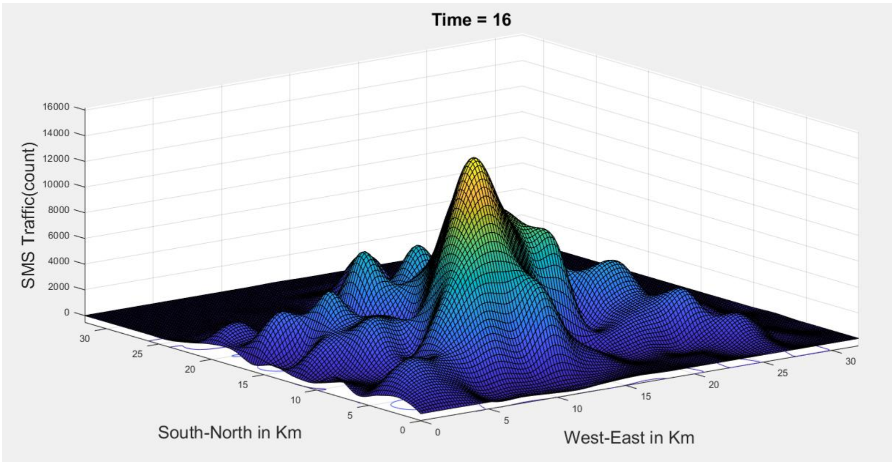

Figure 5- 6 Outgoing SMS at 4 pm

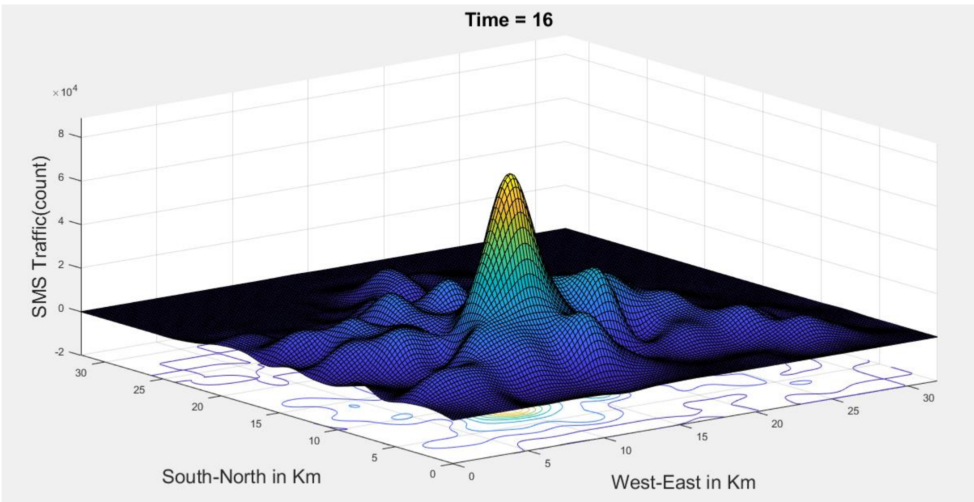

Figure 5- 7 Incoming SMS at 4 pm at 10^4 scale

SMS usage variation in a different location with 24 hours based on the average of a week data; as a sample, we use Legehar (central of the city) and Yeka Kotebe (Northen East direction of the city) in Figures 5-8 and 5-9. As shown in the figure, the red colour shows the incoming traffic and the blue one is outgoing traffic.

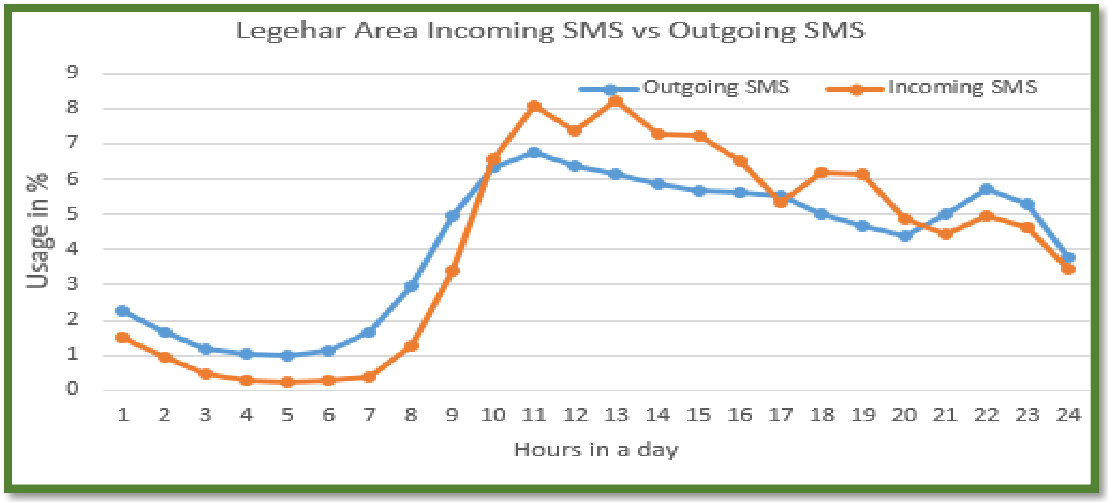

Figure 5- 8 Usage behaviour at Leghar area

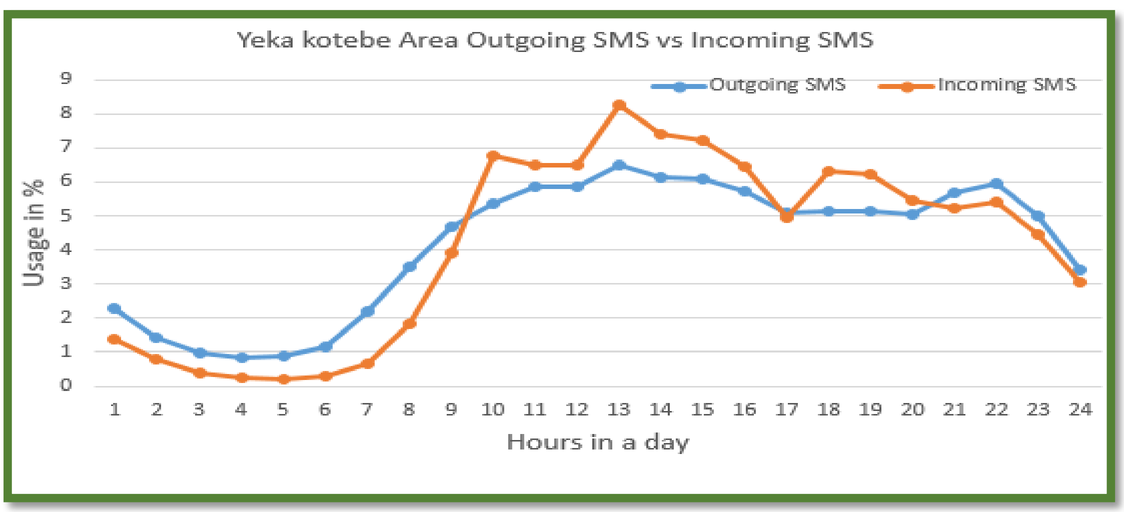

Figure 5- 9 Usage behaviour at Yeka Kotebe area

In the above figure, early in the morning time, the outgoing traffic is higher than the incoming traffic until 4 am. In the middle of the day, the incoming traffic is higher than the outgoing traffic until 8 pm. As observed, the customer usage behaviour of sending and receiving SMS is high from 10 AM up to 4 PM. Thus, it is a better marketing target in terms of time and location. Based on Ethio Telecom rule, sending an advertizement during night time after 6 PM is not allowed.

