Addis Ababa University

College of Business and Economics

Department of Management

Application of Data Driven Decision Making in Case of Ethiotelecom Fault tolerant and Maintenance Management

A Thesis Submitted to the Department of Management
in Partial fulfillment of the Degree of
Masters of Science in Management

By
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Advisor
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March, 2021
Addis Ababa

Declaration

I, Matiwos Mekuria declare that this thesis project entitled "**Application of Data Driven Decision Making in Case of Ethiotelecom Fault tolerant and Maintenance Management**" is the outcome of my own effort and study in which all sources of materials used for the study has been duly acknowledged. I have produced it independently except for the guidance and suggestion of the project advisor.

The study has not been submitted for any degree in this or any other university. It is offered for the partial fulfillment of the degree of masters of science in management.

Matiwos Mekuria

Signature________________________________ Date ___________________________

Statement of Certification

This is to certify that the thesis work entitled "**Application of Data Driven Decision Making in Case of Ethiotelecom Fault tolerant and Maintenance Management**" under taken by Matiwos Mekuria for the partial fulfillment of degree of masters of science. Administration at the Addis Ababa University, to the best of my knowledge, is an original work and not submitted for any degree at this university or in any other university.

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Dr. Mesfin Fikre,
Thesis Advisor

This is to certify that this thesis prepared by Matiwos Mekuria entitled "**Application of Data Driven Decision Making in Case of Ethiotelecom Fault tolerant and Maintenance Management**" and submitted in partial fulfillment for the requirement for the degree of master of science in management complies with the regulation of the university and meets the accepted standards with respect to originality and quality.

Approved by the examining committee

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External examiner	Signature	Date
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Internal examiner	Signature	Date
Dr. Mesfen Fikre (Advisor)	________________	________________
	Signature	Date

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Chair of Department of Graduate Program Coordinator

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Acknowledgment

Above all, I would like to thank my Almighty God for His help throughout my life and also holy of holy St. Mary for giving me her love I have showed in bringing this program to an end which otherwise impossible to do.

Next, my heartfelt deepest gratitude and appreciation goes to my Advisor Mesfen Fikre (PhD) for his advice, guidance and feedback which otherwise difficult to complete.

My sincere thanks and appreciation also goes to my ethiotelecom operation and maintenance staffs and managements without the cooperation of them, this thesis would never have been accomplished.

I am also indebted to all my lifetime beloved family for their love, support and patience they have showed me throughout the program. Special thanks to my beloved honest Mother Emahoy Asnakech my pray keeper. And also for my father Mekuria for everything he did for me, proud by his son from heaven now.

Last but not least, I would like to extend my earnest appreciation to Jerusalem, my love and wife, and all of you whom your names are not mentioned here for your support and encouragement. Thank you in deed.

Glossary of acronyms and abbreviations

1G:	First Generation
2G:	Second Generation
3G:	Third Generation
3GPP:	3rd Generation Partnership Project
4G:	Fourth Generation
5G:	Fifth Generation
AM:	Acknowledged Mode
AUC:	Authentication Center
BSC:	Base Station Controller
BTS:	Base transceiver system
CDMA:	Code Division Multiple Access
E-UTRAN:	Evolved Universal Terrestrial Radio Access Network
FCC:	Federal Communications Commission
FDD:	Frequency Division Duplexing
FDMA:	Frequency division multiple access
GBR:	Guaranteed Bit Rate
GDP:	Growth and transformation plan
GPRS:	General Packet Radio Service
HSCSD:	High Speed Circuit Switched Data
HSS:	Home Subscriber Server
IEEE:	Institute of Electrical and Electronics Engineers
IMS:	IP multimedia Systems

ITU:	International Telecommunication Union
LTE:	Long Term Evolution
Mbps:	Mega Bit Per Second
MME:	Mobility Management Entity
MU:	Multi User
NAR:	Network Availability Rate
NMT:	Nordic Mobile Telephones
NUR:	Network Unavailability rate
Pd.M.:	Predictive Maintenance
PM:	Preventive Maintenance
QoS:	Quality of Service
OMPES:	Operation and Maintenance Performance Enhancing System
RAN:	Radio Access Network
RLC:	Radio Link Control
RLNC:	Random Linear Network Coding
RNC:	Radio Network Controller
RNSAP:	Radio Network Subsystem Application Part
RNSs:	Radio Network Subsystems
RRM:	Radio Resource Management
UMTS:	Universal Mobile Telecommunication System
UTRAN:	UMTS Terrestrial Radio Access Network

Abstract

Today's world competition leads by big data analytic. This study has been conducted with an objective to explore the application of data driven decision making. The analysis of this study was made based on an existing data of wireless network operation and maintenance fault tolerant and maintenance trend in Addis Ababa zones.

Ethiotelecom use data only to routine base operation and maintenance tasks. Due to this there is a number of unknown root causes existing frequently and the reason is invisible to the management. Moreover, to achieve the research objective the research adopted a descriptive research design; using quantitative approach. And secondary data extracted from ethiotelecom central data system to analyses by using Tableau tool.

The research analyses show that the maintenance and fault handling trends of Addis Ababa zone need further improvement. And from the relationships between maintenance and fault tolerant variables the analyses result indicates the effect of variables on network availability rate. There is a need of implementation of data driven decision making to look insight of all existing data. Ethiotelecom must be replaced the network operation and maintenance routine function by data base decision so becoming data driven and instead of asking "what do we think" start asking "what do we know".

***Keywords**: Unavailability, network down , base site , core*

CHAPTER ONE

INTRODUCTION

Many existing companies including telecom industry have built an analytical capability and also created a clear link between company performance and the effective use of existing data to generate insight for decision making. Wireless network capacity is a highly valuable resource and telecom companies are starting to use big data and analytics to effectively monitor and manage network availability rate, build predictive capacity and use it for prioritizing and planning wireless network management decisions. In worlds telecom industry the competitive advantage will be emerged from the real time data driven decision making abilities of the industry (Mandinach, 2012).

1.1 Background of the company

Now a days throughout operational process there is a data exchange and some storage to holding it for some interval of time. Specially in telecom industry data is a day to day tools of operation and maintenance process. Each data user organizations need to gather data, analyze it, turn it into insights to explore knowledge, and then make sure that the results are acted upon (Anderson, 2015).

Ethiotelecom has currently over 446 connected Huawei network mobile sites from central computer based controlling system. In Addis Ababa there are six zones which are able to operate and maintain the network fault 24 hours per day. All the six zone network mobile sites in Addis Ababa area are connected with the central monitoring center data server. Each detected trouble alarm or fault from any network site around Addis Ababa will be collected to the central data server and ready to assign staffs to maintenance. Based on the alarm sent by controller team the operation and maintenance department go to the respective mobile sites and fix the problem as quick as possible.

The main thing in ethiotelecom operation and maintenance management is to resolve or minimize disturbances. To keep the network healthy, the habit of good fault management is important. Network sites by its nature need special follow up and monitoring techniques.

Each mobile sites are installed with second generation (2G), third generation(3G) & fourth generation(4G) mobile technology equipment's. Almost all Addis Ababa sites are holding both 2G,3G & 4G supporter network elements and a few are on progress to support 4G technology which is advanced. All mobile networks may be affected due to either by power or environmental factors in some case both are affect the network at a time.

To handle this interruption ethiotelecom structurally organized with fault and maintenance management sections. All the six Addis Ababa zones operational and maintenance procedure is the same and they centrally monitored by network operation control department.

Because of some reason one or more wireless network sites are down/fail frequently. Sometimes the site may remain without network even for days. And also some mobile sites are down frequently without knowing the root cause by management as well as by maintenance team. So this will affect ethiotelecom network quality and performance. But to know what is happening in real time data is important. As such, big data is working in the background and able the organizations to analyses an unprecedented amount of information (Henke et. al., 2016).

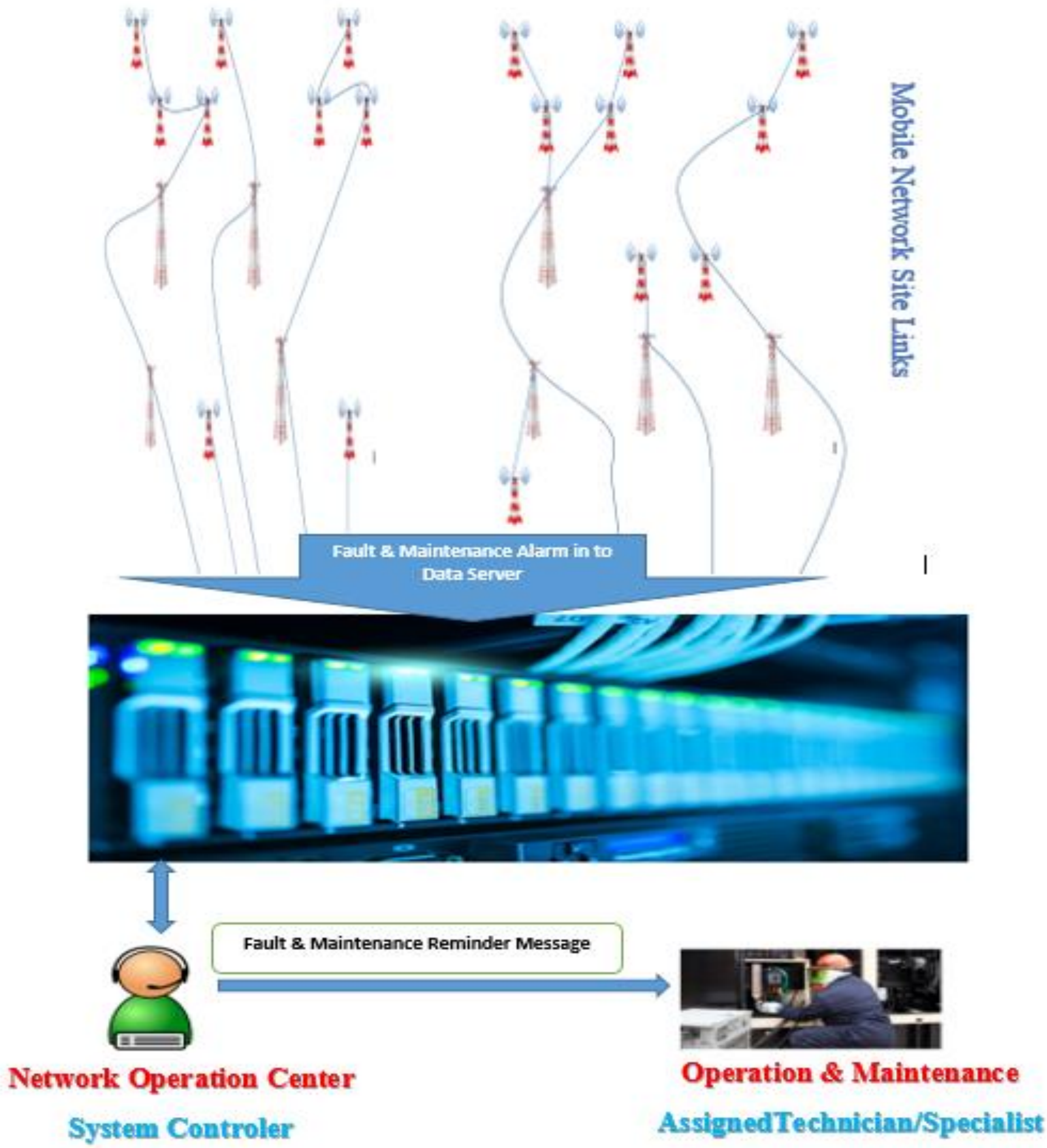


Figure 1 Fault and maintenance alarm data flow & handling

From the fig.1 above we clearly see that all the mobile network sites detected fault data and status alarm is collected to central data server. There is a huge /big fault data collection in daily bases. The main server reset itself to clear recently stored data to clean up some spaces for further collection.

Ethiotelecom operation and maintenance department use this real-time when at a time to inform & fix if some problem was existing to mobile network. This company operation and maintenance trend is not fit with present time data driven world management. Due to lack of insight knowledge about the previously fault and maintenance history, frequently down sites some network sites are totally down for large duration of time. And this will have exposed the company for customer compliance. So it is must to start to focus on data resource and to get insight knowledge to plan for fixation. To do this use of existing data analyses is must and appropriate to identify the issues and permanent solution (MEleCon, 2000).

1.2 Problem Statement

Telecommunications companies have a unique advantage which is compared to other industries. Companies are becoming data driven and instead of asking "what do we think" start asking "what do we know". This concept of big data analysis builds up insight imagination as well as thinking and derived from big data analytics is dramatically changing the competitive nature in many companies and the traditional decision making in organizations (McAfee & Brynjolfsson, 2012).

Ethiotelecom is the one and the only telecommunication sector in Ethiopia. In ethiotelecom wireless network operation and maintenance process data is very essential input. Every data collected from respective network elements of all mobile sites, which are located in different areas, and stored in data server as a history data. All the companies operational task facilitated through digital system and as a result the company use different software's and data server.

Data itself is meaningless unless it changes to meaningful information to get insight information and to enable data based decision. Separately stored and recorded data history of ethiotelecom wireless network division is a driving weapon to efficiently manage the fault and maintenance activities. But it needs awareness of knowing its important and using it to make decision in management.

In ethiotelecom keeping the network availability rate without disturbance for all time service is mandatory to customer satisfaction. Which means fault tolerant and maintenance management quality is directly related to the company's futurity and competitiveness. The mobile network availability rate is poor due to unexpected maximum out-of-service duration and it implies maximum unavailability rate.

Considering the huge mobile sites infrastructure in ethiotelecom and the significant number of daily mobile site fault, quality of service is negatively affected & this is continuous unless the collected data from different sources properly analysis and make a decision based on the result. The maximum cost and time of corrective maintenance will be the result of lack of data based decision and prediction.

From ethiotelecom fault and maintenance management trend we simply observe the problem of learning from existing data, giving priority for emergency case and reducing wastage.

The fault and maintenance management decision is not based on existing data analytic result. Instead routine day to day alarm reset trend is experienced almost in all Addis Ababa operation and maintenance department. Almost all technical staffs are lead their day to day fault management and corrective maintenance duty randomly in routine bases without data reference and insight knowledge about previous history. There is a probability of existing similar faults frequently and it takes more time and cost of corrective maintenance.

The same gap is observed in the company's maintenance management. Sites are weekly assigned by the operation and maintenance performance enhancing system(OMPES) to make preventive maintenance. On the other hand, the central system again reminds generator timed maintenance alarm. Even if both systems are properly work the way of fault and preventive maintenance management culture is not good. In some reason fault occurrence time and corrective maintenance repetition is not decline even if preventive maintenance is made which is clearly shown from existing data. Almost all spare parts are not produced in Ethiopia and so thousands of USD are used for purchasing.

There are a lot of late closed alarms are visible from central data base system. But no one gives attention for this. This large number of fault alarm occurrence indicates frequently down sites and poor corrective maintenance trend. And due to this maintenance cost and time are high. For example, from previous time random seven months existing data collected report from November 17-to May 17,2020 there is an estimation loss of over 500 ,000 USD due to network interruption.

Even if the daily based operation, maintenance and follow up is seems good it is not an indicator of efficiency. By taking an existing data from the system server it is important to analyses and observe insight knowledge to assure. But no one is aware about this reality unless the existing data itself tells about the truth of the ground status.

Figure 2 Fault management Decision Confusion

So in order to explore the application of data driven decision making to minimize the gap of learning from existing data, routine and random fault and preventive maintenance management culture for better wireless network overall availability rate performance in all ethiotelecom Addis Ababa zone this paper has a greater positive impact.

1.2.1 Research Questions

This study is guided by the following research questions:

- What is the trend of using existing data to deduce insight knowledge of preventive maintenance?
- Is there any relationship between preventive maintenance and fault tolerant factors?
- How cost of maintenance can be reduced by referring findings?
- How the relationship between network availability and unavailability rate of extracted data analytics?
- What can be recommended to implement data driven decision making based on findings?

1.3 Objective

1.3.1 General Objective

By taking wireless network fault tolerant and preventive maintenance management, this study intends to explore the application of data driven decision making.

1.3.2 Specific Objectives

- ✓ To examine and explore the trend in preventive maintenance and deduce insights from existing data.
- ✓ To explore the relationship between preventive maintenance and fault tolerant variables (factors).
- ✓ To explore how corrective (fault clearing) & preventive maintenance cost can be reduced through data analytics.
- ✓ To evaluate the relationship between 2G,3G & 4G Network Availability Rate (NAR) and Network Unavailability rate of Addis Ababa Zones.
- ✓ To draw data driven decision based recommendations based on the findings.

1.4 Scope and Limitation

1.4.1 Scope

Ethiotelecom is the only wire/wireless service delivering operator in Ethiopia and settled both in zonal and regional structural level. This paper will use the extracted Addis Ababa zonal wireless data from the central system data server as well as from specific zonal performance database.

1.4.2 Limitation

In ethiotelecom the system that we used to extract the network performance is vendor dependent. Ethiotelecom network division staffs and vendor staffs are busy to provide all other supportive related data. The tool capacity is also another issue because it can keep 3-month log data only in central system.

1.5 Significant of the study

After the completion of the research paper it gives visible, measurable and significant data driven based decision for concerned management body's as well as for all ethiotelecom operation and maintenance staffs. To sustain network availability rate and to operate in consistency in all Addis Ababa zone this paper will prepare real time data based insight information for Wireless network fault and preventive maintenance real time status.

The study also will provide deep knowledge for the researcher on data based wireless network fault tolerant and maintenance management system and their decision making value as the first reference paper specifically prepared in this field of area in Ethiopia. Also for the company itself has significantly a key map to plan and decide about fault and maintenance management practices based on the analytic results and useful in building up ground work for further research on the same area or other related fields.

CHAPTER TWO

LITRATURE REVIEW

2.1Introduction

Chapter two define and summarize related topics with data driven wireless network fault tolerant and maintenance management decision making. Under this chapter we discuss about data driven decision making basics, wireless network basics, network fault management, maintenance principles and finally, about data driven management decision making.

2.1.1 Wireless Communications

Wireless communication defines as the way of transfer information between two or more destinations that are not connected by an electric line /wire. For example, wireless communication system includes mobile cellular networks, wireless LAN, broadcast and television systems, Global positioning system (GPS), and others are from the type (Huang & Gao ,2013). The Wireless communications are the growing fastest segment of telecom industry. In most developed country mobile phones have become a significant business tool and taking part of everyday life, as they are rapidly succeeding the previous time wire line systems. Wireless communication is a technology that achieves the communication any time and place between terminal objects without wire connection (Provost & Fawcett ,2013).

Wireless network devices and connections are not only getting smarter in their service capabilities but are also evolving from 2G to 5G. So at a time of this technological capability is combined with other faster, higher bandwidth and smarter networks in order to wide adoption of a high-tech multimedia applications that contribute to increase mobile trafficking. Wireless mobile networks have ever-transfer typologies, mostly composed of bandwidth-constrained wireless connection link. So this equipped with all wireless transmitters and receivers, even sometimes with a platform like a router type. Wireless mobile devices such as smart high-tech phones and private digital assistants have reached new stage of usability, availability rate, and computing energy. So quickly these devices are equipped with network wireless-communications capabilities and location technologies in wireless mobile network there is a device like mobile phone and the account is registered in a module by the name of SIM card which implies Subscriber Identity Module card. So that after entering the sim card in the wireless mobile phone, network begins to check the validity of the Sim card by verification steps of order which connects to an authentication center (Miragliotta, Sianesi, Convertini and Distante 2018).

2.2 Mobile Network Generation

Cellular wireless network generation generally refers to a transfer in the fundamental nature of the service, non-backwards compatible transmission technology, and new frequency bands which is high-tech. In the previous decades, Wireless Communication networks have experienced a remarkable change in its function. The network mobile wireless Generation (G) generally refers to a change in the nature of the system reference, speed, technology, frequency, data capacity, latency and all other relative elements. Each generation have its own standards, different capacities, new techniques and new features which differentiate it from the previous technology. For example, the first generation (1G) mobile network wireless communication was analog used for voice calls only and the second generation (2G) is a digital technology and also supports text messaging in addition but the third generation (3G) mobile technology provided higher data transmission rate, increased potential and provide multimedia support functions. The fourth generation (4G) on the other hand integrates 3G with fixed internet to support wireless mobile internet in addition, which is an evolution and improvement to mobile technology and it overcome the service limitations of 3G. It also increases the bandwidth and minimize the expense of resources (Anju Uttam Gawas ,2015).

