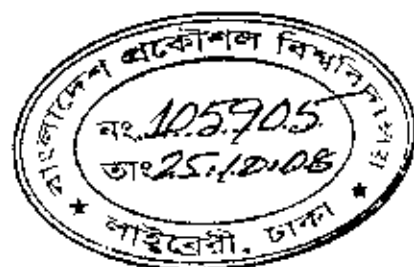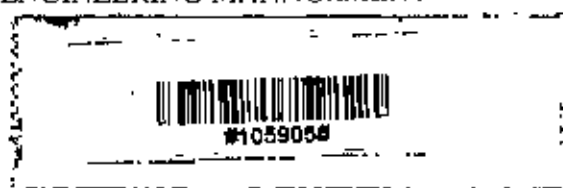# PERFORMANCE ANALYSIS OF A COMMUNICATION NETWORK: CASE OF A MOBILE OPERATOR

BY

MD. ABDUR RAIHAN

A THESIS SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING, BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ADVANCED ENGINEERING MANAGEMENT
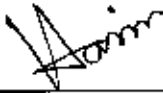
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CERTIFICATE OF APPROVAL

The thesis titled 'PERFORMANCE ANALYSIS OF A COMMUNICATION NETWORK: CASE OF A MOBILE OPERATOR, submitted by Md. Abdur Raihan, Student No. 040308157 (P), Session- April 2003, has been accepted as satisfactory in partial fulfillment of the requirements for the Degree of Master of Advanced Engineering Management on September 13, 2008.

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It is hereby declared that this thesis or any part of this has not been submitted elsewhere for the award of any degree or diploma.

Md. Abdur Rathan

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And I want to thank all the people who are not listed here but have contributed in any way, being my side or any other senses.

Md. Abdur Raihan

ABSTRACT

Presently in Bangladesh, mobile phone service providers are playing a vital role in the telecommunication services which is ultimately helping in total development of the country. Six operators are in service now and more than 30 million subscribers are using this service. So it is important to maintain good quality of network for these operators to make its customers happy.

Brief discussion has been done on the different network elements through which mobile phone network is established. Different types of faults of GSM network system has been discussed for better understanding. All the faults have been categorized in 5 major types. Besides, fault management process has been described.

Different Total Quality Management tools have been studied here. In control chart, 8 types of different charts are there. It has been identified that all the control charts are not applicable for the analysis of this type of data.

Regional O&M department of Grameenphone is responsible for maintaining the access network through 6 regions. Author of this thesis is the head of Dhaka region. Two major KPIs of this department – one is the reduction of number of faults and another is the restoration of faults within the shortest possible time (MTTR)

Analysis has been done on the outage reports of this region for the period of 1st to 30th October, 2007. Through Pareto analysis, major focus areas have been found which will help the department for setting the action plan to achieve the target with fewer efforts. The two major KPIs have been analysed by C-chart analysis. This showed the status of the process- whether the system is in control or not. For the out of control process, through detail investigation, root cause has been found.

TABLE OF CONTENTS

CHAPTER 4: FAULTS AND MANAGEMENT PROCESS

CHAPTER 5: STATISTICAL PROCESS CONTROL (SPC)

CHAPTER 6: PROCESS ANALYSIS FOR NO. OF FAULTS

CHAPTER 7: PROCESS ANALYSIS FOR MTTR OF VARIOUS TYPES OF FAULTS

CHAPTER 8: ANALYSIS OF PARETO CHART & CAUSE EFFECT DIAGRAM

CHAPTER 9: CONCLUSION AND RECOMMENDATIONS

REFERENCES

LIST OF TABLES

LIST OF FIGURES

.

Page

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Telecommunication is playing a vital role in the development of Bangladesh for the last one decade. Mobile phone service is playing the most vital role in this sector. Now mobile phone services have reached even those parts of the country where electricity is not available yet. People are solely dependent on mobile phones for fulfillment of their communication facility.