As shown in the sample, SMS usage behaviour of two different locations is presented in Figures 5-10 and 5-11 based on 24 hours average of a week data;

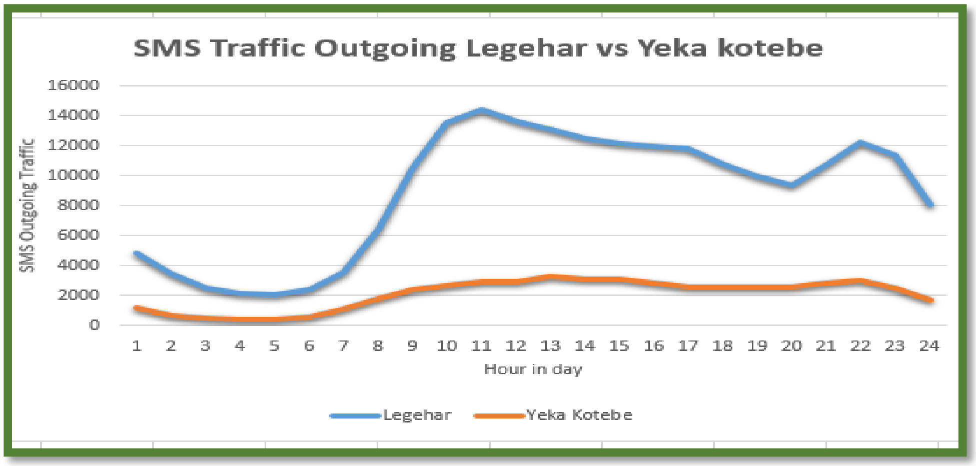

Figure 5- 10 Outgoing SMS Traffic

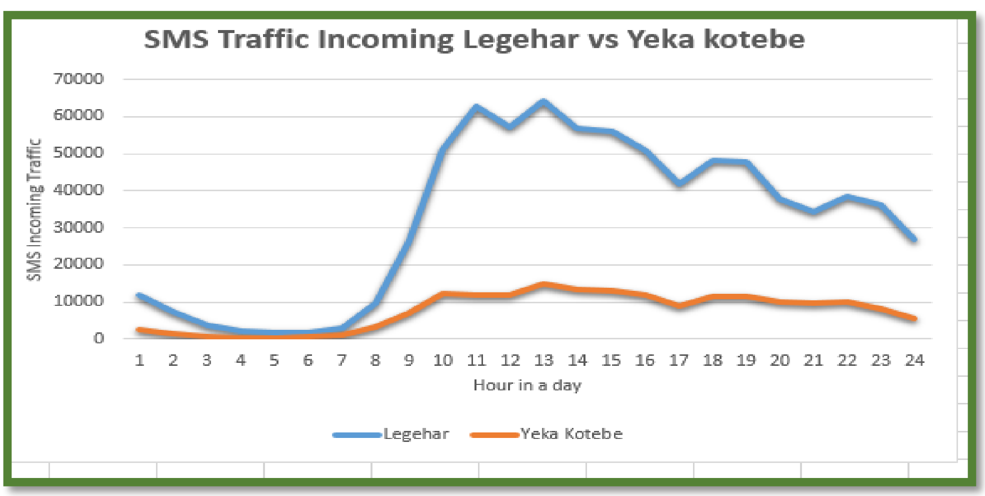

Figure 5- 11 Incoming SMS Traffic

As shown in the figure, the blue colour shows the Legehar area and the red one is the Yeka Kotebe area.

The usage behaviour of SMS traffic Legehar area is more utilize in terms of the number of SMS traffic count both in incoming and outgoing traffic. Therefore, the company or business partner can target the specific place and time to address many customers for those advertising.

5.3 Correlation Analysis of Incoming and Outgoing SMS

Correlation is an analysis involving exactly two variables, measures the strength of association and the direction of the relationship. By standardizing measures, correlation is also able to measure the degree to which the variables tend to move together.

One of the correlation analysis methods is the Pearson correlation. Pearson correlation measures the linear relationship between two continuous variables. Firstly, it is observed that the circles on the scatterplot are reasonably closely scattered about an underlying straight line. Thus, there is a linear relationship between the two variable. There appears to be a positive correlation between the variable. In the Figures 5-12 represent the scatterplot of sample data.

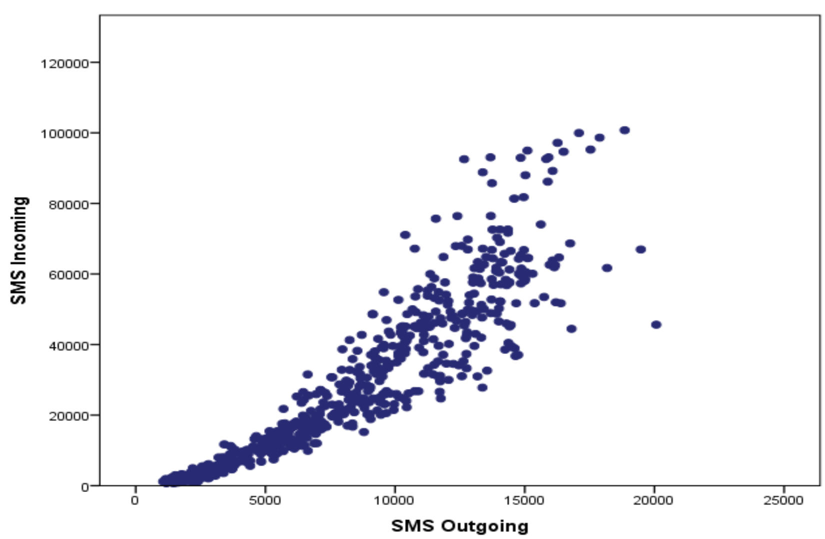

Figure 5- 12 Scatter plot of sample data

Therefore, using Pearson correlation to calculate a coefficient requires the assumption that the relationship between the two variables is linear. The absolute value of Pearson "r" is used to measure the degree of relationship between two variables [38] and [39].

If the coefficient value lies between ± 0.5 and ± 1, then it is said to be a strong correlation or high degree. If the value lies between ± 0.3 and ± 0.49, then it is said to be a medium correlation or moderate degree. When the value lies below ± 0.29, then it is said to be a small correlation or low degree. Whereas, the value is zero (no correlation) [38] [40].

In mathematics and statistics, covariance is the measure of the relationship between two random variables. The matric evaluates how much, to what extent, the variable change together, that is represented in Equation (5-2).

$$Cov(X,Y) = \frac{\sum(X_i - \bar{X})(Y_j - \bar{Y})}{n-1} \quad (5\text{- }2)$$

X_i and Y_j is the values of the X variable and Y variable respectively. $\bar{X}$ *and* $\bar{Y}$ mean (average) of the X and Y variable and n is the number of the data.

On the other hand, correlatio**n** measures the strength of the relationship between variables. To calculate the correlation coefficient for two variables correlation is used in Equation (5-3).

$$p(X,Y) = \frac{Cov(X,Y)}{\sigma_X \sigma_Y} \quad (5\text{- }3)$$

Where, p(X,Y) is the correlation between the variable X and Y, Cov(X,Y) is the covariance between the variable X and Y, σ_X and σ_Y is the standard deviation of X-variable and Y-variable respectively.

In this research, the correlation between outgoing SMS and incoming SMS is analyzed for investigating the fact that one's increase in magnitude also affects the increment of the other. Correlation between incoming and outgoing SMS was recognized using randomly selected sample areas to understand the kind of relationship with the location that exists between incoming and outgoing SMS are presented as follows.

The sample area one and two has coverage of 4kmX4km each. Whereas sample area three has coverage of 6kmX6km. The location of sample area one around central Addis Ababa; area two around CMC, Samit and Kotebe; area three around Saris Abo, Nifaselk and Lafto. The data used has a total sum of three sample areas in a one-week recorded data within an hourly interval. The total sum of recorded data in area one, two and three is 201,598, 63,904 and 66,972 respectively.

By using these recorded data's, the correlation coefficient of incoming and outgoing SMS in area one, area two and area three are is 0.921, 0.806, and 0.832 respectively. Thus, the correlation results of all three areas indicate that there is a high correlation between incoming and outgoing SMS. This high correlation demonstrates an increase in the magnitude of incoming SMS also results in the increment of outgoing SMS and vice versa. It can generally be concluded that incoming and outgoing SMS in all areas is directly proportional to each other.

The summary of the three sample areas is summarizes based on the correlation coefficient result and the ratio of incoming and outgoing SMS in each sample areas as shown in Table 5-4 below.