2.2.1 First Generation (1G)

First generation (1G) of wireless mobile technology systems came in to being early1980. That was not digital but based on the analog technology many European countries adopt First Generation technology(1G). Every country developed its own first generation system that is not compatible of others. Each country has different equipment’s and that equipment function different operations (Gill, Borden & Hallgren, 2014). From this kind of technology, the two most popular analogue systems were Nordic Mobile Telephones

(NMT) and Total Access Communication Systems (TACS). This analog system was allocated a 40-MHz bandwidth within the 800 to 900 MHz frequency range used by the Federal Communications Commission (FCC) for AMPS. But this is not the only thing in fact, the smallest reuse factor that would fulfill the 18db signal-to-interference ratio (SIR) using 120-degree directional antennas was found to be 7. Hence, a 7-cell reuse pattern for instance was adopted for AMPS. Transmissions from the base stations to network mobiles occur over the forward channel using frequencies between 869894MHz.The reverse channel is but used for transmissions from mobiles network to base station, using frequencies between 824-849 MHz AMPS and TACS use the frequency modulation (FM) technique for radio transmission accordingly. Network traffic is multiplexed onto a frequency division multiple access system (Salau, Yinka-Banjo, Misra, Adewumi, Ahuja & Maskeliunas ,2018).

2.2.2 Second Generation (2G)

The second generation (2G) were commercially launched on the Global Network System for mobile (GSM) standard in 1991 and also based on the Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) technologies is working.

2.2.3 Third Generation (3G)

The third Generation network is mobile phone standard and technology based on the ITU (International Telecommunication Union) family standard. At the same time wireless networks phenomenal deployment and distribution of user terminals are used. We know that Internet has seen a similar revolutionary growth. The Wireless network provides the integrated quality the services both technologies so UMTS uses the 3GPP standard and also the 3GPP standards support the web, email, multimedia, and other data services in a broadband wireless network.

2.2.4 Fourth Generation (4G)

The first fast and modern successful field trial for fourth generation was conducted in Tokyo, Japan on June 23rd, 2005. At a time, Japan Telecom Operator NTT DoCoMo was successful in achieving 1Gbps real time packet transmission in the downlink at a moving speed of about 20km/h and this is achievable. According to the principles to use 4G services, multimode user terminals must be able to select the target wireless systems. In

GSM systems of course, base stations periodically broadcast network signaling messages for service subscription to mobile network stations. However, this operation becomes complicated in 4G heterogeneous systems that is because of the differences in wireless network technologies and access protocols. To provide wireless network services at anytime and anywhere, terminal mobility should be in 4G infrastructure.

2.3 The world becoming data-driven

Now a day's big data has become a popular and familiar term to describe the exponential growth, availability, and use of data or information and is often explained by Laney's (2001) three V's: Volume, Variety and Velocity. Hence, big data is characterized by big amounts of data, extracted from a variety of sources, with a high speed of generation. This kind of big data is incorporated into our daily lives as most people use it indirectly every day informally, whether it is searching for something online or reading an article (EY, 2014). Every day in today's world, we create over a large quintillion bytes of data, which is so large and big that 90 % of the data in the world today have been created in the last two years alone based on findings (IBM, 2017). Hence, the amount of the created data constitutes the backbone of big data (Baro et. al., 2015). With such large amounts of big data being generated, being able to capture it effectively in high speed and derive real-time updated information is vital for organizations today (Turban, 2015; Gandomi & Haider, 2015; Sharda, 2014; LaValle , 2011).

It is when such organizations actually take and use data in their decision-making that they are becoming data-driven (Anderson, 2015). Furthermore, in principle big data can be divided into two categories, structured data and unstructured data (Turban, 2015; EY.com, 2014; Hand, 2007; Stone, 2014). The first which is Structured data refers to the data that is already filtered, has a predictable format, and is defined and implied by a set of rules. On the other side with unstructured data, there are no rules and regulations so as such it does not have a predictable format.

2.3.1 Why data is important to organizations?

The potential or capacity to make sense of unstructured data through analytics enables organizations to incorporate valuable insights knowledge about their business status into their everyday routines operations, processes and decisions. This likely means that each data user organizations need to gather data, analyze it, turn it into insights to explore knowledge, and then make sure that the results are acted upon (Anderson, 2015). If this is done effectively with quality, all organizations can gain needed competitive advantages from being well-informed about their business and also used to increase their performance (Brynjolfsson, 2011; Marr, 2015). Being able to utilize the extracted knowledge gained through big data analytics will enable each organizations to make quick and best decisions, and the biggest problem they will be facing is to incorporate the data-driven insights into their scheduled day-to-day business processes (Mohanty, 2013; McAfee & Brynjolfsson, 2012; Pearson & Wegener, 2013; Henke, 2016).

2.3.2 Knowledge extraction through big data analytics

The inspection and extraction of knowledge is an active process to communicate, to a targeted audience or management staffs. The output message should be clear, simple, and really actionable in order for the end-user to be able to make a decision. This is, due to the fact that some data analytical tools are too complex for the end-users to understand and implement on the ground. In order to maximize the potential and probability of impact of big data analytics, organizations must have processes in deep quality for getting the right knowledge, to the right people, at the right time efficiently.

challenging aspect as the process of sharing the extracted information is a more complex process than the process of capturing information first. Developing effective and accurate knowledge sharing processes is an important key for assisting the telecom wireless network operators in their effort to become more data-driven in their decision-making making.

2.3.3 Data Driven Decision Making (DDDM)

DDDM is a process and way of deciding on a course of action based on big data (Williams & Brunner, 2011). As data systems and technologies have become more accessible and intelligent, it has become easier to use big data to inform decision making in every telecom industry and other services as well, organizations and systems. It is not just only about the numbers or the data extracted but it is also about making actionable the data by transforming them into usable knowledge.

2.3.4 The Process of Data-Driven Decision Making

Through this process of DDDM, telecom data are used to find, check, and improve a program, activity, or operation as a strategy. These activities occur through four important and iterative stages, which are summarized below This process begins with identifying or inspection and clarifying the key questions to be answered from the result for the company. These questions may address the need to solve a specific problem or faults, learn more about a target population of specific element, or improve a program or organizational process (Hallgren, 2014). This will facilitate by and guided by the key questions, available data are identified from and new data are collected or extracted as needed so to achieve this access to high-quality of big data is critical.

The final results of analyses are shared with key decision makers within and between levels of the organization or broader service system concerned. Dissemination may take place through various communication channels and formats during the process depending on the information needs of stakeholders.

Decision makers use information gathered during the previous stage of analyses to assess gaps in services; strengthen and improved the performance of programs, organizations, or systems; and assess the impact of services on outcomes of interest. As more information is collected during process time, the process continues in an iterative manner, with additional evidence producing new insights understanding and subsequent questions for further data collection and analysis in addition (Hallgren,2014).

2.4 network fault and Corrective maintenance management

There are three different mobile generations (2G ,3G & 4G) working simultaneously and, each one, with a different network element. Obviously there are common elements allowing network mobile users moving from one technology to another one even during a call time. The first part of this closer to mobile customers is the site including the tower, antennas in the top some were and the station in the ground where electronic equipment’s for different technologies are installed. Site is the most expensive element but not because of the electronic equipment’s. It is needed electricity supply and it used to be rented. Additionally, are located in remote places making the maintenance difficult. This is the reason why the three technologies are deployed in the site as the extra cost is not too much.

Figure 3. Wireless network tower and antennas

So “Base Transceiver Station” BTS is installed in a small building next to the tower in the site and it is connected through cables to the antenna in the top of some places. BTS is connected to one or more antennas for the different cells of this site for communication purpose. Every antenna for every cell and so monitor and manage all the antennas/cells of the same site at a time. This BTS managed by “Base Station Controller” BSC in a specific area so in this area are connected to the BSC and their traffic flow through it. BSC controls all BTSs are working properly in all time, manage BTS configuration in system and participate actively when a mobile user is moving from one BTS to another (hand-over). Mobile Switching center (MSC) are on the way for Communication exchanges and managing voice calls in mobile networks.

Not only BSCs but Radio network controllers (RNC) are also connected to this element but this connection is only for mobile voice ones. Data connections follow a different way so technology used in MSC is the same used for fixed networks but the software of the element is more complex as mobiles users are moving continuously and they could connect from any were.

2.4.1 Wireless Network Element Power Source

Every wireless network element in each site gets three phase power input from Ethiopia Electric power corporation main transformer outage. Then from the transformer three color coded wires with one neutral which is blue in standard color connected to the inside of the network site Distribution board. Beside of that for emergency in case of power intermittent there are backup powers like DG(Generator) and Battery cabinet. not in Addis Ababa but for regional remote sites solar power are installed.

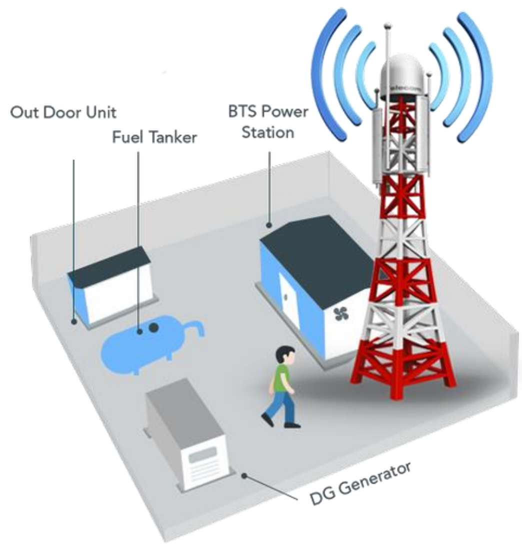


Figure 4. wireless network mobile site

2.4.2 Ethiotelecom wireless network Zonal structure

Ethiotelecom revised the previous Zonal and Regional structures to provide organizational structure which gives proper attention for the service quality, network availability and infrastructure management.

Based on the new organizational structure all Zonal structures segmented under three categories which are Departments, Section and Group. All the three units are under different Division. In Addis Ababa Zonal operation office all six Zones Network Division are managed by the head entitled Operation Director.

There is a manager for wireless network Operation & Maintenance department and also one supervisor for each of the sections under the manager. In all section there are more than 10 staffs qualified as specialist and technicians.

2.4.3 Wireless Network Performance Section

Wireless network performance section takes the responsibility of supporting each sections by giving the real time information from Network Operation Center (NOC), Element management system (EMS) and fault management system (FMS), by reminding the daily tasks and network alarms, by sending the daily network availability rate status for all section and reminding the frequently down sites if any and preventive maintenance weekly report. So simply the section acting as a bridge between the operation and maintenance department and central network operation center.

2.4.4 Ethiotelecom Network Operation System (NOC)

A Network Operations Center(NOC) is managed as a central office where the network operation department provides all days' supervision, monitoring, and management of all wireless network, servers, databases, devices and other network elements. This infrastructure environment may be located on-premises and/or with a cloud-based provider.

In case of ethiotelecom NOC has centrally manage all the tasks by using a specified system called NetEco. Huawei company developed and provide NetEco software system to ethiotelecom which is used to supervision, monitoring and fault management and reporting by ethiotelecom Network Operation Center. It is mandatory that to fix a complex network effectively, it must be care to check in their working order each network elements as well as other parts. At a time of fault occurrence, it must be sure that to identified the specific cause of the problem issued and isolate from the rest of network elements to keep and save without affection of that. So as a result all the rest system components are waiting in proper function. This may need resetting the system to come back to its normal state.

Fault is not same as error rather it is a condition of abnormality due to some causes which is either internal or environmental. The management of fault then will provide a good state of function. The management must give attention for improper behavior of each network elements as much as possible.

For example, a network line cut or other related causes occur, it is impossible to get good communication of system checker. Even if the fault is serious damage the user expected fast and quality fixation solution which implies best fault management action. To achieve this expectation quick and accurate maintenance correction is must so it needs best management follow up.

To increase network availability rate and to satisfy the user system based fault management is needed. Which means to give degree of fault tolerance the fault management communication center first compiled with high tech.

Nowadays the improvements of technology type rise from 2G to 5G which is advanced broad band service. due to the worlds rapid change this evolution of technology transfers in to high capacity tech. So the industries specially telecom company's get an advantage of attracting user through this reality. People wants to use high tech communication system and by using it they get better and easy way of life.

There are different services provided by ethiotelecom including Digital Subscriber Line Access Multiplexer(DSLAM), Code Division Multiple Access (CDMA) networks, Multi-Service Access Gateway (MSAG), Public Switched Telephone Network (PSTN) and mobile networks including Global System for Mobile Communication (GSM), Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE).

The occurrence of fault has an impact over the network performance. Due to this corrective maintenance cost will rise and time is waste to fixation. So fast elimination of problem is must be needed and also resolving the root cause of the existing problem is essential. To do this use of existing data analyses is must and appropriate to identify the issues and permanent solution (MEleCon, 2000).

2.5 Preventive Maintenance

Benchmarking standards are carefully applied as a standard in order to achieve integrity and reliability of network management by reducing maintenance cost and time.

Traditionally, wireless network operators and administrators have focused their deep attention primarily on the operational, administrative and provisioning aspects of all network management, while deeming the preventive maintenance aspect of their network communications as a necessary burden. One of the immediate problem facing companies is the lack of maintenance planning decision support tools. Maintenance decisions are frequently not fact-based and influenced by human guesswork based on experience or ad hoc decisions.

As a result, several studies have confirmed that the severe traffic congestion, poor performance and unacceptable availability exhibited by many communications networks are often due to poor network maintenance. For instance, ITU Buenos Aires Action Plan (2004), yet everyone agrees that, being the backbone of corporations, communication networks need to be kept operating at peak performance around the clock, all days and nights. Instituting a genuine and effective preventive network maintenance program is a key step towards achieving world-class maintenance status. First, the network maintenance organization needs to review and be familiar with the manufacturer's recommended preventive maintenance procedures. In addition, by using experience of previous time operation it is possible to build up maintenance strategies and plans.

Nowadays Preventive maintenance is one of the most common types of important maintenance strategies used in different industries to prevent equipment from breakdown or fail. The preventive maintenance actives (inspection, repair, replacement, etc.) are implemented at regular intervals. The periodic intervals are basically rise from fixed number of operation cycles, fixed cumulative outputs, calendar- based which may be weeks, months or number of operating time (run time based) (Kelly,1997).

According to Alsyouf (2007), Preventive maintenance define as the regularly scheduled repair and maintenance needed to save a facility component operating at good quality of efficiency and extend its useful life. It includes scheduled activities intended to prevent breakdowns of network elements, such as periodic inspections, lubrication, Generator wash, calibrations, and replacement of equipment. Changing filters in an air-handling unit on a proper regularly scheduled basis is an example of preventive maintenance. Because prolonging the life and function of major facility systems requires periodic replacement of equipment, preventive maintenance typically requires operating expenditures.

Moubray (1997) also pointed out that the design life of most network equipment requires preventive maintenance. Anytime we fail to perform maintenance activities intended by the equipment's designer, we shorten the operating life of the equipment. Preventive maintenance is aimed to avoid premature failure or defect of the systems and their components. Normally, Preventive maintenance is the way of checking in function and replacement in predetermined period of time to overcome the fault problem of wear and tear (Bevilacqua, 2000).

Eventually, Hameed et al. (2010) proposed that maintenance activities performed at regular scheduled time interval are means to reduce highly the probability of failures and breakdowns.

The maintenance quality and performance of preventive maintenance fall on the criteria of educated labour, availability of Spare parts and materials, Predetermined interval for maintenance, Cost allocation for failure or downtime – the cost incurred due to unexpected damage or failure (includes the system breakdown that requires additional repair and fault network downtime for rectifying work) or scheduled preventive maintenance downtime.

According to international telecommunication union (ITU) the maintenance basic principles are closely match with network availability rate, network technical performance and cost. The effectiveness of any action related to maintenance is around the circle of those criteria's. Without enough knowledge and knowhow of this it is risky to make maintenance. Based on the parallel over view preventive maintenance principles and strategies of international organization for standardization (ISO) all tasks of the maintenance management determine the maintenance objective, responsibility, cost aspects and improvement.

According to Batun and Azizogln (2009) preventive maintenance affected by frequently down time. So systems are subjected to downtime because of preventive maintenance activities, network element failure, inspection and spare part shortages. Groote (1995) remind that the fault or down time are of two either planned or unplanned down time. Bad preventive maintenance management and inadequate finance are one of the factors which is influence the preventive maintenance decision from implementation (Derek and Paul ,1987).

From classification of maintenance condition-based maintenance is applied when some regular scheduled or random request due to some reason is overcome. Wireless network by its technological or digital nature it needs continuous treatment. Predetermined or scheduled preventive maintenance is a key in order to minimize the economy of corrective maintenance. Improving a balance between the preventive and corrective maintenance is important and necessary to reduce maintenance cost.

Through the operators' participation in maintenance, such as through inspections, cleaning, lubricating and adjusting, early and fast quick detection of hidden faults, before service down or breakdown. Total productive maintenance (TPM) objective on the other hand is to diminish and avoid 6 significant losses of equipment effectiveness – i.e. breakdowns, setup and adjustment, idling and stoppages, minimize speed, fault in process, and minimize yield (Jardine & Tsang, 2013).

Reliability-centered maintenance (RCM) is also the best tool to improve wireless network quality, reliability rate, availability rate and efficiency which bases on design and technology. RCM principles is based on systematic assessment of preventive or corrective maintenance needs after a complete understanding of the system function and the types of failure causing function losses from existing data history

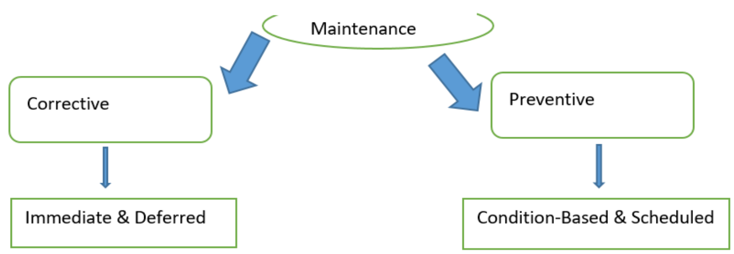


Figure 5 Classification of maintenance.

Predictive maintenance (Pd.M.) is an existing phenomena based type that initiated by the current status of network elements. Pd.M. highly relies on engineering techniques and statistical tools to process the data and analyze the real time status in order to predict possible network equipment failure. The important factors associated with Pd.M. in Maintenance Policy Management (MPM) emphases criticality, availability of sensory data, reliability in quality, timeliness, relevance or importanc and knowledge-oriented strategy (Lee, Ardakani, Yang & Bagheri, 2015).

International Telecommunication Union described that, Controlled maintenance A method of sustaining a desired schedule technical performance improvement by the systematic application of supervision, monitoring, testing and performance sampling in order to minimize preventive maintenance and to reduce corrective maintenance.

2.6 Empirical review

Nowadays, adopting big data is a reality. Wireless Telecommunication company must find the right solution to store all important information available across the organization to maximize revenue using the analytics. With big data analytics, the service provider can utilize the full potential of their data set by correlating relation, processing, and deciphering the hidden information from it. However, the understanding of how these big data technologies analytics adopted inside the telecom industry still can be ambiguous and confusion. This thesis will fill the gaps in the implementation of big data technologies inside the telecom industries.

The previous time study on Ethiopian telecommunication development plan recommend about the importance of collecting data and using it for analytic purpose to improve efficient maintenance culture. The study said, the reported site history data shall be analyzed by the operation and maintenance (O/M) division of each region/zone in order to formulate the action plans (or ad-hoc action plan) required for the allocation of the budget and for placing the action order to the site.

O/M division shall make the utmost efforts to tackle the annual target of quality of service (QoS). In this regard, the management shall place the detailed annual target for each section/team and periodically monitor/evaluate. (The Study on Telecommunications Development Plan, Ethiopia). But the implementation of this study is not strong enough due to lack of learning from existing data.

Over the years, operators introduced more proactive tools, applying analysis of customer and network data to determine potential network performance issues, which enabled faster detection and resolution of faults, often before the customer became aware of them.

Big Data analytics has attracted intense interest recently for its attempt to extract information, knowledge and wisdom from Big Data. In telecom industry, with the development of sensor technology and Information & Communication Technologies (ICT), reams of high-dimensional, streaming, and nonlinear data are being collected and curated to support decision-making (Liangwei Zhang ,2016). Big data analytics can be involved in several topics including predictive wireless resource allocation, interference avoidance, optimizing the network in light of Quality of Experience (QoE), and flexible network planning in light of consumption prediction (Hadi, Lawey, El-Gorashi, & Elmirghani, 2018).

Ethiotelecom tend to regard the customer’s engagement process and internal channels as a guarantee of smooth functioning of the operations. Network fault and maintenance management gives an opportunity to define the score points to identify the root causes of complication. Looking into existing data/historical data and predicting possible future problems.

The balance between corrective maintenance and preventive maintenance for minimizing cost varies between organizations based on their strategies. In ethiotelecom to assure this data must be analyses. If so the corrective maintenance cost will minimize only if preventive maintenance is made properly in standard.

According to, McKinsey Global Institute (MGI) research, big data is becoming the key basis of competition, underpinning new waves of productivity growth, innovation and customer surplus of the future market. With vast amounts of data now available, companies in almost every industry are focused on exploiting data for competitive advantage.