Grameenphone is the leading mobile phone service provider among the all mobile, PSTN and Internet Service Providers in Bangladesh. It has the widest network coverage, highest number of subscribers and very good quality of network and customer service. Expansion of its network occurred hugely in the last 3 years among its 11 years in operation. At present, it has base stations at more than 6000 locations all over the country.

Regional Operation and Maintenance department of Grameenphone is responsible for keeping the base stations working as well as provide better network for its customers. Customers' satisfaction depends on the availability and quality of network. It's a huge and challenging task for this department to meet the target.

To achieve the target, the whole GP network is being maintained from 6 regional offices considering the geographical situation and number of base stations in every region. Regional O&M Management has set some Key Performance Indicators (KPI) and working process to maintain the target. Two major KPIs are – Reduction in number of faults and restoration of faults (MTTR) within the shortest possible time.

Author of this thesis is heading one of the 6 regions-Dhaka. Analysis has been done here on the network outage report for the period of 1st to 30th October 2007. Source of the data is the daily outage reports published by Network Management department of Grameenphone during this period. All the outage events of these 30 days have to be compiled under one sheet.

Faults have been categorized in 5 types- BTS Hardware, External and Internal Power, High and Low capacity microwave. From the outage reports, all the faults have been distributed to these 5 categories as per process. Similarly, restoration time (MTTR) has been calculated from the event and clear time.

High network availability is one of the major targets of a mobile operator. This is possible if number of faults can be limited to a certain level. On the other hand, since there are lots of equipments and factors for which network outage incidents are inevitable. But availability will be increased if faults as well as network can be restored within the shortest possible of time.

Aim of my thesis is to see the status and analyze the performance of this department regarding these two KPIs. Different methods of statistical process control have been used for this purpose.

1.2 OBJECTIVE WITH SPECIFIC AIM AND POSSIBLE OUTCOMES

The main objectives of this study are:
- Study and analyze the two major KPIs of Regional Operation and maintenance department.
- Develop statistical Process control system for this department.
- Identify and suggest for removing the root causes of different types of problems.

The main outcomes of this study are:
- Check whether the system is under control or not regarding no. of faults and period of fault restoration.
- Find out root cause in case of out of control and recommendation.

1.3 METHODOLOGY

To reach a well defined destination this research will follow the step-by-step approach as stated bellow:

- Collect data of all faults and restoration time of Dhaka region for the month of October, 2007
- Distribute the faults in 5 categories- BTS HW, External and Internal Power, Low and high capacity microwave.
- Analyze different methods of statistical process control
- Analyze the system by Pareto principle, fish bone diagram, C-chart
- If the system is out of control, try to find out the root cause
- Recommendations for improvement.

CHAPTER 2

PROFILE OF A MOBILE OPERATOR: GRAMEEN PHONE

2.1 OVERVIEW

Grameenphone is now the leading telecommunications service provider in the country with more than 20 million subscribers as of June 2008. Presently, there are about 30 million telephone users in the country, of which, a little over one million are fixed-phone users and rest mobile phone subscribers. Starting its operations on March 26, 1997, the independence day of Bangladesh, Grameenphone has come a long way. It is a joint venture enterprise between Telenor (62%), the largest telecommunications service provider in Norway with mobile phone operations in 12 other countries, and Grameen Telecom Corporation (38%), a non-profit sister concern of the internationally acclaimed micro-credit pioneer Grameen Bank.

Over the years, Grameenphone has always been a pioneer in introducing new products and services in the local market. GP was the first company to introduce GSM technology in Bangladesh when it launched its services in March 1997 The technological know-how and managerial expertise of Telenor has been instrumental in setting up such an international standard mobile phone operation in Bangladesh. Being one of the pioneers in developing the GSM service in Europe, Telenor has also helped to transfer this knowledge to the local employees over the years.