Table 5- 4 Correlation Result

Sample Area	Equations	Correlation Coefficient	R^2	Ratio Outgoing vs Incoming	Coverage
One (Central Addis Ababa)	Linear	0.921	0.848	1:3.7	4kmX4km
Two (CMC, Submit and Kotebe)	Linear	0.806	0.749	1:3	4kmX4km
Three (Saris Abo, Nifaselk and Lafto)	Linear	0.832	0.789	1:3	6kmX6km

The results of the three sample areas are presented in Table 5-4, it is seen that the sample area one has the highest correlation coefficient. This implies that there is a strong relationship between incoming and outgoing SMS and an increase in incoming SMS will strongly affect the increment in outgoing SMS. Sample area three is the second higher correlated area and sample area two holds the least correlated area of the three random sample areas taken. Its concludes that sample area one is a higher correlation result both the incoming and outgoing traffic than the other two sample areas. In addition, R^2 indicates that there is a linear relationship between the two variables (incoming SMS and outgoing SMS) to all sample area.

In the Figures 5-13 represent the correlation coefficient, R^2, in the sample area one, linear graph respectively.

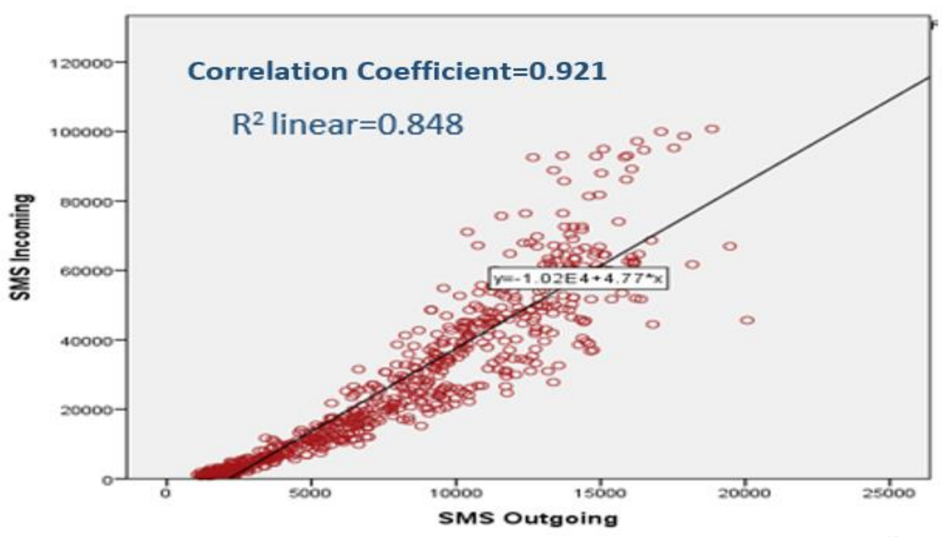

Figure 5- 13 Sample area one linear correlation

Figures 5-14 represent the correlation coefficient, R^2, in the sample area two, linear graph respectively.

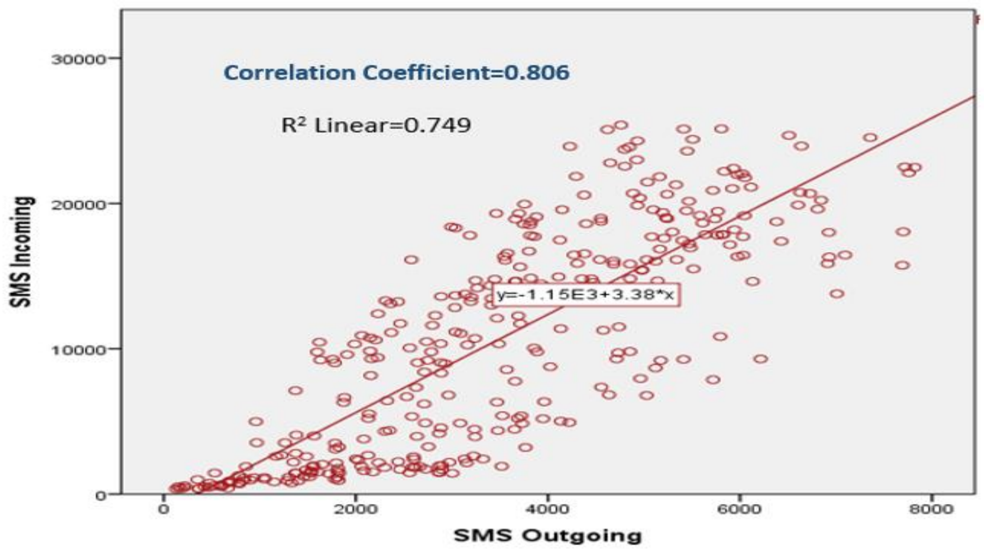

Figure 5- 14 Sample area two linear correlation

The sample area three, correlation coefficient, R^2 linear, is shown in Figure 5-15.

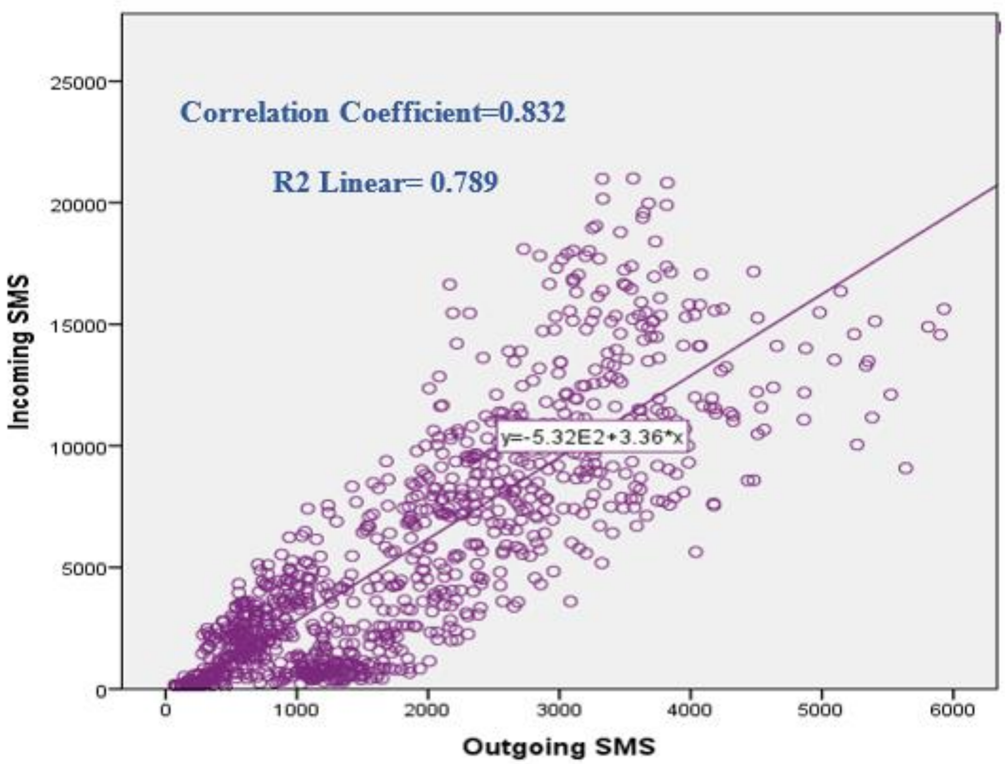

Figure 5- 15 Sample area three linear correlation

5.4 The analysis of responding customers for SMS advertising

Studying the SMS sending and receiving behaviours of SMS advertisement responding customers helps to gain insight on customer's responses to SMS advertisements in accordance with their SMS usage trend. Finally, the general SMS usage trend of customers that respond to SMS advertisements was analyzed. In order to find out the effectiveness of SMS advertising analysis was made on the amount of response and non-response of the traffic.

5.4.1 SMS Advertising Response Vs Non-Response

Analysis of SMS advertising response helps how much the SMS advertisement sent every day is achieving its goal. Knowing the effectiveness of SMS advertising, in turn helps SMS advertising campaigns get an insight into improving SMS advertising.

As a sample, a donation advertising was used to make the analysis of SMS advertisement response and non-response amount in percentage. The SMS advertisement response and non-response customer in percentage are demonstrated in Figure 5-17.