The volume and variety of data have far outstripped the capacity of manual analysis, and in some cases have exceeded the capacity of conventional databases. At the same time, computers have become far more powerful, networking is ubiquitous, and algorithms have been developed that can connect datasets to enable broader and deeper analyses than previously possible (Provost & Fawcett,2013).

One of the most critical aspects of data science is the support of data-analytic thinking. Skill at thinking data-analytically is important not just for the data scientist but throughout the organization.

For example, managers and technical team in other functional areas will only get the best from the company’s data-science resources if they have some basic understanding of the fundamental principles. Managers in telecom industry without substantial data-science resources should still understand basic principles in order to engage consultants on an informed basis.

The benefits of data-driven decision making have been demonstrated conclusively. Economist Erik Brynjolfsson and his colleagues from MIT and Penn's Wharton School recently conducted a study of how DDD affects firm performance. They developed a measure of DDD that rates as to how strongly they use data to make decisions across the company. They show statistically that the more data-driven a company is, the more productive it is—even controlling for a wide range of possible confounding factors (Provost & Fawcett,2013).

Big data analytics brings in considerable value to decision making and provide more accurate and actionable insights which eventually help to build competitive advantages and a more efficient cost structure. In comparison to traditional data warehousing technologies, big data offers following advantages/ opportunities for telecom operators to prepare the networks for future demands and understand customer experience:

Even if there are many researches in the area of data driven management decision making only a few literatures are prepared on telecommunication industry. Specially in Ethiopia no literature is available on data driven management decision making in case of ethiotelecom. So almost all papers are focuses on customer satisfaction and a few are on either 3G or 4G network availability performance quality. But they try to point out that the quality of network performance needs further improvement.

Thomas (2014) on assessing the effect of service quality factors on broad band internet customer satisfaction. and based on his findings he recommended that Network quality is important so Ethiotelecom should improve its network areas of providing 24 hours and 7 days' available network without break, high and consistence speed, because it is the network quality in which customers are complaining. Which means it needs fault management improvement.

Bisrat (2018) Given that the failures will occur, operation managers must first have mechanisms in place which ensure that they are aware that a failure has occurred and, second have procedures in place which analyze the failure to find out its root causes. Once a thorough understanding of the cause and effect of failure have been established, organizations should try to prevent the failure occurring in the first place.

From both recommendations we clearly inspect fault management weakness and they give their own findings. But they miss to point out the use of existing data in order to evaluate those findings in analytical way of management decision.

Big data analytics can improve the quality of management in telecommunications by making use of real-time data analyses and monitoring machine logs. Predictive analytics can also be used to minimize performance variability and to prevent quality issues by providing early warning alerts (Elgendy and Elragal, 2014).

Tadesse (2019) also prepare on the area of 'Evaluating Quality of Services of 4G LTE Cellular Data Network' and in his findings managing network quality is must in order to achieve the company's target. Which clearly appointed the area of improvement rather than the specific tools to improve the management skill.

So almost all previous researches are not address all three 2G,3G & 4G network elements based on the real time data analysis where stored in data base. And the rest are focused on some related areas rather than directly to the field of study. This gap will fill by using data driven decision to see and conclude the trend of fault and maintenance management to keep network availability rate and the present time status of the network as well as the paper itself use as a source for future study's.

CHAPTER THREE

METHODOLOGY

Overview

Ignoring from using existing data continues to be a problem in fault and maintenance management practices in ethiotelecom wireless network. The goal of this study is to collect and analyses separately stored existing wireless network fault and preventive maintenance data to explore the application of data driven decision.

This section tries to answer the question how the data collected and finally how it analyses. In this chapter the researcher tried to describe all the above listed information as much as possible.

3.1 Research approaches

The approach of this study uses quantitative data approach, which involves the generation of data in quantitative or numerical forms which can be subjected to severe quantitative analysis. This research also uses descriptive research design in order to describes a situation, or phenomenon that is being studied. The major purpose of descriptive research is description of the state of affairs as it exists at present. The reason for selecting descriptive research approach for this research is to evaluate the real time wireless network availability rate and the present time fault and pm management culture in Addis Ababa wireless network. So that it aims to accurately and systematically describe a situation or phenomenon to understand past and current network performance and make informed decisions.

3.2 Data generation and collection

This research used secondary data source. In order to collect secondary exported data from Central data server and from operation and maintenance performance evaluation system (OMPES) report is used. And also some data of fault with its route cause detail history collected from individual zonal performance specialist report dashboard or excel if available.

3.2.1 Different systems in wireless network

Net Eco System

Developed and provided by Huawei company which is used to monitoring, supervision and real time alarm history detection and reporting work in ethiotelecom. All element managed and monitored 24 hrs. so in every 5min the system collects real time information and update itself based on the received data from ECC-500. NetEco is only access Huawei sites, it can't be access ZTE & Ericsson company's developed equipment's.

Fault Management System (FMS)

Developed and provided by ZTE which is used to manage all network elements status and faults management digitally and reset a specific alarm automatically after corrective maintenance is done. This system is, synchronized with NetEco and Trouble Ticket (TT)system, enable to see and manage both Huawei, ZTE and Ericson in a single display window at a time.

Operation and Maintenance Performance Evaluation System (OMPES)

This is also a recent network operation and maintenance performance evaluation system new software developed by ethiotelecom staff his name is Mr. Gezahign. The aim of this software is to remind pm sites and check the maintenance quality based on standards which first registered in the software.

3.2.2 How the data or information exchanging process

In ethiotelecom wireless network every data or information exchanging process and reporting issues are supported by computer based digital process which are mentioned in the previous topics. The overall end to end data or information exchanging process is appointed in figure below.

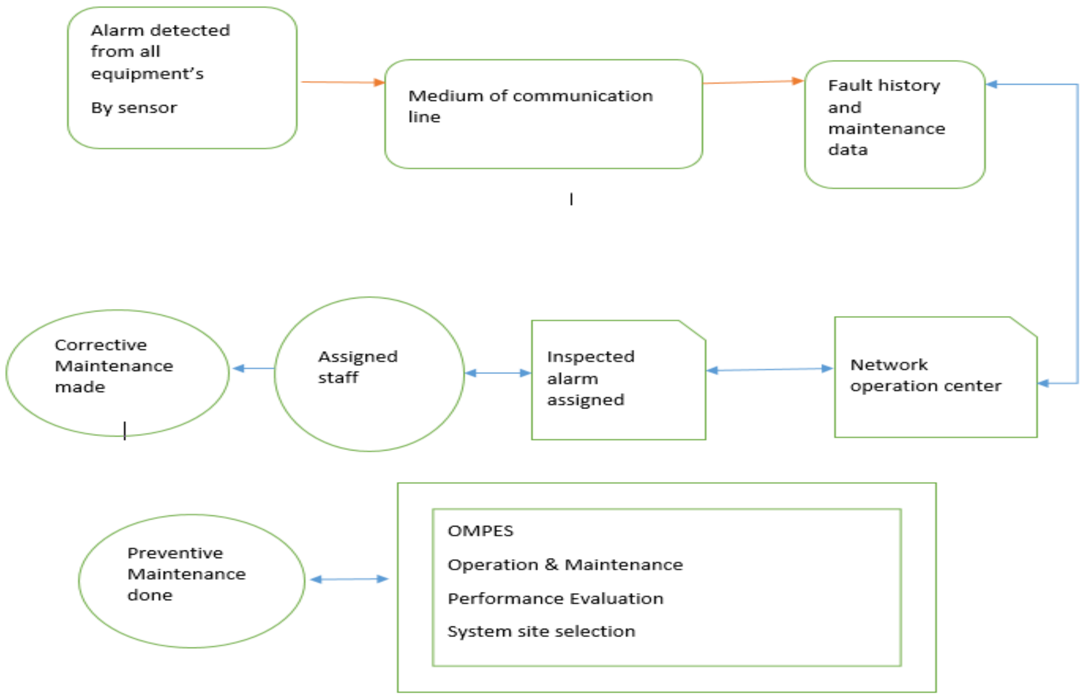


Figure 6 Data exchange flow

Every wireless network equipment's are monitored and controlled by using sensor technology. The sensors which are installed in each network elements are detect information based on specific command every sensor are assigned to.

First step of information exchange begins by Energy Control center 500 (ECC-500), installed and use as data center, collecting detected data from network elements through sensors. Then the regional telecommunication network transfer the real time data collected by ECC500 in to central Net Eco server.

The central NetEco server data then use this ECC500 stored alarms as an input data to Element Management system (EMS). EMS monitor by NOC staffs centrally 24hrs. and in every 5min updated data reach from server to EMS. EMS use NetEco different features to rename, categorize and distribute detected faults types to concerned managers and supervisors.

For example, in Backup Generator (DG) alarm detection case four terms are used namely: - D.G start failure, D.G stop expectation, D.G stop failure and D.G start expectation. Which means every route cause of alarm or fault in generator is fallen under this four types of alarm type. NOC also use four fault level / Severity Level of NetEco system as a standard which is already installed and configured by Huawei.

In ethiotelecom maintenance issue is processed by operation and maintenance performance evaluation system (OMPES). This system is accessible by performance and all section supervisors and monitored and controlled by central NOC. Initially preventive maintenance (PM) standard check lists and site address information are installed to the system so OMPES send messages by selecting sites which needs pm based on standard equipment service time.

3.2.3 Sensor data collection and data nature

The data used here are first collected through different sensor which are synchronized electrically to ECC500 data controller and stored in Net Eco and OMPES data server.

Fault alarm, Network availability rate daily performance and maintenance alarm & report history data of Addis Ababa 2G ,3G & 4G mobile sites are extracted from the database of Net Eco and OMPES. The fault and maintenance report data is collected and aggregated at a network operations center (NOC). The amount of data collected are listed in the table below.

Data Type	Extracted from	Amount of data
Network Availability rate(NAR)	Performance Dashboard	2,050 row daily based history
RCA detail	Zonal performance data base	1,280 row data reports
Preventive maintenance report	OMPES	4,266 row data daily based reports
Real time Alarm history	Net Eco	Over 1000 Fault & Maintenance alarm history for Month of December,2020

Table 1Extracted Data type and amount

In ethiotelecom data server system all recorded data are numerical in their type. The extracted data nature for analysis process is so in numerical form. To indicate each recorded data information for appropriate department or section structurally all data histories are categorized in titles based on textual naming forms as a column heading. The wireless network mobile site names are assigned in string format number like 111763 which is six-digit naming. And every site holds a suffix description at the end and called site ID and name.

Each and every data are collected by central server data base system by pointing specific day, week, month and year with specific time of data capture. This enable to see insight and describe in time based way of interpretation during analysis process. All Addis Ababa regions are described in short form like NAAZ, CAAZ and so which are described in next section. this trend is appeared in most columns of the extracted data.

3.3 Data Preprocessing

3.3.1Cleaning Process

The Extracted Data initially hold a number of repeated rows and columns of the specific system format for some reason. So in order to prepare input data's with the specific research format in excel for analysis cleaning unwanted null or empty row and column data's are cleaning manually and by tableau software data interpreter tool the final input data format is arranged properly.

Due to a huge data collection data base system format some variables or titles like Date, week, time, alarm name and remarks are recorded with main extracted data. So those repeated and unwanted columns and rows are cleared by using excel sheet.

3.3.2Data type Correction

Some format assignment of columns and row names are renamed in order to clarify their meaning for the audience. So based on this the data type name in column TAG replaced by CORE/NORMAL, and abbreviations in the header of columns set in full text format to clear the assigned name meaning of the data source system. Due to same procedure of all zones the data history was registered in similar naming format. To reduce an error during analysis due to same naming format arrangement adding a suffix in number after the assigned name type was done.

3.3.3 Column leading Description of the data

Before the raw time series data is applied to the analysis methods, usually it undergoes several transformations. Proper data processing significantly affects the analysis result quality. After wireless network mobile sites fault and maintenance history data of six zones is extracted from the server and data base, the fault first and second occurrence and clearance time with occurrence number, preventive maintenance planned and done time, network availability and unavailability rate with cell out-out-of-service time, number of cells, of both 2G ,3G &4G mobile technology data are again extracted and arranged in sequential order in different excel sheets.

The Operation and Maintenance Performance Enhancing System extracted and cleaned preventive maintenance history data are containing six columns such as Year, Week, Region, Site id, Maintenance planned time and Maintenance Closed time.

The fault history data, which are extracted and arranged for analysis, containing seven columns namely Severity, Alarm Name, Alarm Source, Number of Occurrence, First Occurrence Time, Last Occurrence Time and Cleared Time. Here alarm source implies site name were alarm is occurred.

The network availability rate performance report history data, which are extracted from performance data base sheet, containing six columns namely Region, Date, Number of Cells, Cell out-of-service Duration, Network Availability Rate (NAR) and Network Unavailability Rate (NUR). The column entitled by region holds all six Addis Ababa zones in short form by saying central Addis Ababa zone CAAZ, east Addis Ababa zone EAAZ, north Addis Ababa zone NAAZ, south Addis Ababa zone SAAZ, west Addis Ababa zone WAAZ & south west Addis Ababa zone SWAAZ. In addition to this for both 2G,3G & 4G technology, cell out-of-service duration count in second.

3.4 Method of Data Processing (analyses)

Tableau Public 2020.4 was used to data processing (to analyze), compute and present research findings by considering initial research objectives this paper intended to address at the outset. The research was used descriptive statistical analysis used to analysis quantitative data. In order to presenting quantitative descriptions in organized form, to describing a specific variable or the relationship of one variable with another. The Network

Operation Central and performance section extracted data is exported by Excel format, so that the researcher analyzed the data by using tableau tool, tableau is advanced and widely used analytical tool by scholars and company researcher's worldwide. It's latest attractive futures give additional benefits at time of result outputs to give the expected insight knowledge easily and more briefly than any other tools. And also the correlation of wireless network availability rate, network fault and preventive maintenance Factors (variables) is analyzed.

3.5 Ethical Consideration

Concerned management officials of Ethiotelecom were informed about the study. In addition, the respondents were asked for their consent prior to the tools to gather the relevant information. The respondent's responses are taken absolutely confidential and they were informed that no part of their response is exposed to anyone without their complete consent.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Result

As described in Chapter three, data has been extracted from ethiotelecom network operation center data base and from performance network management system server. The analysis is done by tableau analysis tool. The output of analyses and interpretations are displayed in different sub classes. This chapter describe Addis Ababa wireless network preventive maintenance trend, the relationship between preventive maintenance and fault tolerant factors(variables) to keep Network Availability Rate performance, how network maintenance cost can be reduced through data analytics.

4.1.1 Addis Ababa wireless network preventive maintenance trend in ethiotelecom

A greater knowledge of maintenance and its ability for long term profiting have increased the interest in the topic. It is all based on minimizing the downtime and the key to success is to ensure that preventive maintenance is properly being used. Hence, by leaving the firefighting perspective and striving to use preventive maintenance there is a lot to gain. Less failure, minimized downtime, lowered stress and higher quality, all working in the favor of profit (Lind & Muyingo 2009).

The maintenance trend of ethiotelecom wireless network operation and maintenance department is computer based. Which is basically follow system scheduled method of maintenance. The main criteria to assigning each mobile site is based on equipment factory life time. And the department use operation and maintenance performance enhancing system (ompes) to remind weekly based preventive maintenance time. On the other hand, the Huawei Net Eco system consistently remind D.G. timed maintenance alarm by its own power equipment running hour based schedule which is 300 hrs.

From the two maintenance reminder system ethiotelecom use the weekly ompes scheduling time of maintenance. According to the table below based on the sites degree of priority, which is either Core/Hub site or Normal site, every zones are expected to make preventive maintenance.

Type	Time interval to do pm
Normal Generator	Once Per 12 weeks
Core/Hub sites	Once per 4 weeks
Solar sites	Once per 16 weeks

Table 2 OMPES maintenance standards

Based on analyses result we have got insight knowledge about ethiotelecom Addis Ababa zones maintenance trend. For example, from collected maintenance data history analyses between January 1-2019 to July 1-2020 the maintenance trend of three zones are slightly different and in some time out of schedule.

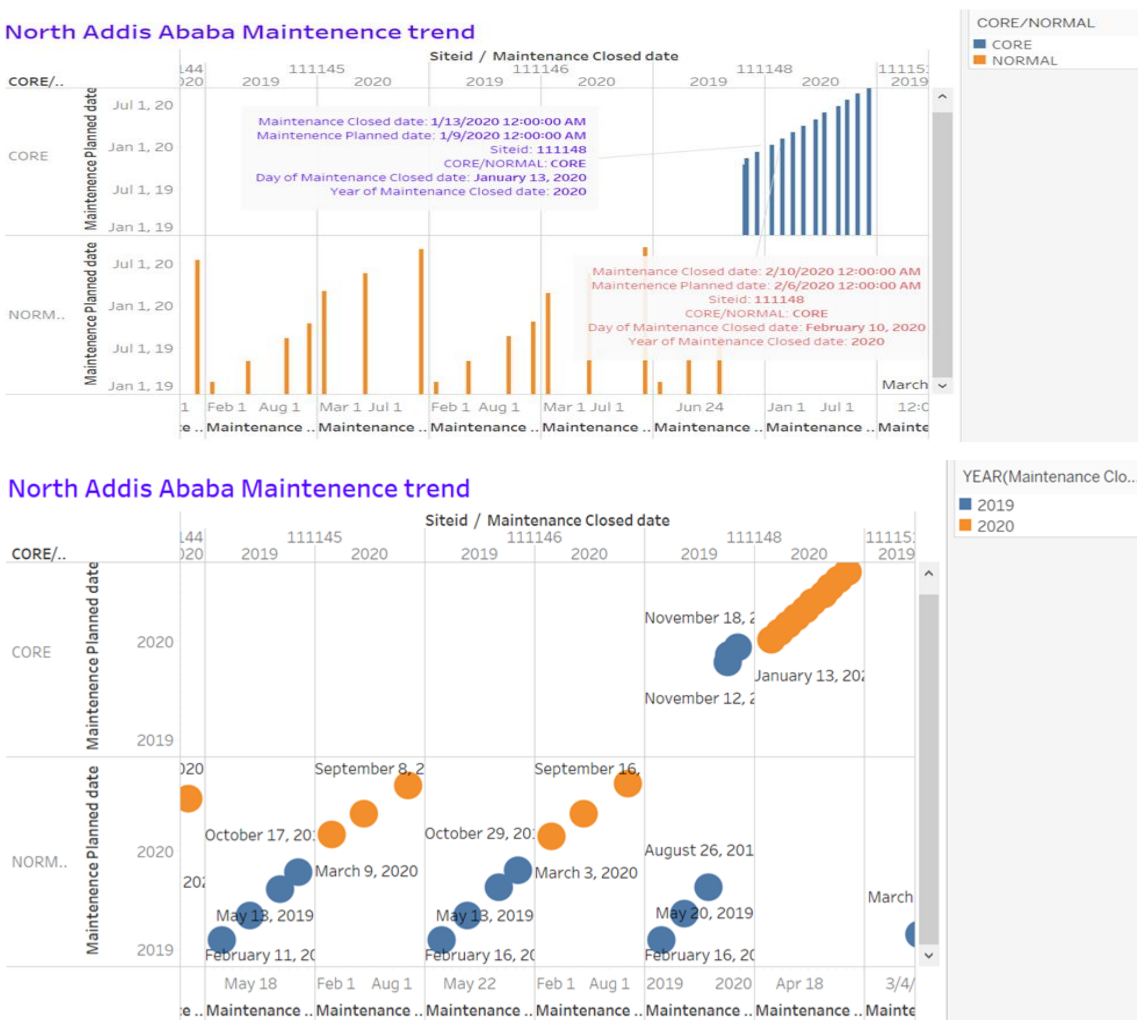


Figure 6.North Addis Ababa maintenance trend

From the above analyses output we see the North Addis Ababa preventive maintenance trend. Both core and normal sites are maintained but there exists a slight gap of consistency on both sides. For instance, mobile site ID 111148, which is core, needs maintenance once per month. And one is taking on January 13,2020 and the next is February 10,2020 which is good. But in some point we clearly see some gap which implies inconsistency.

From the existing data history in the table below for example clearly see that Hub/critical site 112205 previous time pm work history is not scheduled based pm. In some time, it takes more than four months which is out of standard.

PM Closed Day	ID1	REGION	SITEID
28/01/2019	543	NAAZ	112205
17/06/2019	12530	NAAZ	112205
2/9/2019	12530	NAAZ	112205
10/12/2019	12530	NAAZ	112205
22/01/2020	12530	NAAZ	112205

Table 3 Preventive maintenance trend of core site 112205

The same is true for Western and Central Addis Ababa zones.