The company has so far invested more than BDT 10,700 crore (USD 1.6 billion) to build the network infrastructure since its inception in 1997. It has invested over BDT 3,100 crore (USD 450 million) during the first three quarters of 2007 while BDT 2,100 crore (USD 310 million) was invested in 2006 alone. Grameenphone is also one the largest taxpayers in the country, having contributed nearly BDT 7000 crore in direct and indirect taxes to the Government Exchequer over the years. Of this amount, over BDT 2000 crore was paid in 2006 alone

Since its inception in March 1997, Grameenphone has built the largest cellular network in the country with over 10,000 base stations in more than 5700 locations. Presently, nearly

98 percent of the country's population is within the coverage area of the Grameenphone network.

Grameenphone was also the first operator to introduce the pre-paid service in September 1999. It established the first 24-hour Call Center, introduced value-added services such as VMS, SMS, fax and data transmission services, international roaming service, WAP, SMS-based push-pull services, EDGE, personal ring back tone and many other products and services.

The entire Grameenphone network is also EDGE/GPRS enabled, allowing access to high-speed Internet and data services from anywhere within the coverage area. There are currently nearly 3 million EDGE/GPRS users in the Grameenphone network.

Grameenphone nearly doubled its subscriber base during the initial years while the growth was much faster during the later years. It ended the inaugural year with 18,000 customers, 30,000 by the end of 1998, 60,000 in 1999, 193,000 in 2000, 471,000 in 2001, 775,000 in 2002, 1.16 million in 2003, 2.4 million in 2004, 5.5 million in 2005, 11.3 million in 2006, and it ended 2007 with 16.5 million customers.

From the very beginning, Grameenphone placed emphasis on providing good after-sales services. In recent years, the focus has been to provide after-sales within a short distance from where the customers live. There are now more than 600 GP Service Desks across the country covering nearly all upazilas of 61 districts. In addition, there are 81 Grameenphone Centers in all the divisional cities and they remain open from 8am-8pm every day including all holidays.

GP has generated direct and indirect employment for a large number of people over the years. The company presently has more than 5,000 full, part-time and contractual employees. Another 100,000 people are directly dependent on Grameenphone for their livelihood, working for the Grameenphone dealers, retailers, scratch card outlets, suppliers, vendors, contractors and others.

In addition, the Village Phone Program, also started in 1997, provides a good income-earning opportunity to more than 280,000 mostly women Village Phone operators living in rural areas. The Village Phone Program is a unique initiative to provide universal access to telecommunications service in remote, rural areas. Administered by Grameen Telecom

Corporation, it enables rural people who normally cannot afford to own a telephone to avail the service while providing the VP operators an opportunity to earn a living.

The Village Phone initiative was given the "GSM in the Community" award at the global GSM Congress held in Cannes, France in February 2000. Grameenphone was also adjudged the Best Joint Venture Enterprise of the Year at the Bangladesh Business Awards in 2002. Grameenphone was presented with the GSM Association's Global Mobile Award for 'Best use of Mobile for Social and Economic Development' at the 3GSM World Congress held in Singapore, in October 2006, for its Community Information Center (CIC) project, and for its HealthLine Service project at the 3GSM World Congress held in Barcelona, Spain, in February 2007.

Grameenphone considers its employees to be one of its most important assets. GP has an extensive employee benefit scheme in place including Gratuity, Provident Fund, Group Insurance, Family Health Insurance, Transportation Facility, Day Care Centre, Children's Education Support, Higher Education Support for employees, in-house medical support and other initiatives. [10]

2.2 GRAMEENPHONE CORPORATE GOVERNANCE

In the fast-paced world of telecommunications, vibrant and dynamic Corporate Governance practices are an essential ingredient to success. Grameenphone believes in the continued improvement of corporate governance. This in turn has led the Company to commit considerable resources and implement internationally accepted Corporate Standards in its day-to-day operations.