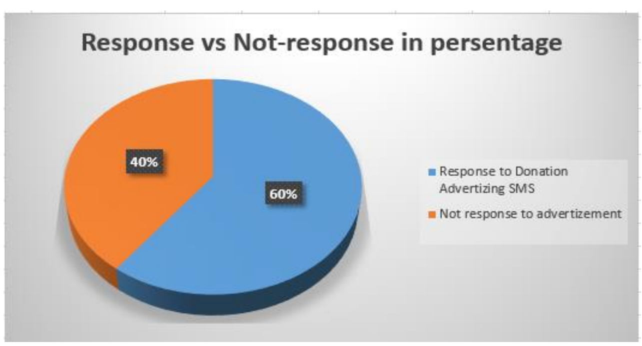

Figure 5- 16 Response vs Not-Response

Based on the analysis shown above, 60% of the customers receiving the SMS advertising response while the rest 40% of the customers do not a response to the SMS advertisement. The ratio of customers responding to SMS advertisements with the total SMS advertisements sent to whole customers is 1:1.7. From customers responding to SMS advertisement, 25% of them respond more than two times in three days.

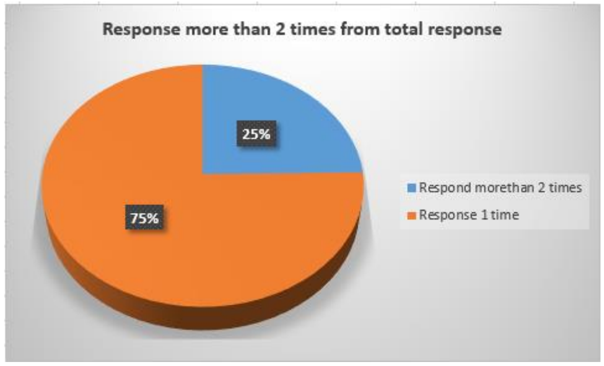

Figure 5- 17 Response more than two times

5.4.2 SMS Usage Behaviour Trends

In this section, the SMS usage behaviour of SMS advertisements responding customer's usage trends is analyzing. Sample of SMS advertisement responding customers were used to analyzing their SMS usage behaviours and their SMS sending and receiving trend with other customers. Figure 5-18 illustrating SMS advertisement responding to customer's SMS usage trend.

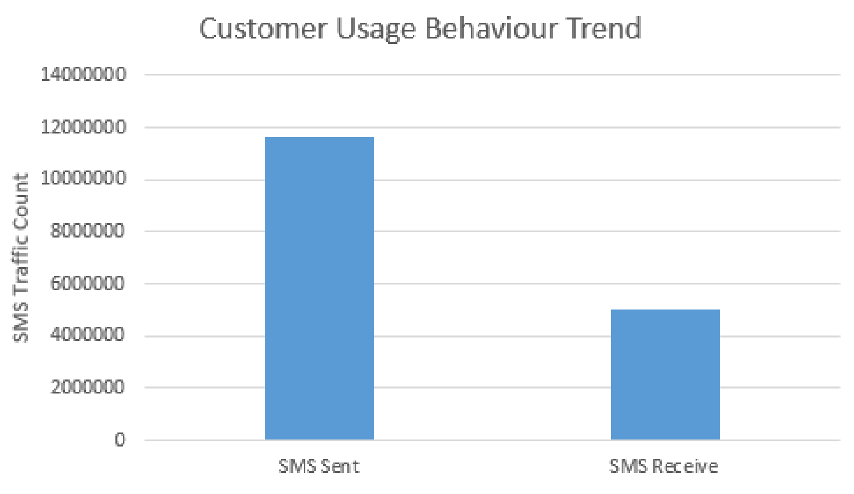

Figure 5- 18 Customer behaviour trend

Based on the figure, the SMS advertisement responding customers have SMS usage trend of sending more SMS than they receive. This result demonstrates that customers use SMS service frequently. Thus, it is preferable for SMS advertising campaigns to target areas with customers who use SMS service more frequently. For instance, the spatiotemporal model of outgoing SMS at a different time which was shown in the previous section demonstrates areas with high SMS frequency at a specific time and location. Using these spatiotemporal models SMS advertising campaigns can get an insight on where to send the SMS advertisement and at what time. To sum up the analysis, it is advisable for SMS advertising campaigns to target areas with high and frequent SMS service using customers to increase their effectiveness.

5.4.3 Incoming vs Outgoing SMS Correlation of SMS Advertisement Responding Customers

In this section, to see SMS sending and receiving trends of customers responding to SMS advertisements and shortcodes; the correlation between incoming and outgoing SMS was done.

In Ethio Telecom, service or content providers have distinguishing 3-digit and 4-digit shortcode and its number is 1,323 shortcodes were identified in the system. Furthermore, from the most active short code numbers, 87 shortcodes are identified from the total for this analysis. Customers responding for the sample shortcodes within a month were found 264,774 number of the customer. The general SMS trend of the above identified 264,774 customers was collected and taken from CDR as an input to find the correlation between outgoing and incoming SMS.

Correlation between sent and received SMS for the above identified sample customers based on their general usage is demonstrated in Figure 5-19 below.

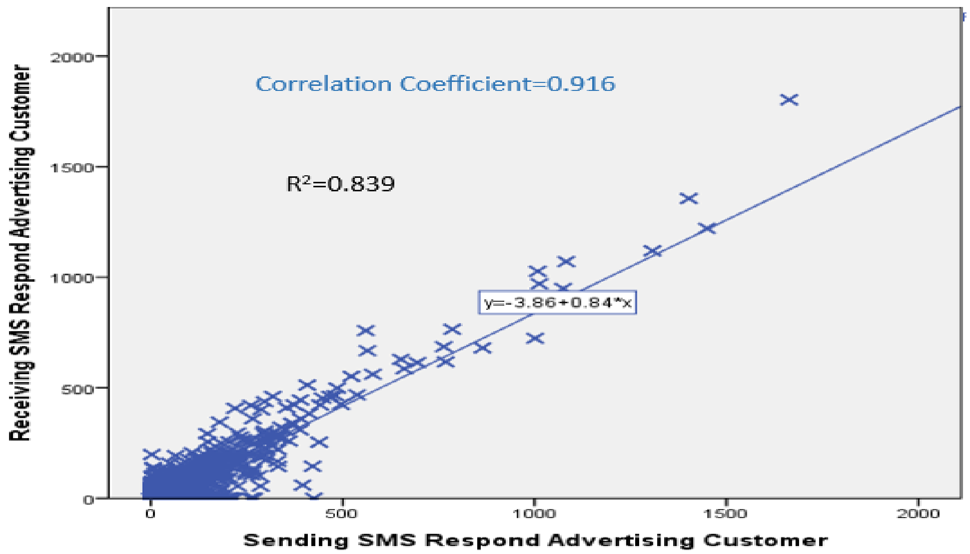

Figure 5- 19 SMS Advertisement Responding Customer Usage Trend Correlation

Based on the above figure, it is seen that the correlation relationship is linear. Moreover, it shows that the correlation coefficient result is 0.916. According to the correlation coefficient standard, there is a strong correlation between sent and received SMS of sample customers that replied to shortcodes. The ratio of receiving to sending SMS is 1:2.3. This analysis helps the company to give an insight about the customer's trends and behaviours of SMS usage.

Chapter VI: Conclusions and Recommendations

6.1 Conclusions

In previous researches, SMS distribution was studied only by statistical method. In this research, SMS distribution is studied using deterministic approach with time and location based on the Fourier Transform method.

For this research, the SMS traffic dataset was collected from the Ethio Telecom network performance system. With the intention of understanding SMS customers' behaviour, the research used the spatiotemporal SMS traffic distribution model in the city of Addis Ababa. The modeling was performed on SMS outgoing traffic and SMS incoming traffic separately. Based on the model, five customer SMS usage patterns that determine the daily traffic variation in the network related to the users' behaviour were identified.

Afterwards, the correlation between incoming and outgoing SMS was analyzed. The correlation implied that there is a strong relationship between incoming and outgoing SMS and an increase in incoming SMS will strongly affect the increment of outgoing SMS. The SMS usage trends of SMS advertisements responding customers were analyzed. The result showed that these customers have SMS usage trend of sending more SMS than they receive. Thus, it is advisable for SMS advertising campaigns to target areas with high and frequent SMS service using customers to increase their effectiveness.