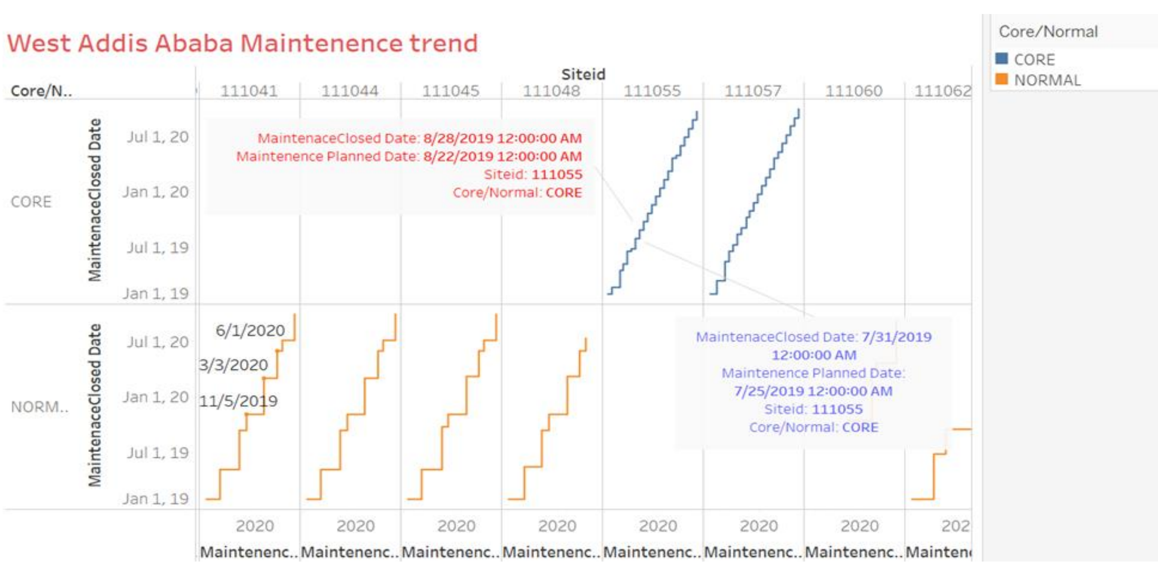


Figure 7 west Addis Ababa maintenance trend

From the analysis result the preventive maintenance of normal site ID 111041 takes four months which is out of schedule. And in Central zone also Core site ID 111051 takes two months, from February 22,2019 to April 16,2019 to make preventive maintenance which is out of standard time.

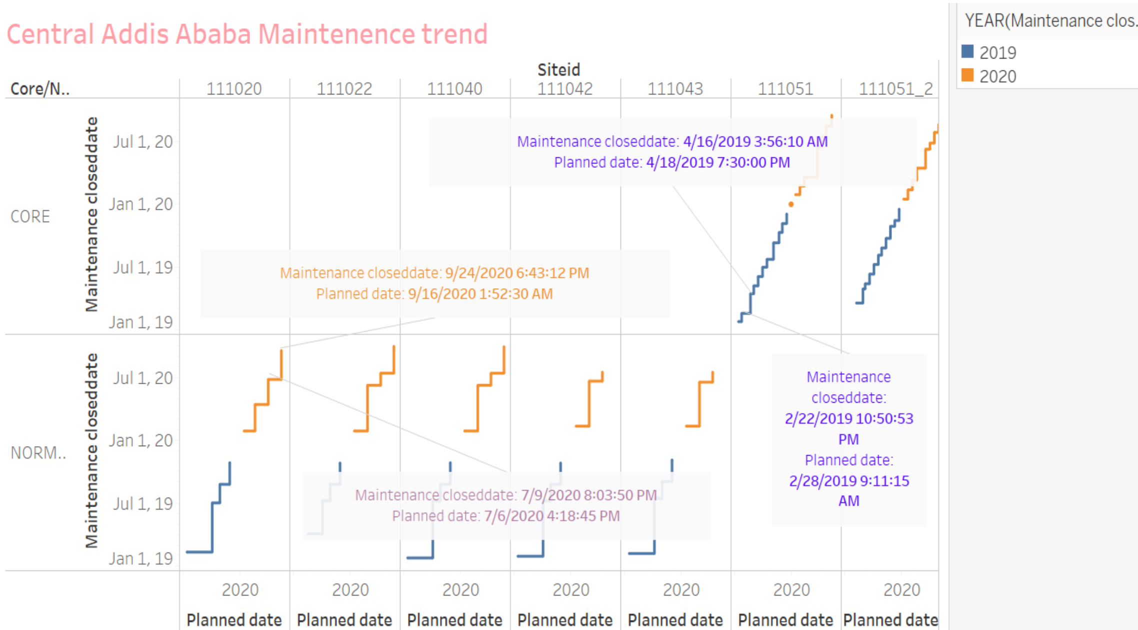


Figure 8 Central Addis Ababa maintenance trend

In general, the preventive maintenance trend is not in consistency in both sample zones because of unscheduled maintenance trend. And due to this the network availability rate may be affected if the power backup generator fails to start. But the degree of priority for core sites relative to normal site is kept good but needs maintenance management follow up.

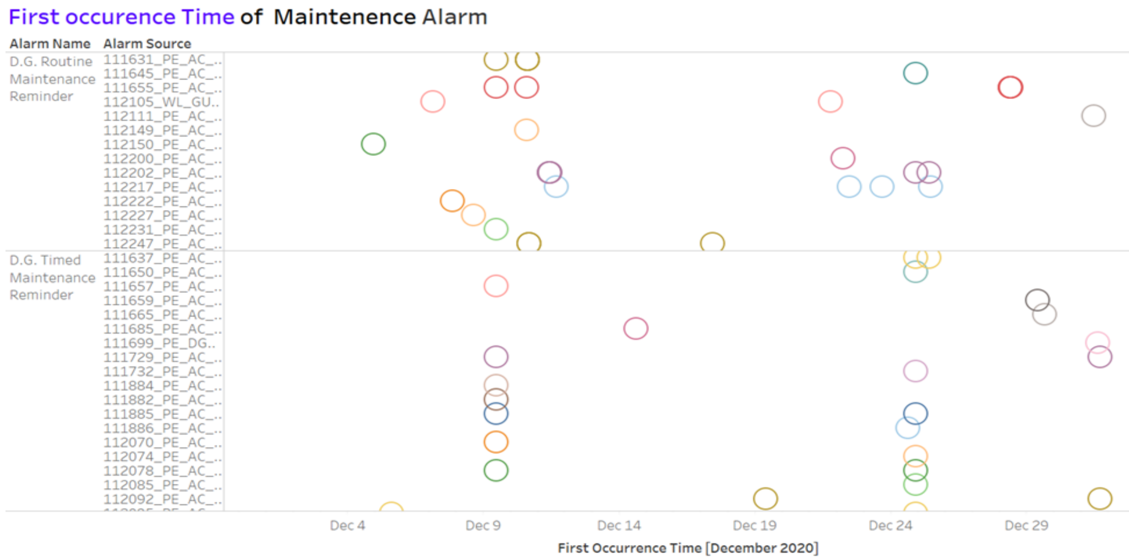


Figure 9 maintenance reminder alarm distribution

In the above output we can observe a lot of maintenance existing alarm distribution over time from the analysis of existing neteco alarm history database. Fault is basically minimized if preventive maintenance is properly managed. If the routine maintenance reminder ignored it becomes a fault type time maintenance reminder alarm.

4.1.2 Preventive maintenance and fault tolerant factors

Ethiotelecom currently provide both 2G, 3G & 4G technology to its customer. according to June 5, 2020 official report of the company ethiotelecom has 45,600,000 subscribers out of which 44,030,000 are mobile subscribers, 43,000,000 subscribers are 3G Mobile subscribers and more than 800,000 customers are 4G/LTE subscribers (EthioTelecom,18 June 2020). The 4G high technology service is provided in the whole Addis Ababa and this network expansion associated with three vendor companies (ZTE, HUAWEI AND ERICSSON) to provide the service out of Addis Ababa in all region of Ethiopia.

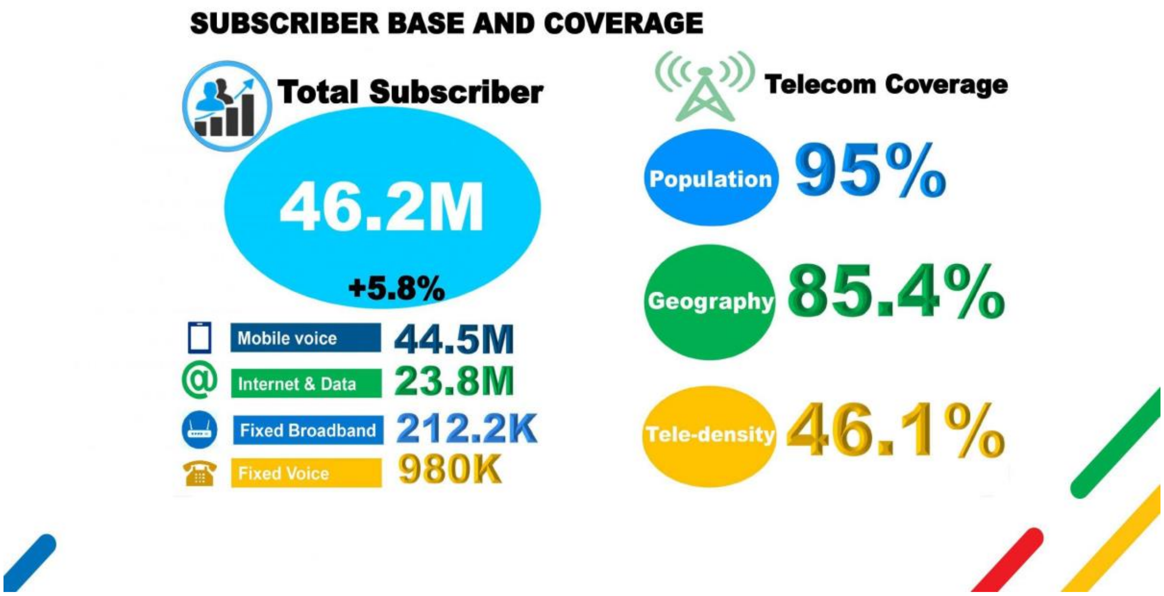


Figure 10 ethiotelecom subscriber base and coverage

All customers need a quality network without intermittent. Due to the technologies complexity it needs a close monitoring and controlling fault management.

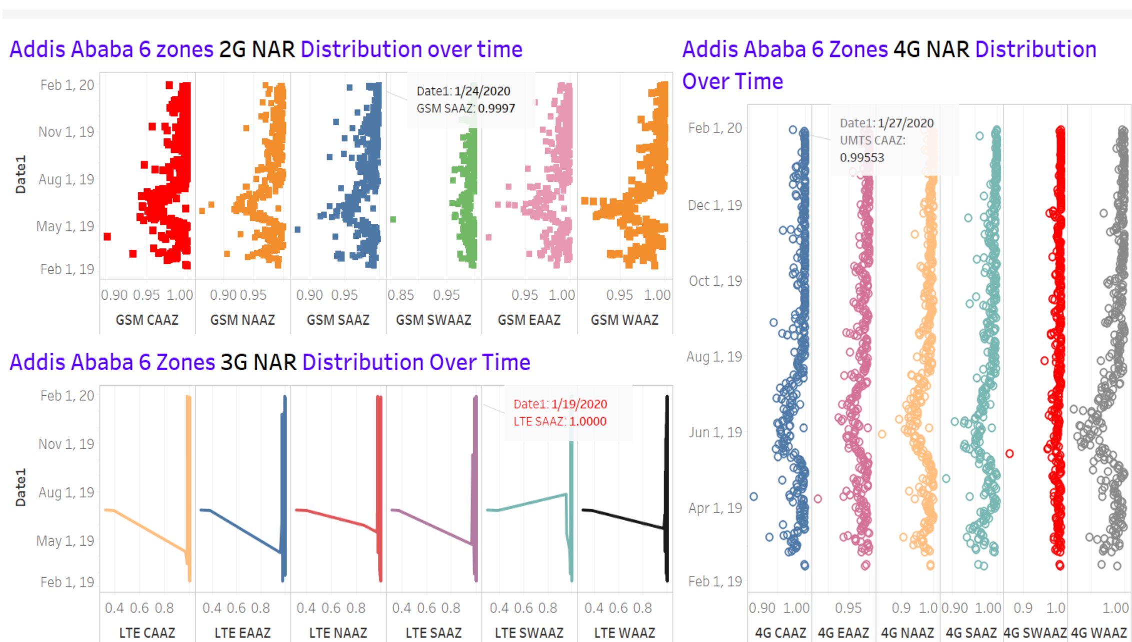


Figure 11 Addis Ababa network availability rate for 2G, 3G & 4G

From the figure above we clearly observe the network availability rate distribution over time between February 1,2019 and February 1,2020. From the analyses result there is a network interruption is occurred between May and August ,2019. This is happening in all technology type and due to this the quality was affected.

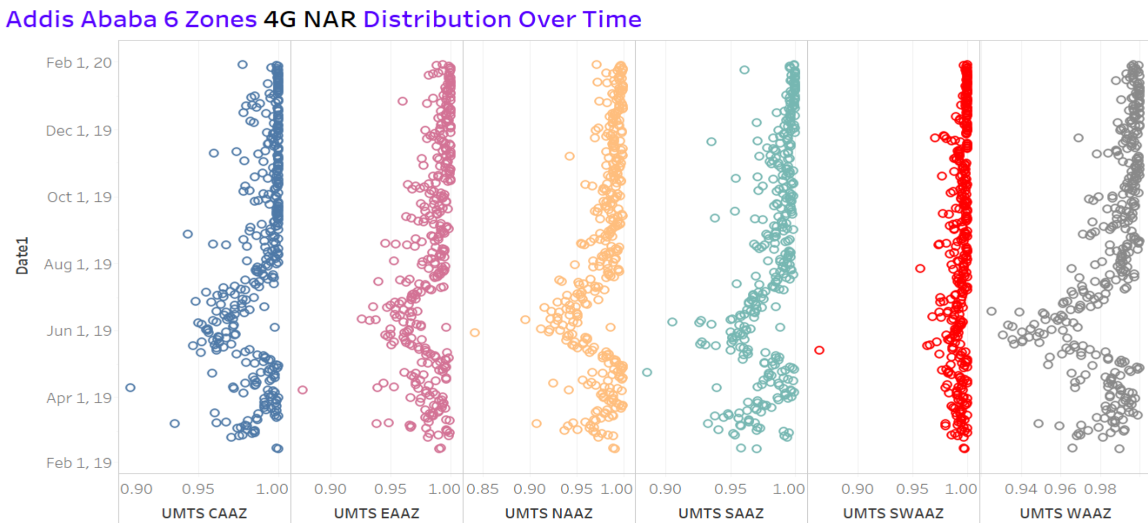


Figure 12 Addis Ababa 4G NAR

The population demand for the broadband services has not stopped rising in the last couple of years. Not only that the number of users is getting higher, but they extensively use the newly offered services. That is why 4G is very expensive in its investment capital and fast in service quality. 3G is also relatively fast and modern time technology. Due to its service limitation and technology type 2G is only for call and a minimum part in broadband internet service availability.

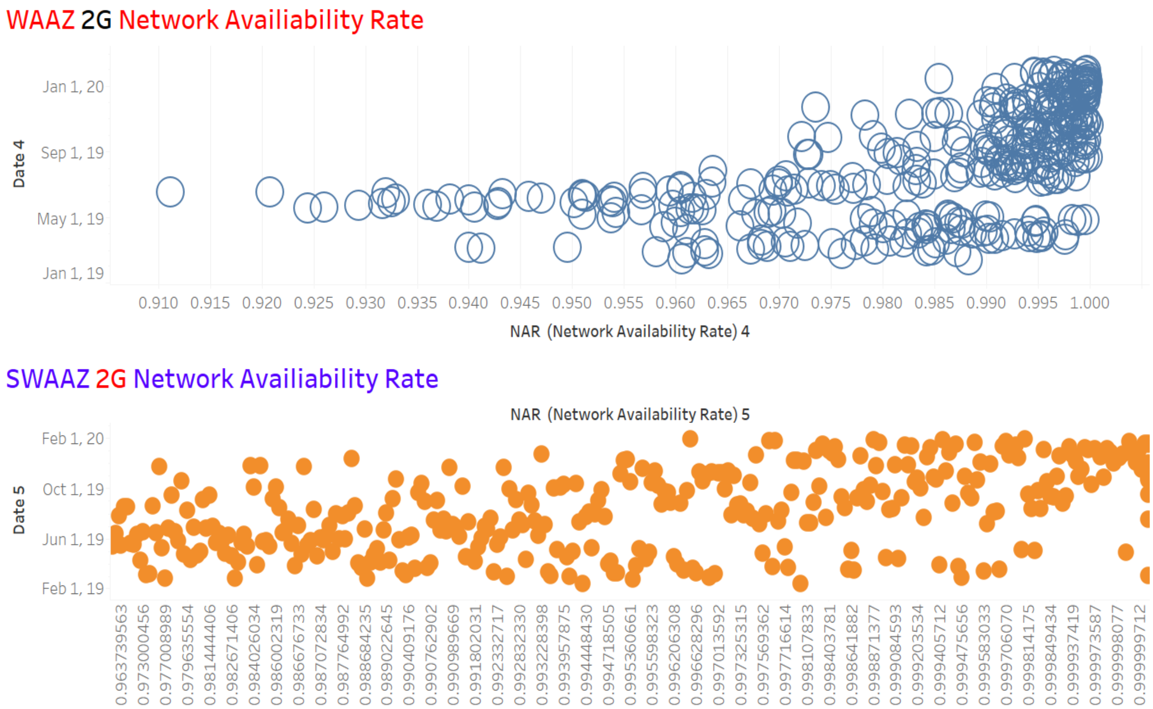


Figure 13 network availability rate

The network availability rate is highly affected by cell out-of-service duration and other related factors. Corrective actions detection of faults and alarm filtering and correlation lead to the next stage of telecommunication network maintenance which is the selection of corrective actions. Based on data analyses result the following preventive maintenance and fault tolerant variables are found in a relationship with one to the other. And from the observation they directly affect positively or negatively the network quality which is availability rate.

4.1.2.1 Number of Cell

In ethiotelecom Addis Ababa mobile site there is a different number of cells per zone for each technology either 2G ,3G or 4G. From the analyses we clearly observe this and even there is a different in number of cells between zones as well as technology types. The network availability rate will be calculated from number of cells and out of cell duration time which is unavailability rate. The figure below indicates the cell distribution over zone with its availability rate

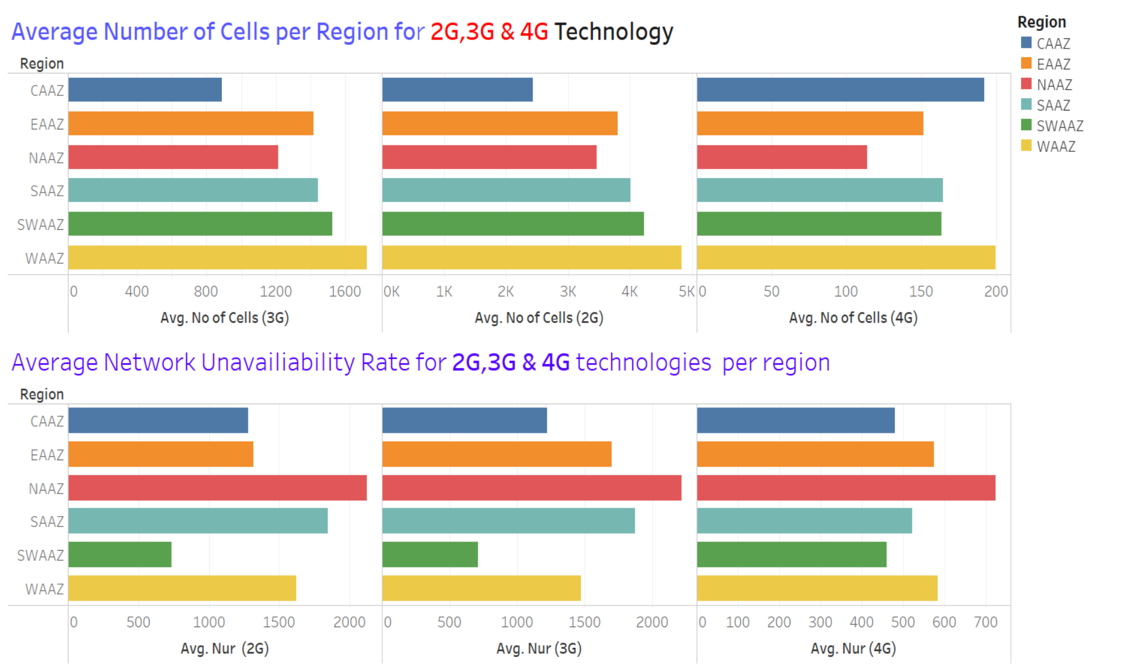


Figure 14 Average number of cell per zone

Based on the analyses West Addis Ababa zone has a large number of cells in all three technology type. And Central Addis Ababa zone holds small number of cell in 2G & 3G technology. North Addis Ababa zone has a least number of cell in 4G technology and the second small number of cell holder in 2G & 3G technology.

On the other hand, we also observe the trend of cell distribution even on each zone are not constant but it varies within a time. For example, the central and south west Addis Ababa zones cell distribution per specific period of time is vary and per network availability rate is also depends on the number of cell distribution nature.

It clearly indicates the relationship between number of cells, time and NAR.

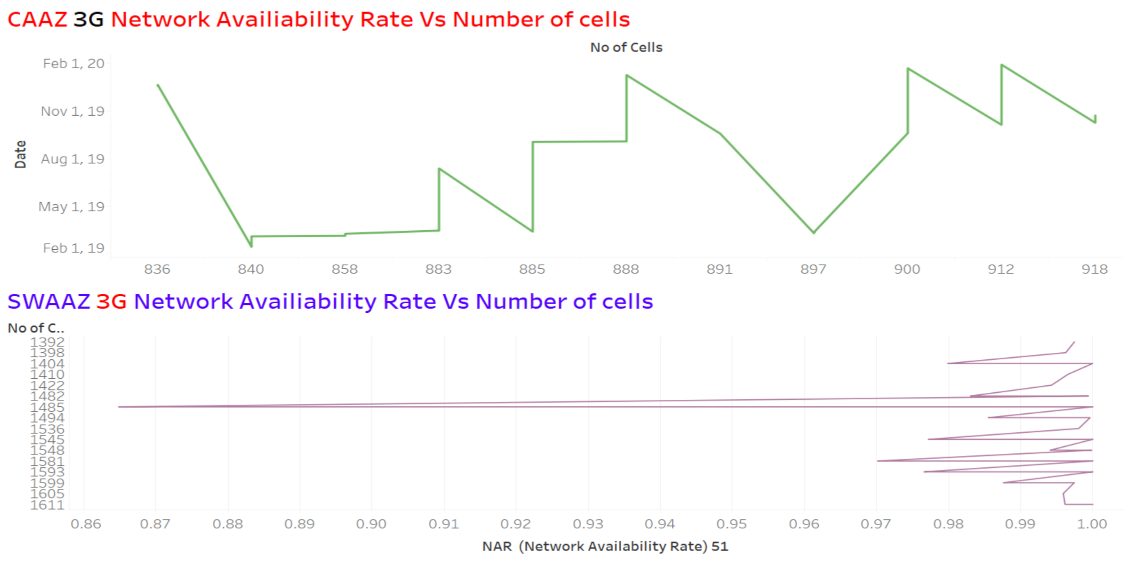


Figure 15 NAR Vs number of cell

4.1.2.2 Cell out-of-service duration time

Number of cell affect the network availability rate and quality based on the working effective time of the network. Network interruption means simply the time duration were the cell not in active mode. So the cell out-of-service duration is directly proportional with network unavailability rate and inversely proportional to availability rate of the mobile network.

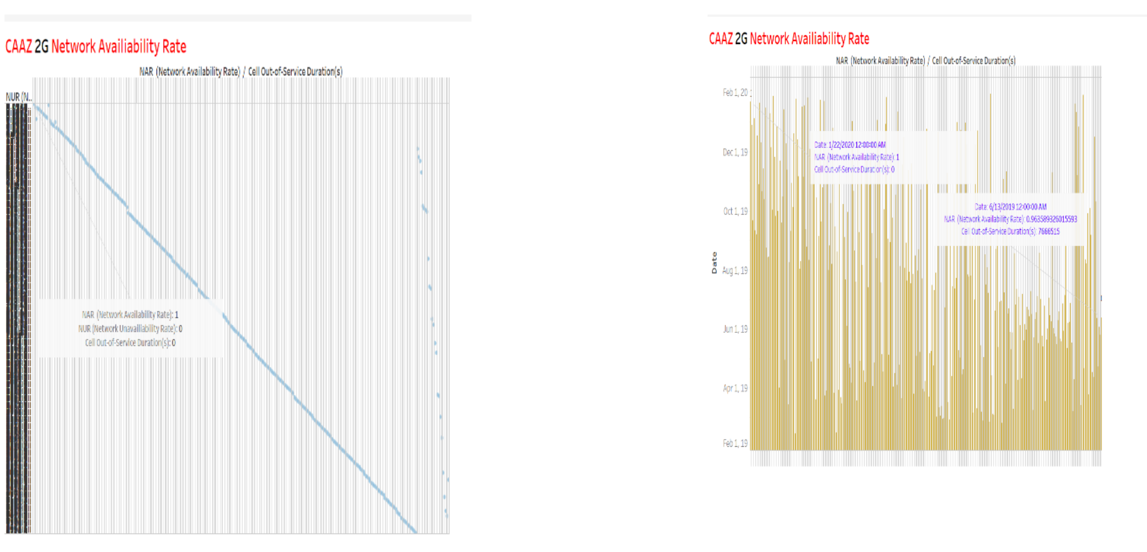


Figure 16 cell out-of-service duration Vs NAR

From the analyses we Observe the total sum of service interuption time which is network cell out-of-service duration. From the figure below the sum of network out-of-service duration in second over the region of Addis Ababa six zone is indicated.

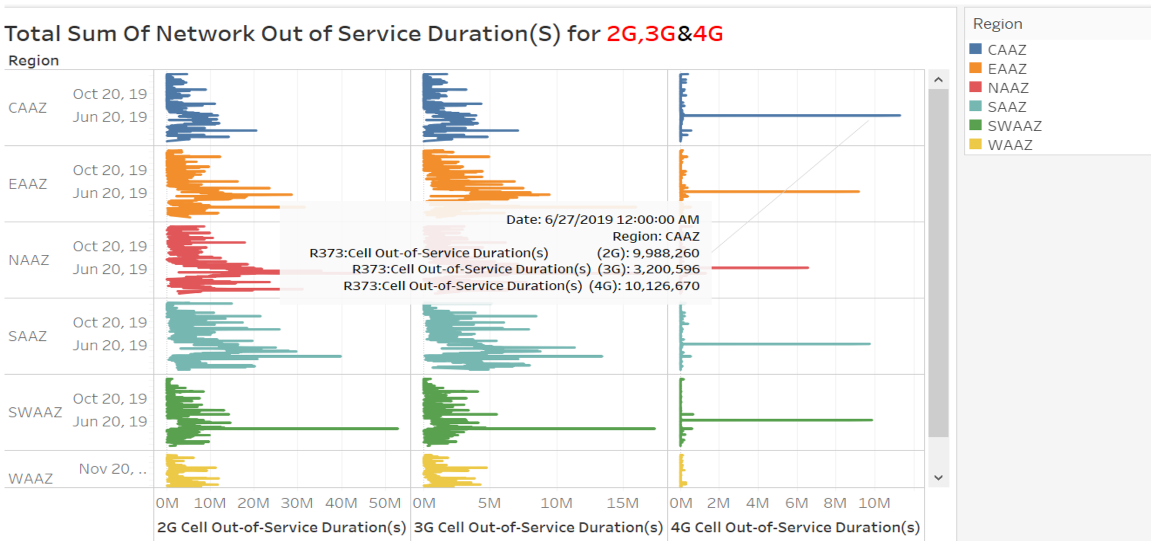


Figure 17 Total cell out-of-service duration for all technology

And also the analyses result tell us the direct effect to increment in rate of unavailiability rate occurred with in the time frame of the previous figure. Which means there is a direct relation between cell out-of-service duration and network unavailiability rate.

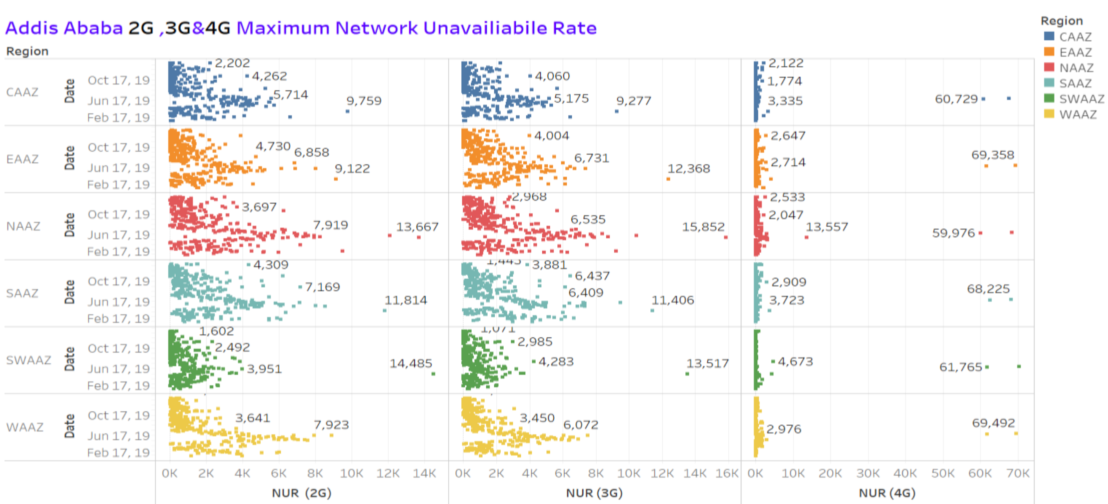


Figure 18 maximum network unavailability rate in Addis Ababa

From the figure above between the month of Jun and October the direct relationship of the two variables are clearly seen from analyses report. Both are affect the network stability unless and other wise fault clearance and maintenance is done properly.

4.1.2.3 Maintenance Time

Here when we talk about maintenance time we mean preventive and fault corrective maintenance time. So care is must in operation and maintenance management to reduce the cost and time of maintenance. High maintenance time indicated us poor fault management and weak preventive maintenance culture. As a result, the overall wireless network stability is disturbed and customer compliant increase. From the observation of the thesis analyses result output we try to identified the maintenance time effect over the network quality.

4.1.2.3.1 Fault Clearance time /Corrective maintenance time

Based on the analyses data we see that during network interruption time the fault alarm sent to the technical staff in two perspective time manner which are first and second occurrence time. Whenever the fault is cleared as quickly as possible the corrective maintenance time become small and the cost needed to fix it will be minimum.

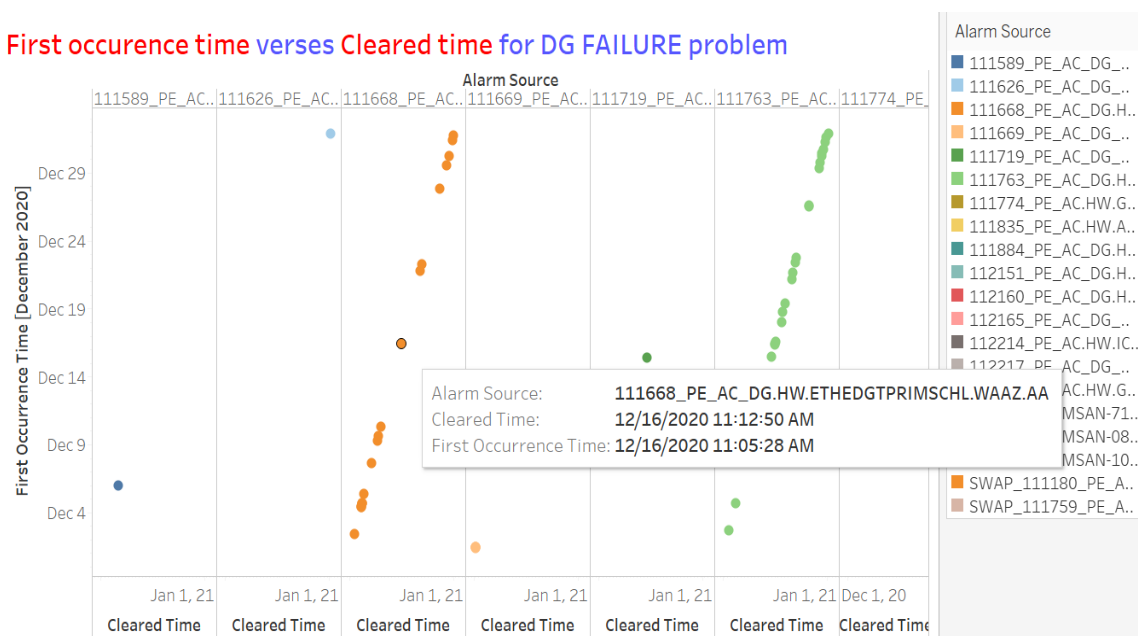


Figure 19 fault first occurrence time Vs cleared time

On the other side if the fault is not cleared on time within a standard time interval it consequences affection in performance. From the figures below we clearly observe the analyses result of corrective maintenance trend on site ID 111668 and111719. Both sites are cleared within a minimum time interval and this is able to reduce maintenance cost and cell out-of-duration time for a specific time. But the number of occurrence is high and it indicates the frequently down site. So the corrective maintenance either poor in quality or a new root cause may be disturbed the site in repeated manner. But because of the alarm is already identified, which is Generator failure problem, we conclude there is a corrective maintenance gap.

Figure 20 Generator failure occurrence time

On the other way there are also sites like site id 111719 which is already occurred first and then once cleared and it becomes health for that particular day at least so the site is not a frequently down site. And this indicates the effectiveness of corrective maintenance for a particular site.

4.1.2.3.2 Preventive maintenance time

In ethiotelecom maintenance reminder alarm classified in to generator routine maintenance reminder and generator timed maintenance reminder. Both are sent to remind the technical staff to keep in health before the site exposed to some maintenance related problem. From the analyses result we can observe that the preventive maintenance reminder is not considered as a formal scheduled or may be out of awareness to do maintenance. Rather due to some reason the site maintenance reminder alarm will be cleared from maintenance alarm even after a month from first time occurrence. Which simply means either the maintenance is made by different schedule which is based on OMPS or manually reset the alarm without maintenance work report.

That is why in some cases the backup power generator holding maintenance reminder alarm automatically and left from running even the main power source is lost. And this will lead for network interruption and unavailability rate.

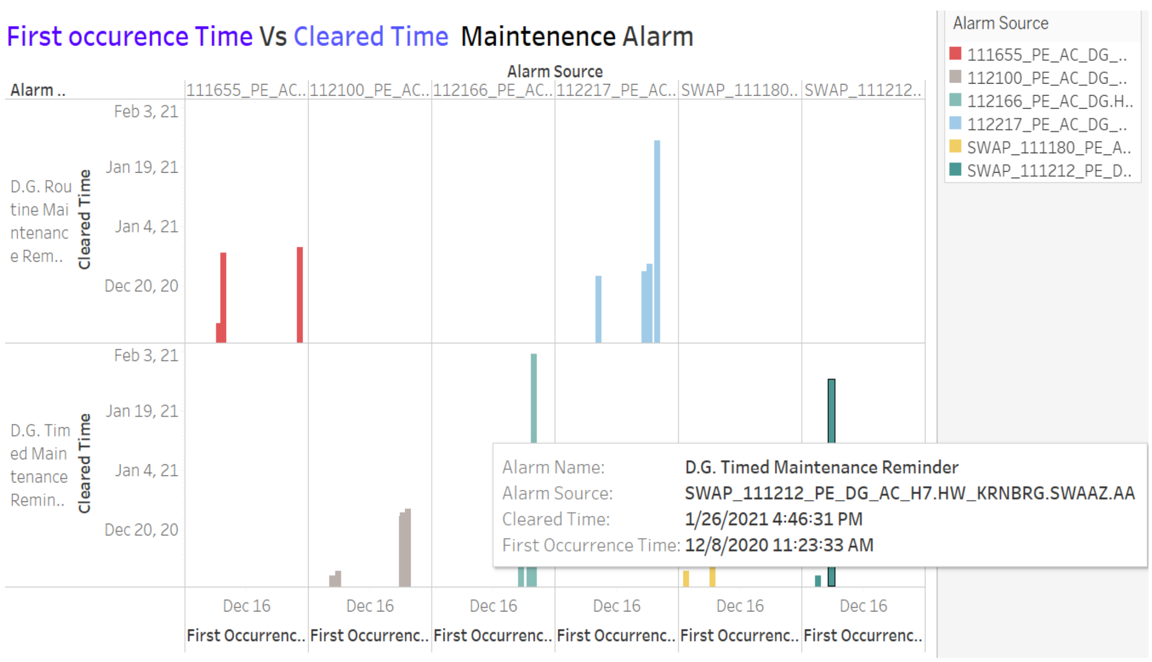


Figure 21 preventive maintenance alarm reminder

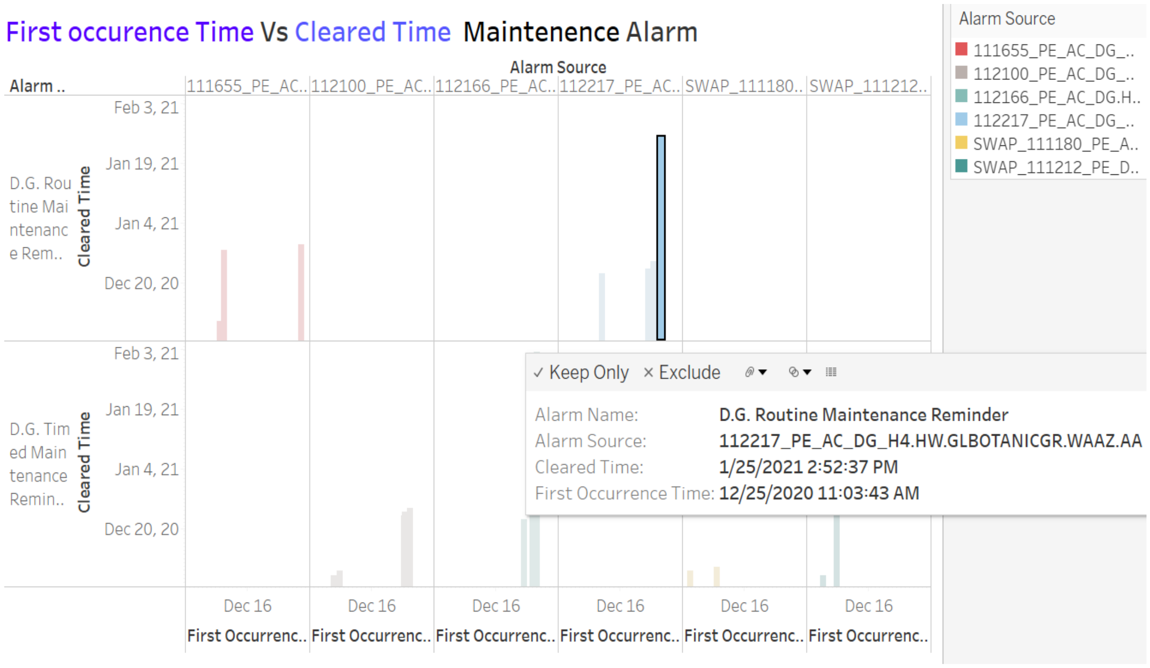


Figure 22 First occurrence time Vs cleared time of 112217 mobile site

For example, South West zone Addis Ababa zone sample site id 111212 is a core site of holding seven more sites as a link and if this sites down means all seven sites are also down. And from the above figure its maintenance alarm was cleared after a month since the remind time (from 12/8/2020 to 1/26/2021 which is almost more than 47 days of delay). Which is out of standard time for core site 30 days.

On the other side West Addis Ababa zone sample site id 112217 which holds 4 site link was cleared exactly with in a standard time of one month. This is good trend to improve the network performance.

4.1.2.4 Severity Level / Alarm priority level

the other variable which is analyses is alarm priority level or severity level which holds four level of priority. The four level of severity are critical, major, minor and warning alarm.

Severity Level 1 /Critical alarm

Critical alarms are critical problems that severely affect service, capacity/traffic, billing, and maintenance capabilities. L1 events require immediate corrective action, regardless of time of day or day of the week. Some examples of L1 faults are: - Total or partial outage impacting service effecting more than 10% of Customer subscribers per regional network element, Ongoing short breaks impacting service to > 10% of Customer subscribers, Ten or more sites down in one province and also if all sites down in one city and duration more than 24 hours.