The model used the city of Addis Ababa as a case study for the research. However, a similar approach can be followed for different coverage areas even as big as the whole country.

6.2 Recommendations

Based on the research the following are recommend:

- To develop a spatiotemporal SMS traffic distribution model based on Fourier Transform to study customer usage behaviour.
- To include Location information flags in Ethio Telecom SMS CDR to know the location information of SMS distribution of individual users.
- Setting peak and off-peak hours of utilization based on the traffic distribution model for traffic optimization and to gain customer satisfaction in terms of price.

Future research recommendation:

- Types of advertisements based on location study.
- Short Message Service Center (SMSC) traffic conjunction study based on the SMS traffic distribution model.

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Appendices

SMS outgoing, Matrix of traffic coefficient(C1)

0	7	0	6	36	0	47	0	14	0	0	0	0	0	0	0	0
253	459	208	0	29	3	123	4	19	0	0	18	0	335	0	0	0
134	764	874	946	1615	1247	1908	868	431	29	143	37	305	755	243	0	0
0	308	791	2300	2210	3690	2808	1168	251	567	678	726	1210	64	0	13	0
309	107	846	1026	3838	5128	5104	2594	2984	455	1129	1299	755	529	32	14	19
0	237	1696	1456	1224	4499	4324	3713	3031	2746	1344	1685	537	380	348	0	3
0	1205	1158	1337	1440	2138	2922	3616	3350	1686	1423	279	500	86	168	13	4
124	333	1660	629	1170	1690	1360	1387	106	0	211	487	324	335	46	2	0
6	926	742	384	2227	1347	2124	1186	472	137	9	28	0	153	0	0	0
217	377	463	524	1259	1095	553	795	15	0	10	6	7	0	0	0	0
184	536	8	117	0	670	288	137	0	92	32	1	0	21	0	0	0
54	29	0	0	0	70	515	1088	158	34	0	15	0	0	0	0	0
0	0	9	0	0	0	176	1235	409	174	0	101	0	0	0	0	0
0	0	0	0	29	0	37	475	466	305	292	0	0	0	0	0	0
0	0	0	0	0	0	0	38	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0

SMS outgoing, Matrix of traffic coefficient(C2)

0	2	0	2	15	0	32	0	22	0	0	0	0	0	0	0	0
234	455	192	0	47	1	144	1	11	0	0	53	0	199	0	0	0
68	832	831	961	1262	984	1619	761	339	19	109	38	353	702	207	0	0
0	173	453	1738	1629	2378	1349	1024	239	370	703	727	1124	88	0	13	0
252	96	437	849	3078	2042	1485	1887	1007	466	499	1051	547	493	34	14	19
0	276	1523	1264	882	2418	1292	1701	1291	1475	1205	1619	465	332	280	0	5
0	900	1005	1251	979	1327	1981	1273	1121	1260	1157	250	585	107	152	7	2
120	157	1391	679	1272	1224	929	876	286	0	171	212	282	265	42	2	0
4	761	722	333	1769	1105	1384	1027	437	111	30	21	0	120	0	0	0
194	237	471	408	1085	828	607	714	9	0	25	2	8	0	0	0	0
187	469	3	95	0	705	190	177	0	54	21	0	0	11	0	0	0
28	13	0	0	0	72	405	759	144	46	0	12	0	0	0	0	0
0	0	16	0	0	0	186	1233	456	187	0	68	0	0	0	0	0
0	0	0	0	10	0	22	396	285	304	272	0	0	0	0	0	0
0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0

SMS outgoing, Matrix of traffic coefficient(C3)

0	3	0	3	20	0	16	0	9	0	0	0	0	0	0	0	0
135	229	65	1	22	1	86	2	2	0	0	23	0	52	0	0	0
28	455	505	380	828	410	1005	435	226	13	97	6	132	243	62	0	0
0	136	345	1306	853	1053	265	566	157	303	321	588	472	39	0	2	0
117	46	391	622	1707	1127	268	815	195	109	133	347	216	188	17	8	4
0	158	922	708	230	226	896	290	174	176	685	682	182	126	134	0	2
0	607	659	628	182	259	621	63	457	554	674	149	244	75	69	4	2
69	286	797	359	582	538	339	429	204	0	118	92	136	134	20	2	0
5	363	346	100	713	412	549	468	238	47	10	2	0	52	0	0	0
108	74	304	221	553	303	269	404	5	0	4	0	3	0	0	0	0
101	274	2	61	0	430	39	84	0	26	12	0	0	4	0	0	0
15	16	0	0	0	29	243	379	115	36	0	8	0	0	0	0	0
0	0	3	0	0	0	82	533	223	15	0	38	0	0	0	0	0
0	0	0	0	19	0	7	280	148	100	111	0	0	0	0	0	0
0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0

SMS outgoing, Matrix of traffic coefficient(C4)

0	2	0	4	16	0	10	0	6	0	0	0	0	0	0	0	0
48	233	83	1	11	1	37	2	6	0	0	14	0	66	0	0	0
40	320	328	193	531	373	727	320	125	9	75	17	64	165	106	0	0
0	78	186	775	740	1105	581	462	91	203	269	379	315	18	0	5	0
92	33	207	318	1233	1100	858	742	505	149	117	312	89	154	1	8	6
0	61	489	431	426	1289	834	869	614	682	479	515	161	83	100	0	2
0	278	331	451	251	669	802	564	585	505	316	84	143	44	39	3	0
72	33	445	272	466	520	428	430	124	0	77	115	81	87	14	2	0
3	255	220	110	579	277	534	364	143	22	3	8	0	19	0	0	0
90	84	167	113	367	337	318	284	11	0	16	2	1	0	0	0	0
46	179	3	14	0	174	63	89	0	16	13	0	0	5	0	0	0
19	8	0	0	0	25	181	284	73	16	0	6	0	0	0	0	0
0	0	5	0	0	0	62	438	179	59	0	27	0	0	0	0	0
0	0	0	0	9	0	14	195	147	88	72	0	0	0	0	0	0
0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0

SMS outgoing, Matrix of traffic coefficient(C5)

0	1	0	3	24	0	18	0	4	0	0	0	0	0	0	0	0
24	94	41	0	14	1	46	1	3	0	0	13	0	28	0	0	0
30	201	266	190	315	367	532	171	89	7	25	20	98	75	15	0	0
0	68	130	358	208	630	217	261	81	152	163	157	288	21	0	7	0
45	76	77	201	658	272	170	520	280	112	98	217	140	55	4	4	3
0	38	145	243	171	293	565	269	142	169	310	302	111	54	92	0	1
0	35	193	269	113	180	341	54	234	199	292	54	117	30	22	5	1
21	88	301	138	257	296	145	126	75	0	42	80	64	38	8	2	0
2	122	77	83	294	221	264	173	65	26	2	3	0	17	0	0	0
28	42	93	37	228	194	148	163	12	0	2	2	1	0	0	0	0
45	85	2	26	0	188	45	48	0	28	2	0	0	5	0	0	0
19	4	0	0	0	35	133	246	31	9	0	5	0	0	0	0	0
0	0	7	0	0	0	36	311	128	39	0	10	0	0	0	0	0
0	0	0	0	9	0	4	154	110	76	60	0	0	0	0	0	0
0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0

SMS outgoing, Matrix of Phase in rad (P1)

0.0	-6.5	0.0	0.2	-0.9	0.0	0.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	1.3	1.0	5.6	1.0	1.2	1.8	-1.2	4.9	0.0	0.0	1.8	0.0	0.8	0.0	0.0	0.0
0.5	0.8	0.8	0.8	0.6	0.7	0.7	1.3	0.7	2.4	10.2	0.4	0.3	1.2	0.5	0.0	0.0
0.0	0.4	-11.7	0.1	3.6	0.6	3.5	0.6	0.9	1.1	0.6	0.8	1.4	-11.3	0.0	1.2	0.0
1.2	-11.5	-11.6	0.6	0.6	-0.5	-2.3	0.6	0.1	0.6	3.7	1.2	0.8	1.2	7.4	5.9	4.7
0.0	0.8	0.0	0.7	3.4	0.4	-0.2	0.3	3.9	6.8	0.6	0.6	0.5	0.5	0.8	0.0	1.6
0.0	0.1	0.6	0.6	5.8	3.6	0.4	0.1	0.8	-11.6	0.7	0.6	0.0	-11.7	0.9	3.2	0.8
-11.4	-10.7	0.7	0.7	0.7	0.5	0.5	0.4	-11.6	0.0	1.4	2.3	0.6	0.8	0.8	-0.5	0.0
-0.3	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.7	1.5	-3.1	-2.0	0.0	5.6	0.0	0.0	0.0
0.8	0.9	0.7	0.7	0.7	0.6	0.5	0.7	-4.2	0.0	4.1	-4.0	11.9	0.0	0.0	0.0	0.0
1.3	0.7	5.5	1.5	0.0	1.4	-1.4	5.0	0.0	-1.2	-0.2	-2.7	0.0	3.2	0.0	0.0	0.0
-0.2	-11.7	0.0	0.0	0.0	3.7	0.7	0.7	0.7	-12.2	0.0	-5.1	0.0	0.0	0.0	0.0	0.0
0.0	0.0	12.4	0.0	0.0	0.0	0.5	0.7	0.8	0.3	0.0	5.7	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-0.9	0.0	1.4	0.8	0.6	0.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS outgoing, Matrix of Phase in rad (P2)

0.0	-10.6	0.0	-0.1	3.9	0.0	1.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9	1.4	-0.1	15.0	1.1	-2.6	2.5	-3.3	8.0	0.0	0.0	2.8	0.0	1.1	0.0	0.0	0.0
0.4	0.3	0.7	0.6	0.5	0.4	0.5	1.4	0.6	3.0	15.0	-0.5	-0.8	1.2	-0.1	0.0	0.0
0.0	0.1	-17.9	-0.4	5.1	0.3	5.0	0.5	0.5	0.7	0.7	0.6	1.2	-17.9	0.0	0.2	0.0
1.0	-17.3	-17.7	0.4	0.4	-0.5	-6.2	0.3	-0.9	0.4	5.4	1.3	0.4	1.5	10.3	8.4	6.3
0.0	0.3	-0.4	0.5	3.9	-1.1	-2.3	-0.4	5.9	9.2	0.5	0.3	0.0	0.3	0.2	0.0	-3.1
0.0	-0.4	0.6	0.6	8.6	4.9	0.4	-0.3	0.0	-18.3	0.6	0.5	-0.5	-18.3	1.4	5.4	-3.8
-18.7	-17.9	0.5	0.5	0.4	0.4	0.4	0.2	-18.5	0.0	1.6	3.0	0.4	0.3	0.1	-4.1	0.0
0.4	0.4	0.4	0.3	0.5	0.4	0.7	0.3	0.4	1.6	2.9	-5.4	0.0	8.4	0.0	0.0	0.0
0.3	0.4	0.4	0.6	0.4	0.5	0.2	0.6	-1.7	0.0	4.4	1.9	16.9	0.0	0.0	0.0	0.0
1.1	0.2	5.8	1.8	0.0	1.3	-0.9	7.2	0.0	-3.4	0.8	0.5	0.0	1.0	0.0	0.0	0.0
-0.5	-17.9	0.0	0.0	0.0	5.2	0.9	0.5	0.3	-18.5	0.0	-4.7	0.0	0.0	0.0	0.0	0.0
0.0	0.0	13.5	0.0	0.0	0.0	0.0	0.5	0.5	-0.6	0.0	8.2	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-0.9	0.0	1.4	0.8	0.6	0.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS outgoing, Matrix of Phase in rad (P3)

0.0	-13.9	0.0	-3.4	7.9	0.0	-0.1	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.4	2.3	1.0	15.1	2.5	2.2	3.6	-9.0	10.1	0.0	0.0	3.7	0.0	1.6	0.0	0.0	0.0
0.8	1.1	1.3	0.9	0.8	1.2	0.9	2.1	1.0	3.9	19.9	0.2	-0.2	2.2	0.5	0.0	0.0
0.0	-0.4	-24.1	-0.4	7.0	0.6	7.0	0.8	1.2	1.1	1.1	1.2	2.2	-24.2	0.0	-4.0	0.0
2.6	-24.3	-23.9	0.6	0.5	-0.7	-4.4	0.8	-0.5	0.7	7.5	1.7	1.1	2.1	13.8	11.4	9.0
0.0	1.3	-0.6	0.6	6.0	0.8	0.0	0.6	7.7	13.4	0.8	0.7	0.9	0.8	0.9	0.0	2.6
0.0	-0.5	0.8	0.9	11.3	7.2	0.8	0.6	2.0	-23.8	0.8	0.9	-0.5	-23.7	1.4	2.8	1.4
-24.2	-27.0	0.9	1.0	1.0	0.7	0.7	0.7	-23.1	0.0	2.3	5.6	1.5	1.0	1.2	-1.2	0.0
-3.8	0.8	0.6	0.4	0.8	0.6	1.0	0.9	0.9	2.1	3.4	-3.8	0.0	11.2	0.0	0.0	0.0
0.9	0.9	0.7	0.6	1.0	1.1	0.8	0.9	-0.6	0.0	7.7	-1.8	24.4	0.0	0.0	0.0	0.0
2.4	0.9	13.9	-2.9	0.0	2.0	-2.3	10.5	0.0	-2.6	0.0	-1.8	0.0	7.0	0.0	0.0	0.0
0.4	-23.3	0.0	0.0	0.0	6.1	0.8	1.1	1.1	-25.0	0.0	-4.1	0.0	0.0	0.0	0.0	0.0
0.0	0.0	23.4	0.0	0.0	0.0	0.5	1.0	1.2	0.3	0.0	11.1	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-2.7	0.0	2.0	1.0	0.6	1.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS outgoing, Matrix of Phase in rad (P4)

0.0	-19.7	0.0	-0.2	7.1	0.0	1.5	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7	2.4	-5.0	21.1	2.0	-1.0	4.0	-8.6	11.3	0.0	0.0	4.7	0.0	1.1	0.0	0.0	0.0
-3.2	0.8	1.2	0.8	1.1	0.7	0.9	2.3	0.7	4.6	24.9	0.8	-0.8	1.9	-0.2	0.0	0.0
0.0	-0.1	-30.3	-0.6	8.7	0.5	8.2	0.6	1.0	1.0	0.8	0.9	2.4	-30.3	0.0	1.6	0.0
1.2	-28.9	-29.6	0.3	0.4	-0.1	-6.3	0.3	-0.8	0.4	8.4	1.9	0.8	2.6	14.7	13.7	9.7
0.0	0.0	-0.4	1.0	7.3	-0.1	-1.5	0.1	9.7	15.9	0.7	0.7	0.8	0.4	0.8	0.0	-2.6
0.0	0.0	1.4	1.0	13.9	8.9	0.3	-1.1	1.7	-30.1	0.7	0.6	-0.9	-29.8	1.8	7.1	-3.9
-30.1	-30.5	0.8	0.8	0.5	0.7	0.6	0.8	-29.5	0.0	2.5	5.9	0.4	0.5	1.3	-4.8	0.0
-2.9	0.6	0.5	0.9	0.6	0.6	0.9	0.6	1.4	3.0	4.5	-9.7	0.0	14.1	0.0	0.0	0.0
1.3	1.3	1.8	2.0	0.9	0.9	0.8	0.9	1.1	0.0	7.9	1.8	30.6	0.0	0.0	0.0	0.0
2.7	1.0	13.0	2.7	0.0	2.2	-3.1	12.1	0.0	-4.5	-0.7	0.3	0.0	3.4	0.0	0.0	0.0
-0.4	-30.3	0.0	0.0	0.0	8.0	1.2	0.8	1.5	-31.6	0.0	-3.6	0.0	0.0	0.0	0.0	0.0
0.0	0.0	29.3	0.0	0.0	0.0	0.1	1.0	0.5	0.4	0.0	13.3	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-8.0	0.0	-2.1	0.7	0.8	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS Incoming, Matrix of traffic coefficient (C1)