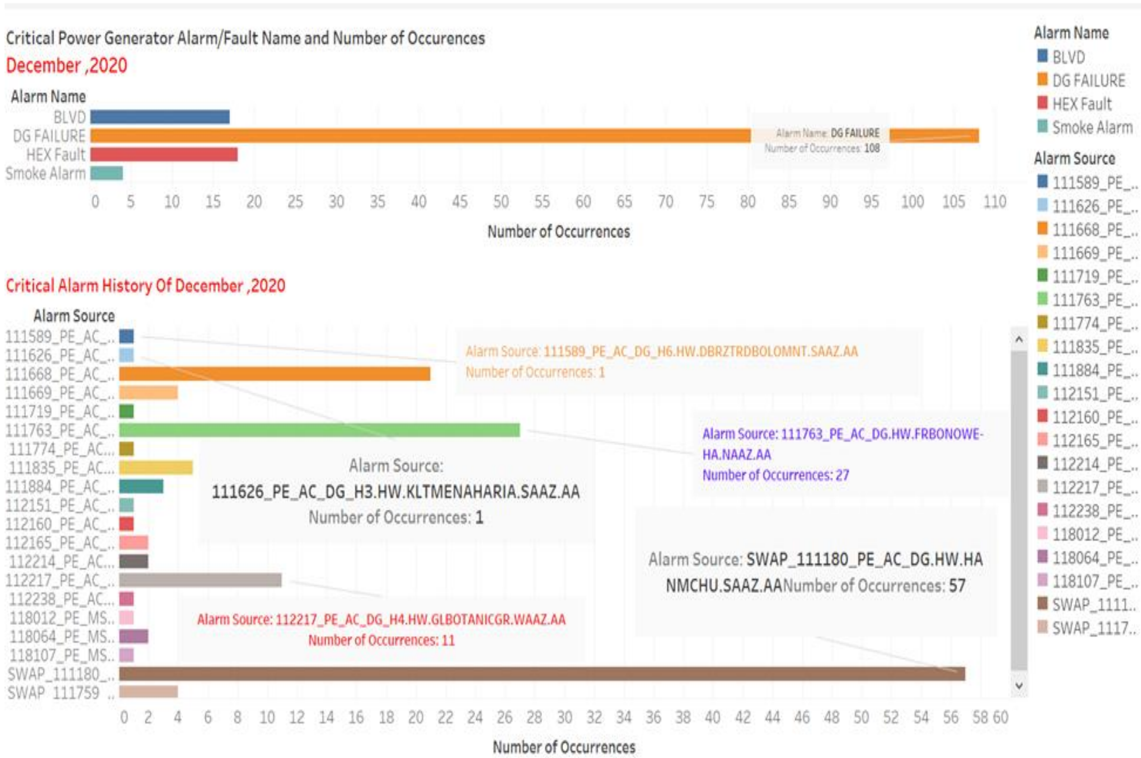


Figure 23 Critical Alarm history

From the analyses of critical alarm history on month of December, 2020 indicates there is a poor trend of handling critical alarms. For instance, the south Addis Ababa zone site id 111180 fail 57 times due to some reason. Which is large in number of occurrence. The same is true for north Addis Ababa site id 111763 which holds 27 number of occurrence.

Here also Southern Addis Ababa zone is better from counting of critical alarm occurrence in repeated trend. Almost 108 critical alarms are occurred due to generator failure which is unexpected. Due to back up generator the company expect zero tolerances to handle the fault with in a minimum clear time interval.

Severity Level 2 /Major alarm

Major alarm are situations that seriously affect system operation, maintenance, and administration. This require immediate attention. The urgency is less than a critical alarm because of an impending effect on system performance, end-users, operation, and revenue. A major alarm on the device could impact a majority of the users.

Some examples of major faults are: - Congestion impacting service to 10% or more of the traffic on a network element, Loss of redundancy or backup system on a network element that could lead to a critical failure, a complaint of 100 or more subscribers highlighting a definite failure which needs to be isolated. Loss of reporting functionality or data/counters used to generate reports, equipment failure where service is not lost but subscriber details cannot be changed or added. Suspected corruption on a network node may lead to possible failures, a critical BTS down (as defined in a Critical site list or HUB site), a BTS that has not been recovered for 24hours.

From the analyses we observe most sites are affected by major alarm on month of December,2020. And most of the alarm was cleared within 24 hours' interval which is good. But the core sites need special care as much as possible.

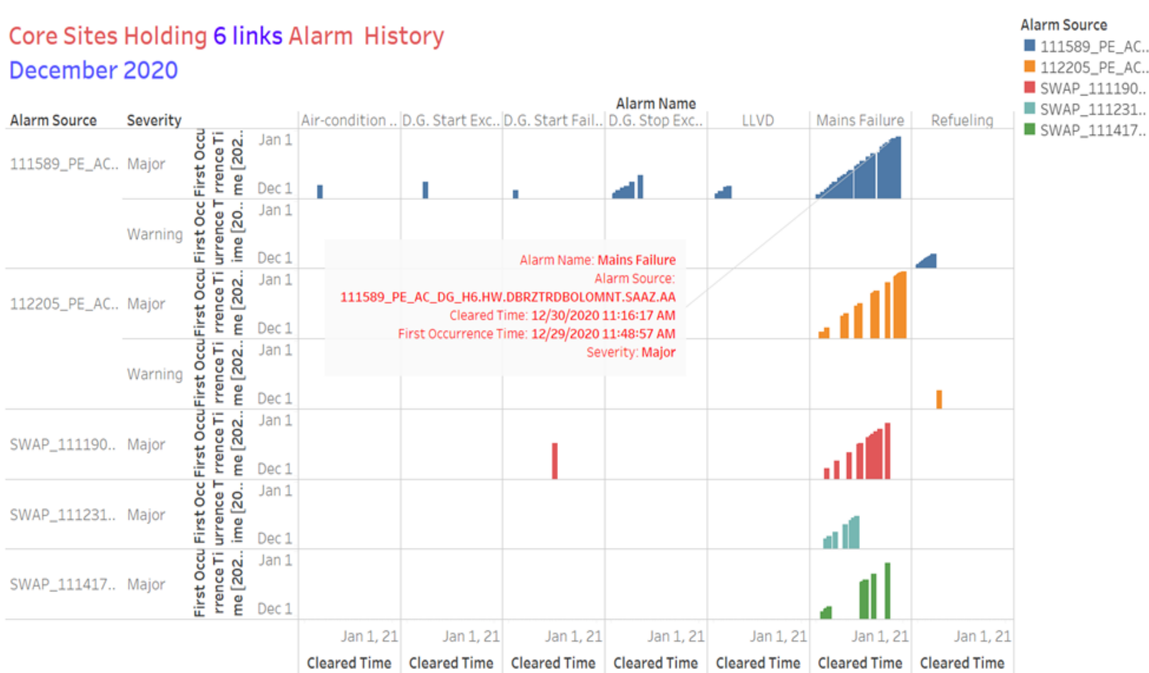


Figure 24 Major alarm history of core site 111589

Minor alarm neither significantly impairs the functioning of the system nor significantly affect service to end-users. Minor alarm on the device may have impact on one or limited number of users. Warning alarm are some inquiries of questions from a customer, or minor problems but services are not affected.

From the figure below we observe and understand the different level of alarm with their specific number of occurrences. Most of the alarm occurred during the specified time interval is critical and major type of alarm. Due to their number of occurrence we simply know there are number of frequently down sites including core or hub sites like 111589 which holds 6 sites as a link. This site exposed to some problem four times within one month which is not good fault handling trend.

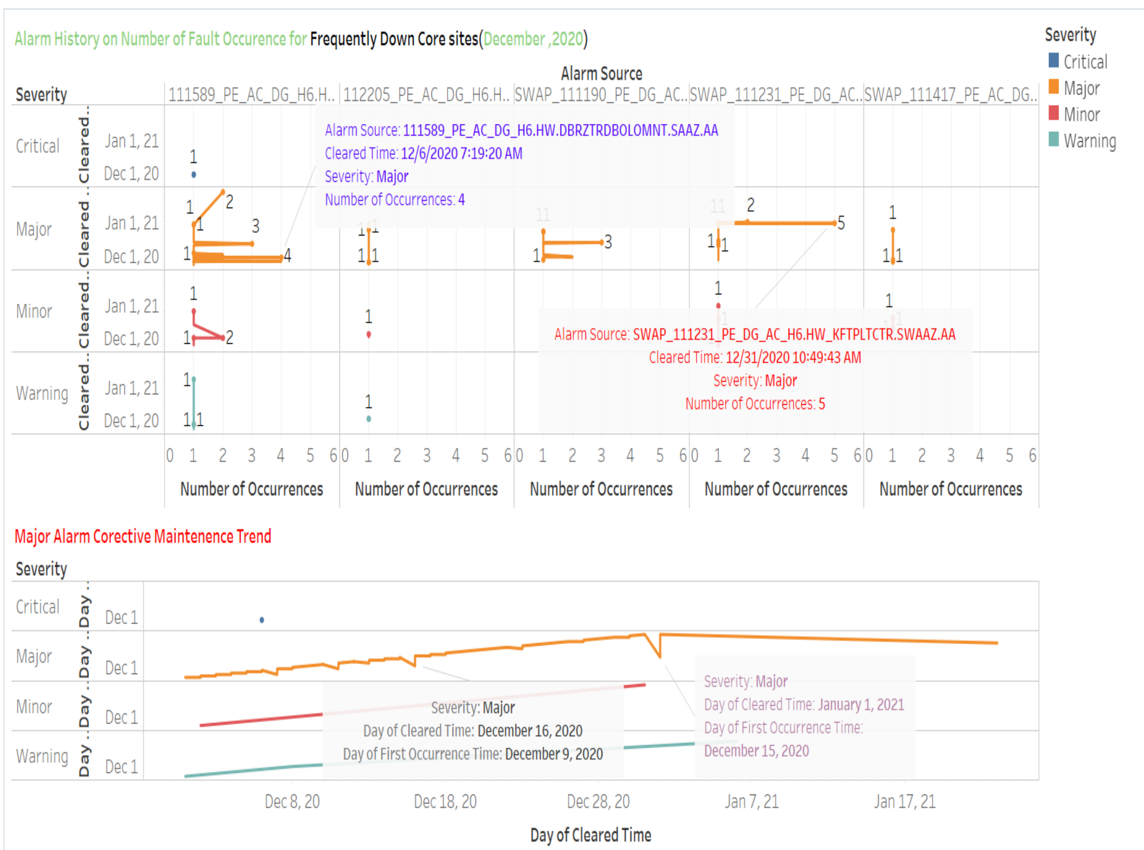


Figure 25 Alarm level and number of occurrence

4.1.2.5 Number of Occurrences and Frequently down sites

Number of occurrence implies the amount of repetition of some events. Due to this frequently down sites are existed. From the analyses there exist a number of failures that have been occurred several times. Because of the high number of occurrence time the network affected and the performance declined.

Severity	Alarm Name	Alarm Source	Number of Oc	First Occurrence Tim	Last Occurrence Time	Cleared Time	Alarm ID
Major	Fuel Level1 Sensor Not Detected	112167_PE_AC_DG.HW.LAFTOKKWRDC	2	12/9/2020 11:17	2/9/2021 11:45	2/16/2021 9:17	8654
Major	Major Load Fuse Broken	111629_PE_AC_DG.HW.CMCALTADMO	6	12/3/2020 15:45	2/4/2021 15:50	2/4/2021 15:51	8628
Major	D.G. Start Failure	112196_PE_AC_DG.HW.KERSAGUL.KER	3	12/29/2020 8:48	2/3/2021 21:17	2/8/2021 8:54	202
Major	D.G. Timed Maintenance Reminder	112166_PE_AC_DG.HW.SEFERAMENDE	8	12/25/2020 10:46	2/1/2021 14:52	2/2/2021 8:54	231
Warning	D.G. Timed Maintenance Reminder	111685_PE_AC_DG.HW.GULELEHOLYS\	4	12/14/2020 14:35	2/1/2021 10:49	2/2/2021 10:42	231
Major	D.G. Start Failure	112166_PE_AC_DG.HW.SEFERAMENDE	3	12/26/2020 13:27	2/1/2021 10:36	2/1/2021 11:38	202
Major	Air-condition Failure	112160_PE_AC_DG.HW.ENTKIDANMHT	9	12/9/2020 11:17	1/31/2021 9:56	1/31/2021 10:24	65203
Warning	Refuel Reminder	111685_PE_AC_DG.HW.GULELEHOLYS\	2	12/14/2020 14:36	1/28/2021 9:47	1/28/2021 9:48	302
Major	Infrared Alarm	SWAP_111212_PE_DG_AC_H7.HW_KRI	10	12/3/2020 11:29	1/26/2021 16:47	1/27/2021 13:52	65237
Major	PSU Communication Failure	111629_PE_AC_DG.HW.CMCALTADMO	5	12/3/2020 15:44	1/25/2021 17:52	2/4/2021 15:50	1602
Major	HEX Fault	111652_PE_AC_DG.HW.SHIROMEDAGE	6	12/31/2020 10:43	1/25/2021 10:04	1/25/2021 10:24	65238
Major	AC SPD Fault	111589_PE_AC_DG_H6.HW.DBRZTRDB	2	12/25/2020 14:27	1/17/2021 11:49	1/23/2021 9:50	65200
Major	D.G. Timed Maintenance Reminder	SWAP_111212_PE_DG_AC_H7.HW_KRI	3	12/8/2020 11:23	1/14/2021 9:42	1/26/2021 16:46	231

Table 4 Extracted row data

From the two figure bellow we observe that the high occurrence number will be registered due to D.G. Running alarm type and counted 5,137 in number. Which means due to some unidentified reason the generator starts to run this much only in the month of December. This tells something to assess the means of startup.

And also the figure exposed other generator related alarm with their number of occurrence which is needed to focus on clearing such type of failure for future maintenance tasks. Number of occurrence is one of the factors to increase the expense of maintenance cost. This is because for every fault occurrence there will be a response by using vehicles, spares, time and labor. Uneducated and unorganized corrective maintenance and preventive maintenance culture leads to increase number of occurrences.

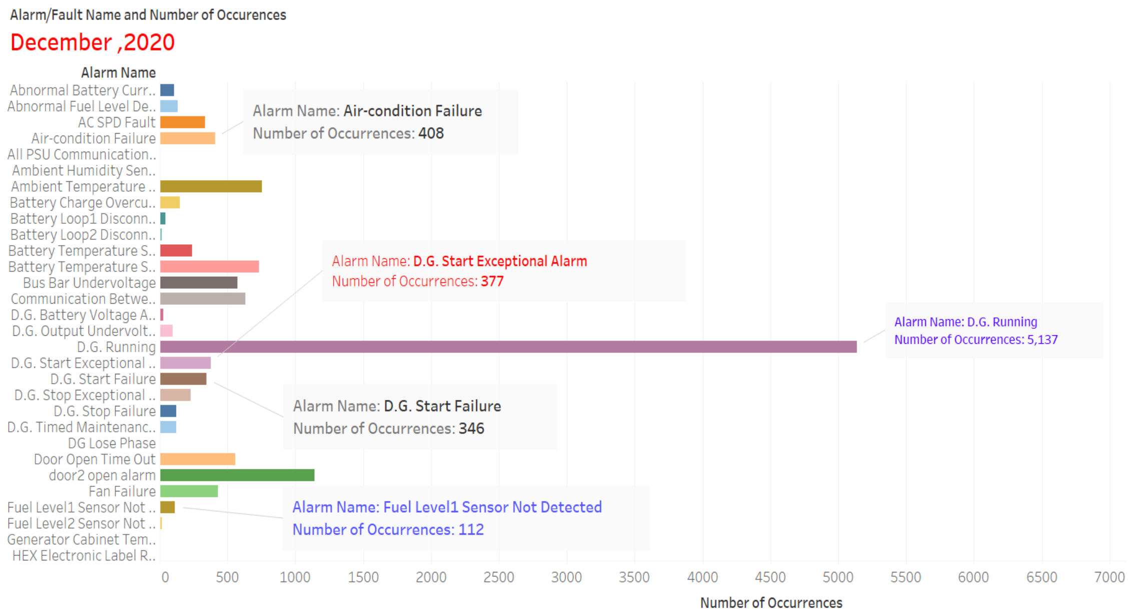


Figure 26 number of occurrence per alarm name

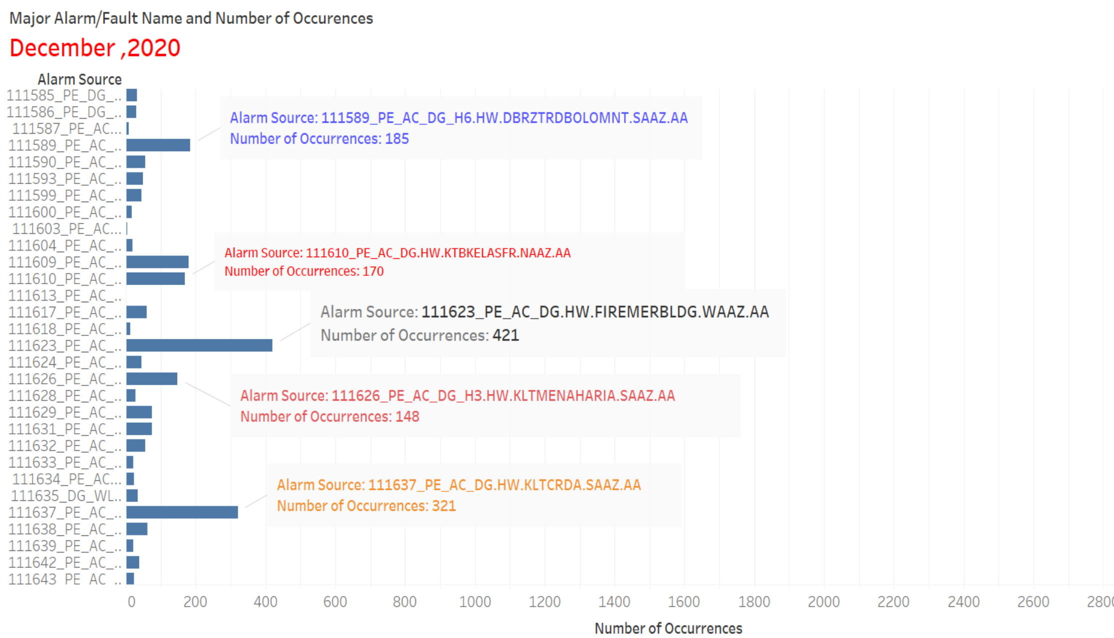


Figure 27Number of occurrence per site ,December 2020

Due to large number of occurrence the site becomes frequently down sites. From the figure below the maintenance reminder alarm number of occurrences was analyses. For instance, core sites of two regions SWAAZ & WAAZ (111212& 112217) the site assigned to do preventive maintenance for 6 and 7 times. This indicates the ignorance from doing maintenance for some reason.

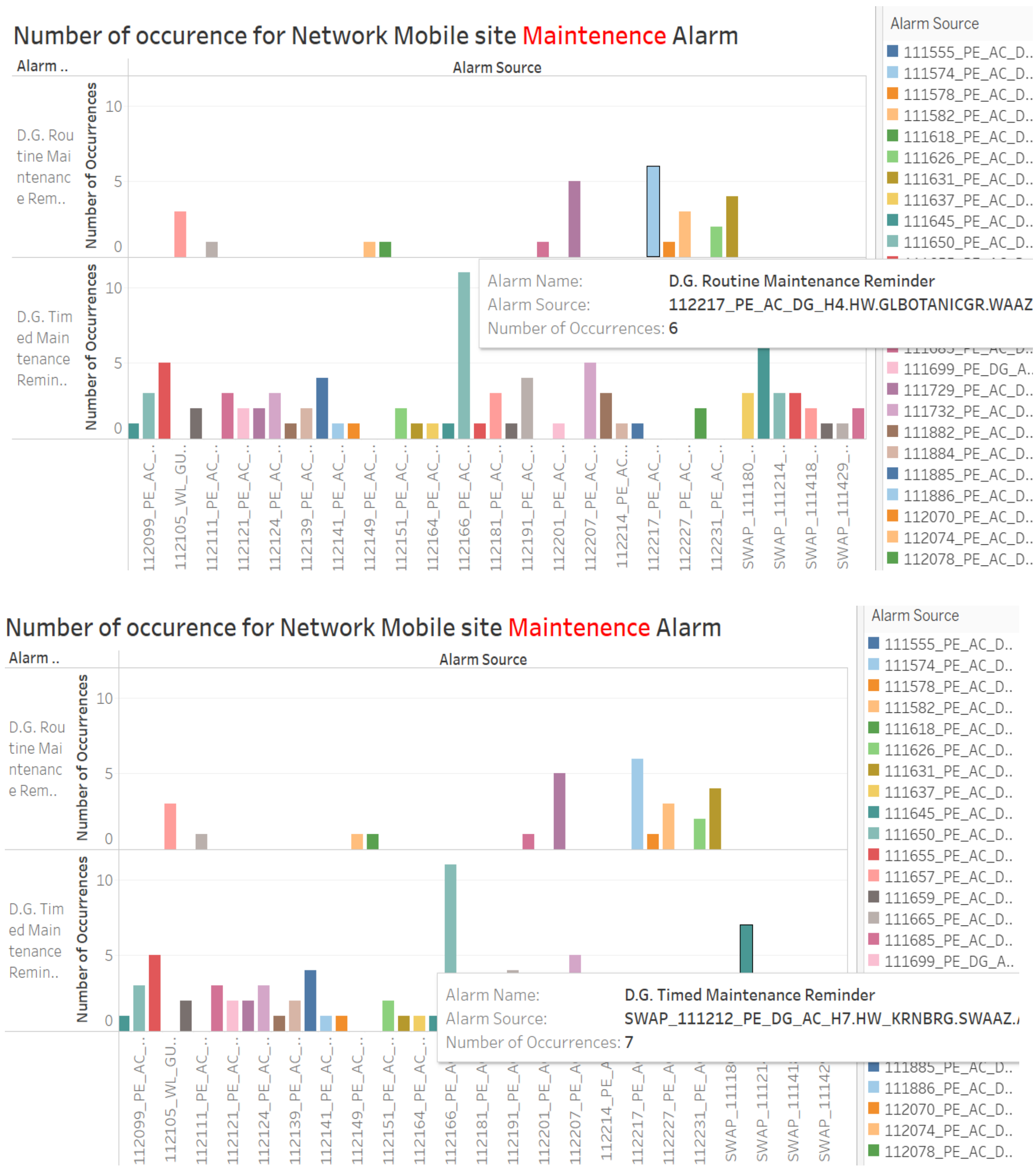


Figure 28 number of occurrence for maintenance reminder alarm

4.2 Discussion

Business data analytics has become an area of great interest for organizations, as it has been recognized as a means by which organizations can obtain valuable insights from data; supporting more informed business decision-making. As a result, more organizations are investing in business data analytics as a means to deliver on their strategic imperatives, innovate, and obtain competitive advantages in their marketplace.