0	42	0	17	158	0	250	0	105	0	0	0	0	0	0	0	0
1309	3193	2014	6	289	24	653	26	109	0	0	456	0	2046	0	0	0
961	5032	5336	4929	6338	7222	10559	4302	1712	123	725	219	2338	4959	1001	0	0
0	1202	1943	8316	11904	17364	13584	5841	1033	2177	4164	4216	7065	372	0	154	0
2333	441	2899	3471	18019	39325	23866	12138	18113	2972	5646	6668	4609	2982	100	99	118
0	1446	7117	6312	6061	24424	18958	17826	14892	13342	7037	8569	2516	1752	1749	0	27
0	4866	5672	6952	5469	9681	15825	12358	12204	10464	7615	1392	3020	454	968	53	10
806	1313	9701	3817	6313	9386	7742	7124	580	0	973	2105	1474	2402	204	1	0
35	5934	3869	2118	11455	7095	12493	5756	2354	668	415	163	0	1294	0	0	0
1170	2479	2152	2287	5525	6795	4535	4102	81	0	183	52	58	0	0	0	0
1135	3706	41	633	0	4255	1671	1278	0	665	256	3	0	114	0	0	0
399	85	0	0	0	466	3210	7041	795	0	164	81	0	0	0	0	0
0	0	93	0	0	0	955	7401	2916	909	0	613	0	0	0	0	0
0	0	0	0	80	0	129	2409	3182	2051	1832	0	0	0	0	0	0
0	0	0	0	0	0	0	207	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	57	0	0	0	0	0	0	0	0	0

SMS Incoming, Matrix of traffic coefficient (C2)

0	35	0	19	94	0	121	0	71	0	0	0	0	0	0	0	0
768	1814	770	4	159	6	490	9	47	0	0	211	0	845	0	0	0
506	3368	3174	3382	4413	3944	6851	2975	1284	90	498	137	1483	3133	608	0	0
0	687	1630	5598	6585	9265	5388	4172	894	1906	2789	3096	5135	351	0	83	0
1061	266	1803	2797	11258	12361	6531	6891	4360	1785	2220	3905	2261	1942	78	70	66
0	1042	4911	4453	3386	10677	6132	6165	4997	5870	4883	5303	1743	1171	1186	0	20
0	3422	3697	4405	2559	4784	7306	3924	3473	4800	5498	899	2258	424	628	38	3
489	939	5401	2522	4294	5060	3679	3594	780	0	728	877	1102	1615	190	3	0
24	3409	2556	1187	6127	3956	6151	3816	1557	456	91	84	0	642	0	0	0
838	996	1442	1470	3703	3425	2710	2862	69	0	99	19	37	0	0	0	0
707	1968	22	423	0	3254	712	855	0	248	175	2	0	34	0	0	0
238	71	0	0	0	314	1798	3353	632	0	169	27	0	0	0	0	0
0	0	63	0	0	0	816	5013	1991	665	0	315	0	0	0	0	0
0	0	0	0	48	0	83	1648	1334	1295	1252	0	0	0	0	0	0
0	0	0	0	0	0	0	119	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0

SMS Incoming, Matrix of traffic coefficient (C3)

0	7	0	8	64	0	58	0	18	0	0	0	0	0	0	0	0
263	393	255	2	34	13	176	5	23	0	0	85	0	386	0	0	0
271	602	830	404	1150	437	1295	536	303	14	63	22	204	426	362	0	0
0	139	585	2592	794	1279	936	905	203	546	440	1094	747	35	0	18	0
186	166	780	906	2590	1235	3604	899	2501	290	610	467	449	239	23	9	21
0	63	1112	1000	311	3217	3852	1420	1416	1410	881	194	70	90	101	0	5
0	902	791	568	314	329	915	1158	335	757	1424	130	112	170	198	6	1
183	430	862	401	628	196	310	208	476	0	251	105	40	131	25	0	0
4	308	290	113	345	285	804	257	170	75	38	17	0	135	0	0	0
134	287	268	219	343	540	213	688	3	0	16	11	10	0	0	0	0
75	144	7	143	0	601	165	110	0	137	51	1	0	23	0	0	0
69	8	0	0	0	91	435	651	156	0	61	26	0	0	0	0	0
0	0	9	0	0	0	37	546	56	66	0	194	0	0	0	0	0
0	0	0	0	11	0	6	297	226	225	198	0	0	0	0	0	0
0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0

SMS Incoming, Matrix of traffic coefficient (C4)

0	12	0	20	64	0	32	0	33	0	0	0	0	0	0	0	0
115	685	358	1	29	14	145	4	10	0	0	46	0	276	0	0	0
342	1404	1084	1235	1926	1282	2480	1077	466	33	157	56	436	856	480	0	0
0	288	688	2720	2525	3054	1552	1472	333	818	1059	1274	1528	27	0	31	0
400	130	1021	1142	4286	3887	1623	2192	533	543	460	934	640	701	29	24	14
0	483	2034	1733	970	3554	2937	2191	1324	1939	1611	1793	556	355	379	0	6
0	1540	1452	1541	849	1830	2365	1261	1198	1541	1736	272	743	170	221	7	2
269	603	1920	817	1449	1722	1305	1345	361	0	292	469	345	539	61	2	0
6	1373	1111	376	2109	1257	2025	1248	559	151	57	35	0	179	0	0	0
367	363	625	590	1318	1087	1000	993	24	0	24	8	12	0	0	0	0
306	721	8	194	0	1194	219	331	0	132	26	2	0	24	0	0	0
112	38	0	0	0	118	657	1052	244	0	75	16	0	0	0	0	0
0	0	22	0	0	0	240	1591	748	156	0	150	0	0	0	0	0
0	0	0	0	17	0	19	609	488	537	433	0	0	0	0	0	0
0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0

SMS Incoming, Matrix of traffic coefficient (C5)

0	4	0	12	35	0	7	0	9	0	0	0	0	0	0	0	0
149	354	250	2	46	9	91	2	7	0	0	32	0	234	0	0	0
130	771	791	777	1191	968	1536	603	225	5	104	15	320	663	354	0	0
0	167	470	1868	1924	2955	1710	895	174	285	543	527	823	97	0	18	0
108	110	673	727	3511	3963	2319	1984	1823	389	680	936	527	373	5	13	20
0	259	1183	1267	988	2514	2862	1951	1757	1656	1245	1210	383	266	265	0	4
0	889	1042	1153	842	1472	2031	1356	1436	1467	1112	182	451	103	57	8	2
202	170	1629	558	1081	1479	1094	1292	191	0	119	234	224	259	38	1	0
1	925	664	289	1657	965	1512	838	345	89	32	26	0	114	0	0	0
188	213	351	315	834	842	646	535	24	0	32	11	9	0	0	0	0
164	580	5	60	0	518	159	167	0	45	23	2	0	15	0	0	0
50	15	0	0	0	62	436	758	126	0	46	14	0	0	0	0	0
0	0	13	0	0	0	137	999	449	168	0	57	0	0	0	0	0
0	0	0	0	17	0	22	331	334	295	217	0	0	0	0	0	0
0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0

SMS incoming, Matrix of Phase in rad (P1)

0.0	7.1	0.0	0.0	0.7	0.0	5.2	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.5	5.6	-0.3	1.4	-0.3	-0.1	5.4	-0.6	1.6	0.0	0.0	0.8	0.0	4.7	0.0	0.0	0.0
0.4	4.1	2.5	2.4	-9.7	2.0	2.4	2.5	1.0	2.1	6.8	1.2	-3.2	0.6	1.4	0.0	0.0
0.0	4.4	-10.8	-8.2	-1.6	-9.9	-3.1	2.5	2.6	1.1	0.9	4.6	2.1	-9.6	0.0	1.7	0.0
0.4	6.4	-11.9	-9.7	-9.8	0.7	-0.2	2.3	-0.1	-3.4	1.7	1.5	-3.2	3.6	1.2	1.4	3.4
0.0	2.4	-9.8	-9.7	-0.3	0.0	-0.2	-3.3	-1.2	0.1	2.4	1.3	1.3	-0.2	2.5	0.0	2.2
0.0	-9.8	2.4	2.4	-3.6	-2.0	0.1	-3.4	0.0	-3.5	2.6	2.4	2.4	1.2	5.3	2.5	0.9
-9.6	4.0	2.4	2.5	2.4	-3.6	-3.1	-5.2	0.5	0.0	1.1	0.1	2.5	7.1	7.1	-1.7	0.0
1.7	2.4	-9.7	-3.4	-3.5	-3.5	-3.4	2.3	4.0	5.2	-0.1	1.0	0.0	-1.3	0.0	0.0	0.0
2.4	-1.3	-8.2	3.9	2.5	-3.3	-0.4	2.6	1.7	0.0	1.5	0.8	1.0	0.0	0.0	0.0	0.0
2.4	-0.4	-13.1	3.8	0.0	2.6	-0.3	-0.5	0.0	1.3	0.4	-1.4	0.0	-0.1	0.0	0.0	0.0
3.7	-5.9	0.0	0.0	0.0	1.2	2.5	-3.3	1.0	0.0	-5.9	0.9	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.4	0.0	0.0	0.0	-3.1	2.5	-3.3	0.4	0.0	5.1	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	4.0	0.0	1.7	4.0	-2.9	4.2	5.7	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS incoming, Matrix of Phase in rad (P2)

0.0	11.0	0.0	-0.4	1.7	0.0	8.9	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.1	9.5	-2.8	-0.2	-3.6	-3.2	8.9	-5.1	-2.3	0.0	0.0	-4.3	0.0	2.3	0.0	0.0	0.0
-3.3	6.0	4.1	3.8	-14.8	4.1	3.7	3.9	1.6	3.5	10.2	-2.4	-9.4	-4.1	-0.7	0.0	0.0
0.0	7.4	-16.6	-12.5	-1.8	-14.1	-8.7	3.8	3.6	1.6	2.0	7.0	3.8	-15.1	0.0	-2.0	0.0
-3.9	6.1	-17.9	-14.8	-14.7	3.9	-3.4	4.2	-3.8	-9.3	-1.6	-2.5	-9.3	6.2	2.1	-1.3	1.8
0.0	3.1	-14.6	-14.7	-4.7	-3.4	-2.8	-8.1	-5.4	-3.5	3.8	-2.3	3.1	0.7	3.8	0.0	-1.9
0.0	-14.9	3.3	3.6	-8.9	-5.9	-4.3	-8.2	-3.9	-7.7	3.9	4.5	3.9	0.0	8.7	4.1	-2.5
-16.3	2.3	3.8	3.7	3.9	-4.7	-8.5	-8.0	-0.4	0.0	1.6	0.8	4.0	10.9	9.7	-3.7	0.0
-2.9	3.7	-15.2	-3.7	-9.7	-4.1	-9.8	3.6	6.2	8.4	-3.4	-1.3	0.0	-6.2	0.0	0.0	0.0
3.4	-6.0	-12.6	5.9	4.1	-9.2	-0.1	4.0	-0.1	0.0	-1.3	-1.3	-0.9	0.0	0.0	0.0	0.0
2.9	0.3	-20.2	5.9	0.0	3.6	-4.1	-0.1	0.0	3.2	-3.4	0.4	0.0	-4.5	0.0	0.0	0.0
6.4	-8.4	0.0	0.0	0.0	2.5	4.4	-9.7	1.2	0.0	-10.2	3.1	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-1.9	0.0	0.0	0.0	-5.8	4.4	-4.5	-2.7	0.0	8.3	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	4.2	0.0	-2.0	6.0	-3.0	6.8	9.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS incoming, Matrix of Phase in rad (P3)

0.0	14.2	0.0	-3.3	2.6	0.0	10.7	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.1	11.4	-1.6	-2.7	-0.2	0.6	10.9	-5.0	3.4	0.0	0.0	-4.1	0.0	10.0	0.0	0.0	0.0
-0.2	8.3	5.1	5.0	-19.3	4.0	5.0	5.2	2.2	4.2	13.3	1.9	-6.2	1.3	2.2	0.0	0.0
0.0	8.9	-21.5	-16.1	-2.6	-19.5	-5.6	5.0	5.1	2.2	2.1	9.3	4.4	-18.7	0.0	3.6	0.0
0.8	11.7	-23.8	-19.3	-19.5	2.9	0.2	4.9	1.2	-6.4	4.6	3.0	-6.2	7.5	2.4	3.2	6.5
0.0	4.9	-19.4	-19.4	-0.5	0.4	0.5	-5.9	-1.7	0.7	5.0	2.8	3.0	0.0	5.1	0.0	5.0
0.0	-19.4	4.7	4.8	-6.6	-3.6	0.7	-6.1	1.1	-6.8	5.2	5.2	5.2	2.5	10.9	5.2	1.3
-19.7	6.7	4.8	5.1	5.0	-6.7	-5.7	-9.8	1.4	0.0	2.2	1.4	5.2	14.3	14.6	-4.3	0.0
3.3	4.8	-19.3	-6.5	-6.7	-6.5	-6.5	5.0	8.3	10.7	1.2	3.3	0.0	-1.7	0.0	0.0	0.0
4.8	-2.5	-16.2	8.0	5.2	-6.2	-0.2	5.3	3.8	0.0	3.8	3.7	3.0	0.0	0.0	0.0	0.0
5.1	-0.3	-25.0	7.7	0.0	5.3	0.8	-0.1	0.0	3.9	1.6	2.3	0.0	1.0	0.0	0.0	0.0
7.9	-11.2	0.0	0.0	0.0	2.7	5.3	-6.3	2.0	0.0	-11.9	-1.6	0.0	0.0	0.0	0.0	0.0
0.0	0.0	3.1	0.0	0.0	0.0	-6.3	5.1	-6.3	1.8	0.0	11.2	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	8.4	0.0	3.3	8.4	-5.5	8.9	11.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SMS incoming, Matrix of Phase in rad (P4)

0.0	16.7	0.0	0.3	0.1	0.0	11.4	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.7	12.7	-2.6	2.1	-2.1	-2.0	13.6	-2.7	2.1	0.0	0.0	-0.6	0.0	9.8	0.0	0.0	0.0
-3.5	8.6	4.9	4.8	-25.3	3.3	4.8	4.8	1.1	3.4	16.0	-0.4	-9.9	-0.7	0.0	0.0	0.0
0.0	10.3	-27.9	-21.3	-4.5	-25.5	-8.7	4.9	5.1	1.4	0.9	10.2	3.5	-25.5	0.0	1.9	0.0
-1.6	12.8	-30.0	-25.3	-25.4	3.3	-1.0	4.6	-0.9	-9.9	3.2	1.9	-9.8	7.2	1.1	1.8	6.1
0.0	4.6	-25.3	-25.2	-1.8	-1.1	-1.4	-8.8	-3.4	-0.8	4.8	1.9	1.9	-2.1	4.6	0.0	3.9
0.0	-25.0	4.9	4.7	-9.8	-5.9	-0.7	-8.8	-0.6	-10.0	4.9	4.6	4.6	2.1	11.1	4.9	2.0
-25.4	5.1	4.7	4.9	4.8	-9.8	-8.6	-13.7	0.3	0.0	1.6	-0.7	4.6	16.4	16.2	-3.3	0.0
1.3	4.6	-25.5	-9.8	-9.8	-9.8	-9.8	4.6	8.6	11.2	-0.6	1.8	0.0	-4.7	0.0	0.0	0.0
4.9	-4.6	-21.4	8.7	4.8	-9.9	-1.8	5.0	2.6	0.0	1.8	1.9	1.1	0.0	0.0	0.0	0.0
4.8	-2.0	-32.1	8.1	0.0	4.9	-0.9	-2.1	0.0	2.0	-0.7	-0.2	0.0	-3.6	0.0	0.0	0.0
9.0	-14.9	0.0	0.0	0.0	1.4	5.0	-9.7	1.1	0.0	-14.4	2.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.9	0.0	0.0	0.0	-9.3	4.8	-9.9	0.0	0.0	10.8	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	8.3	0.0	2.0	8.7	-8.5	8.3	12.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0