Being able to utilize the extracted knowledge gained through big data analytics will enable each organizations to make quick and best decisions, and the biggest problem they will be facing is to incorporate the data-driven insights into their scheduled day-to-day business processes (Mohanty, 2013; McAfee & Brynjolfsson, 2012; Pearson & Wegener, 2013; Henke, 2016). Including ethiotelecom the motive of using data driven decision at any circumstance is not satisfied. Due to this somewhere a row data may have revised as a benchmark of some future time plan. But this is not formal way implementing an existing data source for analyses by using proper tools and procedures.

By taking wireless network fault tolerant and maintenance trend of the company this thesis tries to explore the application of data driven decision making. We bring a lot of insight knowledge from the analyses result. Starting from maintenance trend of the company up to the network availability factors are identified from the output of the analyses. This knowledge will lead the company to improve its service quality and also used to increase over all performance (Brynjolfsson, 2011; Marr, 2015).

Ethiotelecom as a telecommunication company must be start to take and analyses for each segment of the operation and service routine to explore the application of data driven management decision. We assure that by using analytics the company able to understand past and current network performance and make informed decisions, predict the future by examining historical data, detecting patterns or relationships in these data, and then extrapolating these relationships forward in time. And also used to identify the best alternatives to minimize or maximize some objective as well.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In today's world competition data is an engine in all industry to maximize the overall network service quality. Specially for telecom industry due to its digital nature all operation and maintenance process is controlled and monitored through data exchange. And the probability of finding an existing data from different data servers is easy. Ethiotelecom also the one and the only telecom digital operator in Ethiopia. Because of this currently there is a huge amount of stored network status data history on the central data server as well as on performance data basses. But the trend of using this existing data to support and facilitate the operation and maintenance tasks are week. Due to this gap the researcher stand to explore the application of data driven decision making and dig out the insight knowledge through analyses. Specially the network fault tolerant and maintenance management process needs additional existing data insight review to inspect real time knowledge and make a decision.

Due to routine operation and maintenance trend of ethiotelecom the network availability rate was negatively affected. From the result output we can easily identify the gap between the current time status of the site and the way of handling faults. Frequently down sites are occurred because of lack of awareness or negligence to know insight.

So the main objective of this thesis work is to explore the application of data driven decision making in ethiotelecom by taking wireless network fault tolerant and maintenance history data. After we analyze the extracted existing data of wireless network fault and maintenance trend, were first collected from Network operation center and performance data base, made analysis using tableau.

Five factors or variables were considered in the analysis which are explored from existing data and which are closely related one with the other. These are Number of Cell, Cell out-of-service duration, Maintenance Time, Severity Level and Number of Occurrences. In all these five factors analysis the final result insight observation of ethiotelecom wireless network fault tolerant and maintenance management is not fully satisfied and not supported by existing data insight real time knowledge. Even core sites are frequently down due to D.G. failure. This increase cell out-of-service duration time so network unavailability rate is high. Most of the fault and maintenance alarm are not properly closed within a standard time of maintenance and because of this large number of occurrence will be exist. All this are clarified by data analyses tools and it indicates its importance for further investigation of the company's target area.

To conclude this large fault occurrence time, unscheduled preventive maintenance report, frequently down sites and large cell out-of-service duration time are found through analyses. The maintenance trend of some Addis Ababa zones are not in consistency and scheduled based for some time interval. This and other related inputs are investigated through meaningful way of analyses tool and finally result interpretation is made. Systematically cost and time reduction mechanisms are identified through descriptive analyses result as well and this all can explore the application of data driven decision making.

5.2 Recommendation

Based on the above existing data analyses result and findings, the following recommendations are forwarded to the ethiotelecom operation and maintenance managements.

Fault tolerant is important factors to improve network availability rate and quality. To keep the network healthy all the occurrence faults should be cleared with in standard time interval. Severity of alarm is an indicator of priority so give first priority for critical and major alarms as quick as possible.

Ethiotelecom maintenance trend is not in consistency and this may highly affect the network performance in selective times. Due to this reality the management team will make an assessment of all core and normal sites current status and running hours to identify and select weekly pm sites decision.

All Addis Ababa zones are not incapable of enough recording data history or even extracting from central data base system to evaluate their overall work progress as a result the communication link between is not enough. So to address this problem they must be trend and improve data management habits as well as the implication of it.

Finally, to improve fault tolerant and maintenance management as well as effective cost and time utilization in ethiotelecom operation and maintenance department, the researcher recommends the implementation of data driven decision making constantly.

5.3 Further Studies

This study has explored the application of data driven decision making by taking wireless network fault tolerant and maintenance. The researcher recommends further studies to include the rest departments existing data insight knowledge by analyses of different sections operation part in order to explore the application of data driven decision making.

References

Kulin, M., Fortuna, C., De Poorter, E., Deschrijver, D., & Moerman, I. (2016). Data-driven design of intelligent wireless networks: An overview and tutorial. Sensors, 16(6), 790.

Churi, J. R., Surendran, T. S., Tigdi, S. A., & Yewale, S. (2012). Evolution of networks (2G-5G). In International Conference on Advances in Communication and Computing Technologies (ICACACT) (Vol. 51, No. 4, pp. 8-13).

Karevan, A., Tee, K. F., & Vasili, M. (2020). A reliability-based and sustainability-informed maintenance optimization considering risk attitudes for telecommunications equipment. International Journal of Quality & Reliability Management.

HAILU, T. (2014). Assessing the effect of service quality factors on broadband internet customer’s satisfaction in Addis Ababa, the case of ethiotelecom (Doctoral dissertation, St. Mary's University).

Tadesse, A. (2019). Evaluating Quality of Services of 4G LTE Cellular Data Network: The Case of Addis Ababa (Doctoral dissertation, St. Mary's University).

Salau, A., Yinka-Banjo, C., Misra, S., Adewumi, A., Ahuja, R., & Maskeliunas, R. (2018, December). Design and implementation of a fault management system. In International Conference on Innovations in Bio-Inspired Computing and Applications (pp. 495-505). Springer, Cham.

Provost, F., & Fawcett, T. (2013). Data science and its relationship to big data and data-driven decision making. Big data, 1(1), 51-59.

Miragliotta, G., Sianesi, A., Convertini, E., & Distante, R. (2018). Data driven management in Industry 4.0: a method to measure Data Productivity. IFAC-PapersOnLine, 51(11), 19-24.

Gill, B., Borden, B. C., & Hallgren, K. (2014). A conceptual framework for data-driven decision making. Final Report of Research conducted by Mathematica Policy Research, Princeton, submitted to Bill & Melinda Gates Foundation, Seattle, WA.

Mandinach, E. B. (2012). A perfect time for data use: Using data-driven decision making to inform practice. Educational Psychologist, 47(2), 71-85.

Sehgal, A., & Vaishya, R. O. (2017). Availability of network with its maintenance in telecom industry. International Research Journal of Engineering and Technology (IRJET), PEC university of Technology, Chandigarh.

Mahmood, T., & Munir, K. (2020). Enabling Predictive and Preventive Maintenance using IoT and Big Data in the Telecom Sector. In IoTBDS (pp. 169-176).

Saedudin, R. R., Alhilman, J., & Atmaji, F. T. D. (2015). Optimization of Preventive Maintenance Program and Total Site Crew for Base Transceiver Station (BTS) Using Reliability Centered Maintenance (RCM) And Life Cycle Cost (LCC) Method. In International Seminar on Industrial Engineering and Management (Vol. 8).

Salau, A., Yinka-Banjo, C., Misra, S., Adewumi, A., Ahuja, R., & Maskeliunas, R. (2018, December). Design and implementation of a fault management system. In International Conference on Innovations in Bio-Inspired Computing and Applications (pp. 495-505). Springer, Cham.

Huang, J., & Gao, L. (2013). Wireless network pricing. Synthesis Lectures on Communication Networks, 6(2), 1-176.

Dekleva, S., Shim, J. P., Varshney, U., & Knoerzer, G. (2007). Evolution and emerging issues in mobile wireless networks. Communications of the ACM, 50(6), 38-43.

Buratti, C., Conti, A., Dardari, D., & Verdone, R. (2009). An overview on wireless sensor networks technology and evolution. Sensors, 9(9), 6869-6896.

Vora, L. J. (2015). Evolution of mobile generation technology: 1G to 5G and review of upcoming wireless technology 5G. International journal of modern trends in engineering and research, 2(10), 281-290.

Tadesse, A. (2019). Evaluating Quality of Services of 4G LTE Cellular Data Network: The Case of Addis Ababa (Doctoral dissertation, St. Mary's University).

R. Bisrat, Quality of Experience Evaluation for Addis Ababa UMTS, Addis Ababa, Ethiopia: Addis Ababa Institute of Technology, October 2018.

Haile, B. B., Bulti, D. A., & Zerihun, B. M. (2017, June). On the relevance of capacity enhancing 5G technologies for Ethiopia. In 10th Ethiopian ICT Annual Conference (EICTC-2017) (Vol. 3).

Sharma, P. (2013). Evolution of mobile wireless communication networks-1G to 5G as well as future prospective of next generation communication network. International Journal of Computer Science and Mobile Computing, 2(8), 47-53.

Irving, P., & Ochang, P. A. (2016). Evolutionary analysis of GSM, UMTS and LTE mobile network architectures. World Scientific News, 54, 27-39.

Ms. Anju Uttam Gawas, An Overview on Evolution of Mobile Wireless Communication Networks: 1G-6G, JRITCC, VOLUME 3 ISSUE 5, MAY2015

Journal of Computer Science & Computational Mathematics, Volume 7, Issue 3, September 2017 DOI: 10.20967/jcscm.2017.03.002

ITU Buenos Aires Action Plan, Work programme of the Telecommunication Development Sector for the period of 1994–1998. Programme 7. Improvement of Maintenance. http://www.itu.int/ITU-D/bdtint/ baap/sec1_07.html [8 November 2004].

Jardine, A. K., & Tsang, A. H. (2013). Maintenance, replacement, and reliability: theory and applications. CRC press.

Lee, J., Ardakani, H. D., Yang, S., & Bagheri, B. (2015). Industrial big data analytics and cyber-physical systems for future maintenance & service innovation. Procedia cirp, 38, 3-7.

Derek, M., & Paul, S. (1987). Building Maintenance.

Zhang, L. (2016). Big data analytics for fault detection and its application in maintenance (Doctoral dissertation, Luleå University of Technology).

Hadi, M. S., Lawey, A. Q., El-Gorashi, T. E., & Elmirghani, J. M. (2018). Big data analytics for wireless and wired network design: A survey. Computer Networks, 132, 180-199.

Annex

Annex 1: - Sample of preventive maintenance extracted row data from OMPES system data base

YEAR	WEEK	REGION	SITEID	TAG	REMARK
2019	week 6	SAAZ	111132	NORMAL	spare needs change
2019	week 6	SAAZ	111072	NORMAL	spare part needed to change
2019	week 5	EAAZ	112263	NORMAL	we have done full PM
2019	week 20	SAAZ	111765	NORMAL	
2019	week 20	SAAZ	111767	NORMAL	
2019	week 20	SAAZ	111129	NORMAL	
2019	week 20	SAAZ	111132	NORMAL	
2019	week 20	SAAZ	111156	NORMAL	
2019	week 20	SAAZ	111157	NORMAL	
2019	week 20	SAAZ	111729	NORMAL	
2019	week 20	SAAZ	111733	NORMAL	
2019	week 20	SAAZ	111732	NORMAL	
2019	week 6	CAAZ	111104	NORMAL	
2019	week 6	NAAZ	111096	NORMAL	
2019	week 6	NAAZ	111029	NORMAL	
2019	week 6	NAAZ	ET SHOP	NORMAL	
2019	week 6	NAAZ	111031	NORMAL	
2019	week 5	WAAZ	111035	NORMAL	
2019	week 5	WAAZ	111001	NORMAL	
2019	week 5	WAAZ	111394	NORMAL	
2019	week 5	WAAZ	111023	NORMAL	
2019	week 5	WAAZ	111027	NORMAL	
2019	week 5	WAAZ	111032	NORMAL	
2019	week 5	WAAZ	111025	NORMAL	
2019	week 5	WAAZ	111030	NORMAL	

2019	week 5	WAAZ	111004	NORMAL	
2019	week 5	WAAZ	111037	NORMAL	
2019	week 5	WAAZ	111038	NORMAL	
2019	week 5	WAAZ	111041	NORMAL	there is frequent EEU side voltage conflation
2019	week 5	WAAZ	111044	NORMAL	
2019	week 5	WAAZ	111045	NORMAL	low tanker capacity its 70 litter
2019	week 5	WAAZ	111048	NORMAL	
2019	week 5	WAAZ	111062	NORMAL	
2019	week 5	WAAZ	111078	NORMAL	
2019	week 5	WAAZ	111063	NORMAL	
2019	week 5	WAAZ	111057	CORE	
2019	week 5	WAAZ	111055	CORE	due to DG radiator problem radiator water top-up periodically with a week needs top-up
2019	week 5	NAAZ	112206	NORMAL	
2019	week 5	NAAZ	112210	NORMAL	
2019	week 24	SAAZ	111185	NORMAL	
2019	week 24	SAAZ	112212	NORMAL	
2019	week 24	SAAZ	111034	NORMAL	
2019	week 7	WAAZ	111131	NORMAL	
2019	week 7	WAAZ	111152	NORMAL	
2019	week 7	WAAZ	111153	NORMAL	DG radiator leak water, escalated to power functional team for radiator replacement
2019	week 7	WAAZ	111158	NORMAL	
2019	week 7	WAAZ	111159	NORMAL	
2019	week 7	WAAZ	111160	NORMAL	
2019	week 7	WAAZ	111163	NORMAL	
2019	week 7	WAAZ	111593	NORMAL	DG radiator cleaning and PM done
2019	week 7	WAAZ	111245	NORMAL	DG starter battery changed

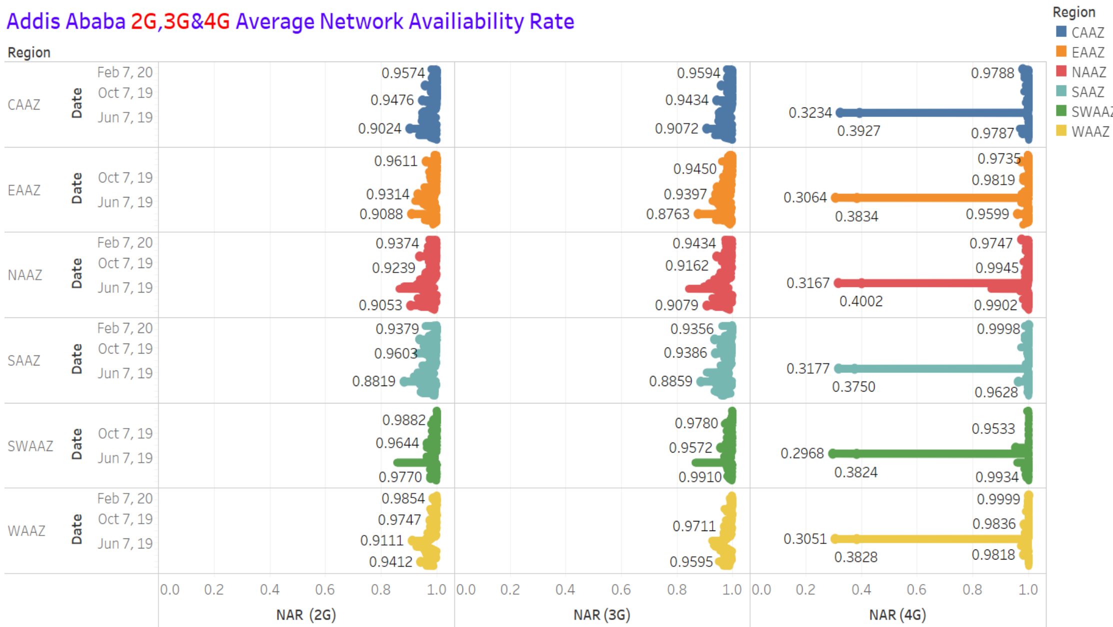
2019	week 6	SAAZ	111071	NORMAL
2019	week 6	SAAZ	111123	NORMAL
2019	week 6	SAAZ	111070	NORMAL
2019	week 6	SAAZ	111077	NORMAL
2019	week 6	SAAZ	111111	NORMAL
2019	week 6	SAAZ	111180	NORMAL
2019	week 6	EAAZ	111164	NORMAL
2019	week 6	EAAZ	111192	NORMAL
2019	week 6	EAAZ	111165	NORMAL
2019	week 19	CAAZ	111143	NORMAL
2019	week 19	CAAZ	111202	NORMAL
2019	week 19	SAAZ	111070	NORMAL
2019	week 19	SAAZ	111071	NORMAL
2019	week 19	SAAZ	111072	NORMAL
2019	week 19	SAAZ	111073	NORMAL
2019	week 19	SAAZ	111077	NORMAL
2019	week 19	SAAZ	111111	NORMAL
2019	week 19	SAAZ	111115	NORMAL
2019	week 19	SAAZ	111123	NORMAL
2019	week 19	SAAZ	111120	NORMAL
2019	week 26	CAAZ	112099	NORMAL
2019	week 26	CAAZ	112110	NORMAL
2019	week 26	CAAZ	112121	NORMAL
2019	week 14	WAAZ	111836	NORMAL
2019	week 14	WAAZ	112128	NORMAL
2019	week 14	WAAZ	112127	NORMAL
2019	week 14	CAAZ	112095	NORMAL
2019	week 14	CAAZ	112096	NORMAL
2019	week 16	SAAZ	112164	NORMAL
2019	week 16	SAAZ	112167	NORMAL
2019	week 16	SAAZ	112165	NORMAL

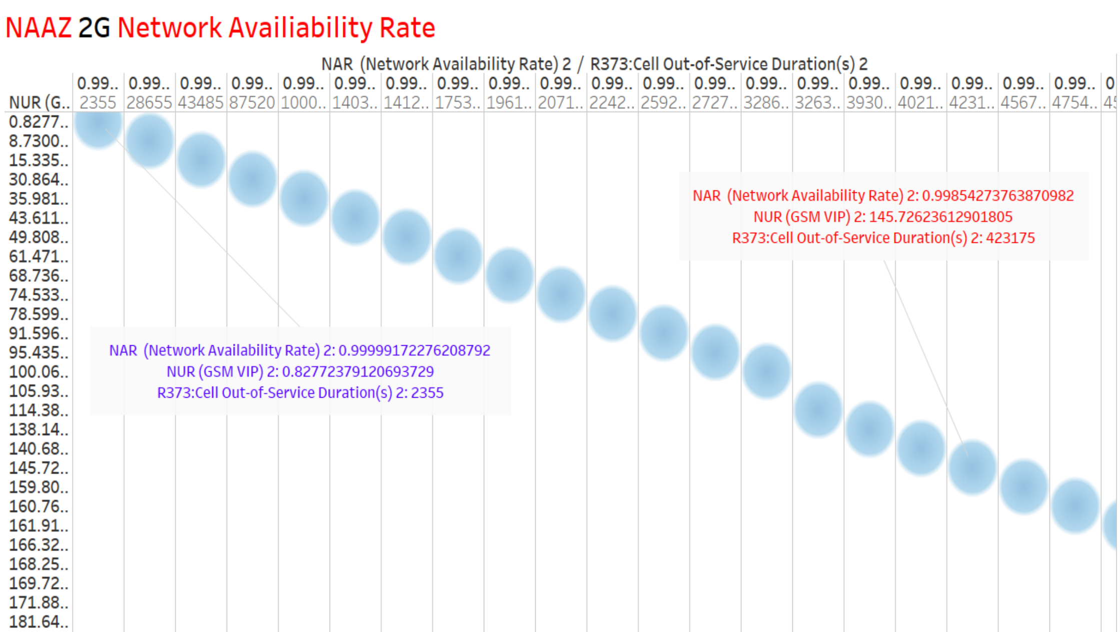
2019	week 15	WAAZ	111696	NORMAL	
2019	week 15	WAAZ	111170	NORMAL	
2019	week 5	CAAZ	112118	NORMAL	
2019	week 5	CAAZ	111040	NORMAL	some ckeck list needs justification
2019	week 5	CAAZ	111051	CORE	
2019	week 20	EAAZ	112080	NORMAL	
2019	week 20	EAAZ	112087	NORMAL	
2019	week 20	EAAZ	112098	NORMAL	
2019	week 20	EAAZ	111165	NORMAL	
2019	week 10	SWAAZ	111546	NORMAL	
2019	week 10	SWAAZ	111430	NORMAL	
2019	week 16	EAAZ	111883	NORMAL	
2019	week 5	EAAZ	111095	NORMAL	
2019	week 5	EAAZ	112188	NORMAL	
2019	week 5	EAAZ	111021	NORMAL	
2019	week 5	EAAZ	111018	NORMAL	
2019	week 5	EAAZ	112257	NORMAL	
2019	week 5	EAAZ	112246	NORMAL	
2019	week 13	SWAAZ	111689	NORMAL	
2019	week 13	SWAAZ	111690	NORMAL	
2019	week 13	SWAAZ	111697	NORMAL	
2019	week 13	SWAAZ	111698	NORMAL	
2019	week 13	SWAAZ	111699	NORMAL	
2019	week 13	SWAAZ	111700	NORMAL	

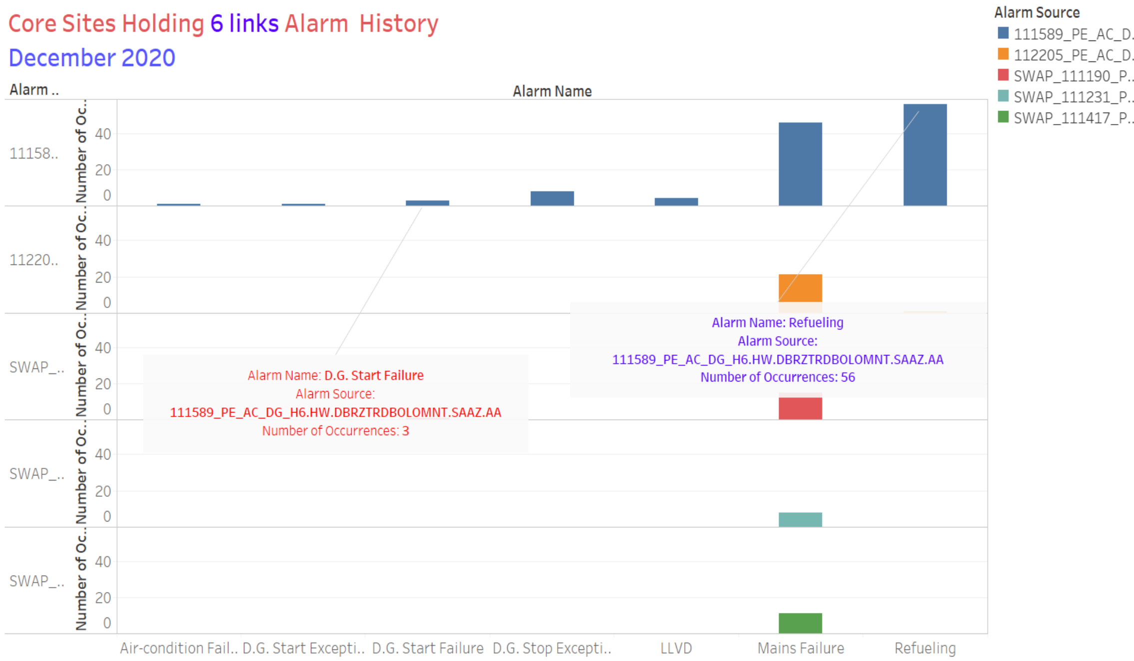
Annex 2: Sample fault alarm history extracted data from central data base

Severity	Alarm Name	Event Typ	Alarm Sou	Number of Occurrences	First Occurrence Tim	Last Occurrence Time	Object Instance	Probable (	Additional	Additional	Threshold	Cleared Time
Major	Fuel Level1 Sensor Not Detected	Communi	112167_PI	2	12/9/2020 11:17	2/9/2021 11:45	Site ID : 112167; Site Summary[0]		Type ID:7683; Device ID:0			2/16/2021 9:17
Major	Major Load Fuse Broken	Equipmen	111629_PI	6	12/3/2020 15:45	2/4/2021 15:50	Site ID : 111629; Site Summary[0]		Type ID:7683; Device ID:0			2/4/2021 15:51
Major	D.G. Start Failure	Communi	112196_PI	3	12/29/2020 8:48	2/3/2021 21:17	Site ID : 112196; EPS-D1[1]		Type ID:1; Device ID:0			2/8/2021 8:54
Major	D.G. Timed Maintenance Reminder	Equipmen	112166_PI	8	12/25/2020 10:46	2/1/2021 14:52	Site ID : 112166; EPS-D1[1]		Type ID:1; Device ID:0			2/2/2021 8:54
Warning	D.G. Timed Maintenance Reminder	Equipmen	111685_PI	4	12/14/2020 14:35	2/1/2021 10:49	Site ID : 111685; Unknown		Type ID:1; Device ID:0			2/2/2021 10:42
Major	D.G. Start Failure	Communi	112166_PI	3	12/26/2020 13:27	2/1/2021 10:36	Site ID : 112166; EPS-D1[1]		Type ID:1; Device ID:0			2/1/2021 11:38
Major	Air-condition Failure	Environm	112160_PI	9	12/9/2020 11:17	1/31/2021 9:56	Site ID : 112160; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/31/2021 10:24
Warning	Refuel Reminder	Equipmen	111685_PI	2	12/14/2020 14:36	1/28/2021 9:47	Site ID : 111685; Unknown		Type ID:10; Device ID:0			1/28/2021 9:48
Major	Infrared Alarm	Environm	SWAP_11	10	12/3/2020 11:29	1/26/2021 16:47	Site ID : 111212; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/27/2021 13:52
Major	PSU Communication Failure	Equipmen	111629_PI	5	12/3/2020 15:44	1/25/2021 17:52	Site ID : 111629; Unknown		Type ID:40; Device ID:6			2/4/2021 15:50
Major	HEX Fault	Environm	111652_PI	6	12/31/2020 10:43	1/25/2021 10:04	Site ID : 111652; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/25/2021 10:24
Major	AC SPD Fault	Environm	111589_PI	2	12/25/2020 14:27	1/17/2021 11:49	Site ID : 111589; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/23/2021 9:50
Major	D.G. Timed Maintenance Reminder	Equipmen	SWAP_11	3	12/8/2020 11:23	1/14/2021 9:42	Site ID : 111212; EPS-D1[1]		Type ID:1; Device ID:0			1/26/2021 16:46
Warning	PSU Lost	Equipmen	111719_PI	4	12/8/2020 12:41	1/13/2021 13:40	Site ID : 111719; PSU Summary[1]		Type ID:94; Device ID:0			1/13/2021 13:45
Minor	AC Surge Protector Fault	Equipmen	111719_PI	4	12/8/2020 12:41	1/13/2021 13:40	Site ID : 111719; Site Summary[0]		Type ID:7683; Device ID:0			1/13/2021 13:45
Major	Ambient Humidity Sensor Not Detected	Equipmen	112227_PI	4	12/8/2020 15:08	1/13/2021 10:54	Site ID : 112227; Ambient System[0]		Type ID:7424; Device ID:0			1/13/2021 10:59
Major	Ambient Temperature Sensor Not Detected	Equipmen	112227_PI	4	12/8/2020 15:08	1/13/2021 10:54	Site ID : 112227; Ambient System[0]		Type ID:7424; Device ID:0			1/13/2021 10:59
Major	AC SPD Fault	Environm	111646_PI	4	12/24/2020 22:23	1/8/2021 10:55	Site ID : 111646; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/12/2021 11:56
Major	Major Load Fuse Broken	Equipmen	112105_W	3	12/11/2020 15:01	1/8/2021 10:05	Site ID : 112105; Site Summary[0]		Type ID:7683; Device ID:0			1/8/2021 10:08
Major	D.G. Timed Maintenance Reminder	Equipmen	112207_PI	3	12/29/2020 15:10	1/8/2021 9:41	Site ID : 112207; EPS-D1[1]		Type ID:1; Device ID:0			1/11/2021 14:53
Major	door2 open alarm	Environm	111743_PI	5	12/3/2020 10:57	1/5/2021 14:12	Site ID : 111743; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/23/2021 10:03
Major	Fan Failure	Environm	112202_PI	3	12/25/2020 9:51	1/4/2021 15:38	Site ID : 112202; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/5/2021 10:48
Major	AC SPD Fault	Environm	112202_PI	3	12/25/2020 9:51	1/4/2021 15:38	Site ID : 112202; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/5/2021 10:48
Major	AC SPD Fault	Environm	112222_PI	4	12/24/2020 22:23	1/4/2021 12:56	Site ID : 112222; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/11/2021 11:08
Warning	D.G. Routine Maintenance Reminder	Equipmen	112217_PI	2	12/25/2020 11:03	1/4/2021 10:57	Site ID : 112217; EPS-D1[1]		Type ID:1; Device ID:0			1/25/2021 14:52
Major	Fan Failure	Environm	112218_PI	3	12/22/2020 12:20	1/4/2021 10:56	Site ID : 112218; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/15/2021 16:23
Major	PSU Fault	Equipmen	112170_PI	2	12/29/2020 17:18	1/4/2021 10:56	Site ID : 112170; PSU[5]		Type ID:40; Device ID:4			1/8/2021 15:55
Major	PSU Fault	Equipmen	112170_PI	2	12/29/2020 17:18	1/4/2021 10:56	Site ID : 112170; PSU[4]		Type ID:40; Device ID:3			1/8/2021 15:55
Major	PSU Fault	Equipmen	112170_PI	2	12/29/2020 17:18	1/4/2021 10:56	Site ID : 112170; PSU[2]		Type ID:40; Device ID:1			1/8/2021 15:55
Major	PSU Fault	Equipmen	112170_PI	2	12/29/2020 17:18	1/4/2021 10:56	Site ID : 112170; PSU[1]		Type ID:40; Device ID:0			1/8/2021 15:55
Warning	System Manual Control	Communi	112153_PI	3	12/5/2020 11:57	1/2/2021 8:42	Site ID : 112153; Site Summary[0]		Type ID:7683; Device ID:0			1/23/2021 9:36
Major	Air-condition Failure	Environm	111699_PI	6	12/2/2020 15:44	1/1/2021 20:59	Site ID : 111699; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/8/2021 15:05
Major	D.G. Timed Maintenance Reminder	Equipmen	111699_PI	3	12/31/2020 14:45	1/1/2021 20:59	Site ID : 111699; EPS-D1[1]		Type ID:1; Device ID:0			1/8/2021 15:05
Major	Infrared Alarm	Environm	118107_PI	3	12/31/2020 10:19	1/1/2021 4:43	Site ID : 118107; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/4/2021 16:12
Major	Infrared Alarm	Environm	118079_PI	1	12/31/2020 23:58	12/31/2020 23:58	Site ID : 118079; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:58
Major	door2 open alarm	Environm	111722_PI	1	12/31/2020 23:58	12/31/2020 23:58	Site ID : 111722; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:58
Major	Battery Charge Overcurrent	Equipmen	111699_PI	1	12/31/2020 23:57	12/31/2020 23:57	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:57
Major	Abnormal Battery Current	Equipmen	111699_PI	1	12/31/2020 23:54	12/31/2020 23:54	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:59
Major	Battery Charge Overcurrent	Equipmen	111699_PI	1	12/31/2020 23:48	12/31/2020 23:48	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:48
Major	Infrared Alarm	Environm	118105_PI	1	12/31/2020 23:48	12/31/2020 23:48	Site ID : 118105; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:49
Major	Ambient Temperature Sensor Not Detected	Equipmen	SWAP_11	1	12/31/2020 23:48	12/31/2020 23:48	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			1/1/2021 2:10
Major	Battery Charge Overcurrent	Equipmen	112235_PI	1	12/31/2020 23:46	12/31/2020 23:46	Site ID : 112235; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:46
Minor	Low Ambient Temperature	Equipmen	SWAP_11	1	12/31/2020 23:46	12/31/2020 23:46	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			12/31/2020 23:48
Major	Ambient Temperature Sensor Not Detected	Equipmen	SWAP_11	1	12/31/2020 23:44	12/31/2020 23:44	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			12/31/2020 23:45
Major	Battery Charge Overcurrent	Equipmen	111699_PI	1	12/31/2020 23:40	12/31/2020 23:40	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:41
Major	AC SPD Fault	Environm	118012_PI	1	12/31/2020 23:38	12/31/2020 23:38	Site ID : 118012; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			1/1/2021 0:07
Minor	Low Ambient Temperature	Equipmen	SWAP_11	1	12/31/2020 23:36	12/31/2020 23:36	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			12/31/2020 23:44
Major	Ambient Temperature Sensor Not Detected	Equipmen	SWAP_11	1	12/31/2020 23:35	12/31/2020 23:35	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			12/31/2020 23:36
Major	door2 open alarm	Environm	111722_PI	1	12/31/2020 23:35	12/31/2020 23:35	Site ID : 111722; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:57
Major	Infrared Alarm	Environm	118079_PI	1	12/31/2020 23:27	12/31/2020 23:27	Site ID : 118079; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:27
Major	Infrared Alarm	Environm	118079_PI	1	12/31/2020 23:25	12/31/2020 23:25	Site ID : 118079; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:25
Major	Infrared Alarm	Environm	118105_PI	1	12/31/2020 23:15	12/31/2020 23:15	Site ID : 118105; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:15
Major	Infrared Alarm	Environm	118079_PI	1	12/31/2020 23:12	12/31/2020 23:12	Site ID : 118079; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:12
Major	Battery Charge Overcurrent	Equipmen	112235_PI	1	12/31/2020 23:09	12/31/2020 23:09	Site ID : 112235; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:16
Major	Battery Charge Overcurrent	Equipmen	111699_PI	1	12/31/2020 23:07	12/31/2020 23:07	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:07
Major	Infrared Alarm	Environm	118079_PI	1	12/31/2020 23:05	12/31/2020 23:05	Site ID : 118079; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 23:06
Major	Abnormal Battery Current	Equipmen	111699_PI	1	12/31/2020 23:04	12/31/2020 23:04	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:09
Major	Battery Charge Overcurrent	Equipmen	112235_PI	1	12/31/2020 22:59	12/31/2020 22:59	Site ID : 112235; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:03
Major	Battery Charge Overcurrent	Equipmen	111699_PI	1	12/31/2020 22:58	12/31/2020 22:58	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 23:00
Major	D.G. Running	Equipmen	112243_PI	1	12/31/2020 22:50	12/31/2020 22:50	Site ID : 112243; EPS-D[1]		Type ID:1; Device ID:0			1/1/2021 1:27
Major	Infrared Alarm	Environm	118105_PI	1	12/31/2020 22:40	12/31/2020 22:40	Site ID : 118105; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 22:40
Major	Infrared Alarm	Environm	118105_PI	1	12/31/2020 22:37	12/31/2020 22:37	Site ID : 118105; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 22:38
Major	AC SPD Fault	Environm	118012_PI	1	12/31/2020 22:29	12/31/2020 22:29	Site ID : 118012; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 22:46
Major	AC SPD Fault	Environm	118012_PI	1	12/31/2020 22:28	12/31/2020 22:28	Site ID : 118012; ECC500 MUE05A Board[1]		Type ID:247; Device ID:0			12/31/2020 22:28
Major	Ambient Temperature Sensor Not Detected	Equipmen	SWAP_11	1	12/31/2020 22:27	12/31/2020 22:27	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			12/31/2020 23:35
Major	PSU Fault	Equipmen	111700_PI	1	12/31/2020 22:25	12/31/2020 22:25	Site ID : 111700; PSU[4]		Type ID:40; Device ID:3			1/1/2021 11:09
Major	PSU Fault	Equipmen	111700_PI	1	12/31/2020 22:25	12/31/2020 22:25	Site ID : 111700; PSU[1]		Type ID:40; Device ID:0			1/1/2021 11:09
Minor	Low Ambient Temperature	Equipmen	SWAP_11	1	12/31/2020 22:24	12/31/2020 22:24	Site ID : 111216; Ambient System[0]		Type ID:7424; Device ID:0			12/31/2020 22:27
Major	Communication Between NMS And NE Is Abnor	Communi	111626_PI	1	12/31/2020 22:19	12/31/2020 22:19	Address=10.204.131.198,Protocol=BINA	Communications Receive Failure				1/1/2021 8:14
Major	Communication Between NMS And NE Is Abnor	Communi	112164_PI	1	12/31/2020 22:18	12/31/2020 22:18	Address=10.204.135.222,Protocol=BINA	Communications Receive Failure				1/1/2021 8:14
Critical	BLVD	Equipmen	111626_PI	1	12/31/2020 22:11	12/31/2020 22:11	Site ID : 111626; Site Summary[0]		Type ID:7683; Device ID:0			1/1/2021 8:14
Major	Abnormal Battery Current	Equipmen	111699_PI	1	12/31/2020 22:08	12/31/2020 22:08	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 22:13
Major	D.G. Running	Equipmen	112030_PI	1	12/31/2020 22:06	12/31/2020 22:06	Site ID : 112030; Unknown		Type ID:1; Device ID:0			1/1/2021 4:07
Major	Battery Charge Overcurrent	Equipmen	111699_PI	1	12/31/2020 22:02	12/31/2020 22:02	Site ID : 111699; ESS[1]		Type ID:90; Device ID:0			12/31/2020 22:04
Major	D.G. Running	Equipmen	112231_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 112231; EPS-D1[1]		Type ID:1; Device ID:0			1/1/2021 9:35
Major	D.G. Running	Equipmen	112205_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 112205; EPS-D1[1]		Type ID:1; Device ID:0			1/1/2021 9:36
Major	D.G. Running	Equipmen	111763_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 111763; EPS-D1[1]		Type ID:1; Device ID:0			1/1/2021 9:36
Major	D.G. Running	Equipmen	111853_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 111853; EPS-D1[1]		Type ID:1; Device ID:0			1/1/2021 9:36
Major	D.G. Running	Equipmen	112143_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 112143; EPS-D1[1]		Type ID:1; Device ID:0			1/1/2021 9:36
Major	D.G. Running	Equipmen	111678_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 111678; EPS-D1[1]		Type ID:1; Device ID:0			12/31/2020 22:02
Major	D.G. Running	Equipmen	111856_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 111856; EPS-D1[1]		Type ID:1; Device ID:0			1/1/2021 9:36
Major	D.G. Running	Equipmen	111654_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 111654; EPS-D1[1]		Type ID:1; Device ID:0			12/31/2020 22:01
Major	D.G. Running	Equipmen	112160_PI	1	12/31/2020 21:59	12/31/2020 21:59	Site ID : 112160; EPS-D1[1]		Type ID:1; Device ID:0			12/31/2020 22:01

Annex 3: - Additional Data analyses outputs






Core Sites Holding 6 links Alarm History
December 2020
Alarm ..
Alarm Name
Alarm Source
111589_PE_AC_D.
112205_PE_AC_D.
SWAP_111190_P..
SWAP_111231_P..
SWAP_111417_P..
11158..
11220..
SWAP_..
SWAP_..
SWAP_..
Number of Oc..
40
20
0
Alarm Name: D.G. Start Failure
Alarm Source:
111589_PE_AC_DG_H6.HW.DBRZTRDBOLOMNT.SAAZ.AA
Number of Occurrences: 3
Alarm Name: Refueling
Alarm Source:
111589_PE_AC_DG_H6.HW.DBRZTRDBOLOMNT.SAAZ.AA
Number of Occurrences: 56
Air-condition Fail..
D.G. Start Excepti..
D.G. Start Failure
D.G. Stop Excepti..
LLVD
Mains Failure
Refueling