Being a private limited company, the Board of Directors of Grameenphone have a pivotal role to play in meeting all stakeholders' interests. The Board of Directors and the Management Team of Grameenphone are committed to maintaining effective Corporate Governance through a culture of accountability, transparency, well-understood policies and procedures. The Board of Directors and the Management Team also persevere to maintain compliance of all laws of Bangladesh and all internally documented regulations, policies and procedures.

Grameenphone is a truly transparent company that operates at the highest levels of integrity and accountability on a global standard.

2.3 GRAMEENPHONE ORGANOGRAM
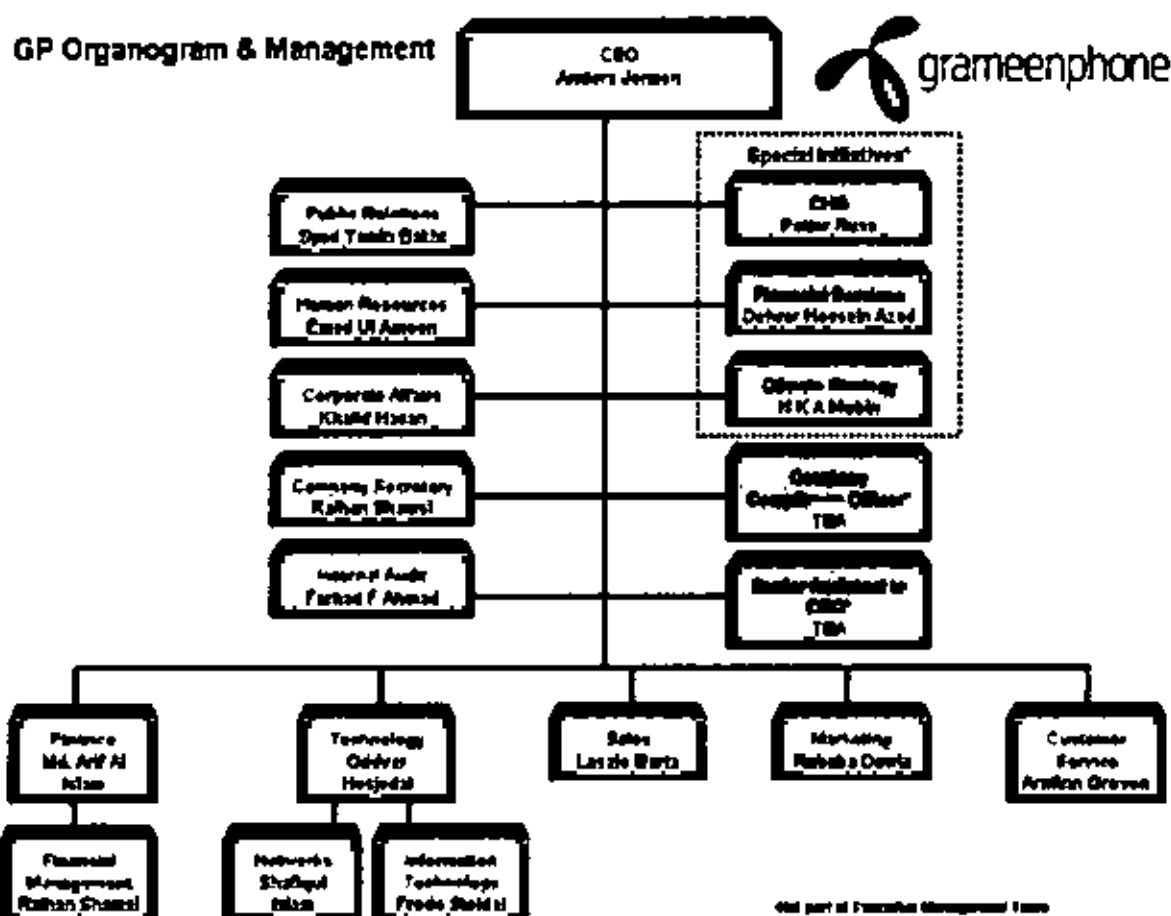
Figure 2.1: Organogram of Grameenphone

2.4 SHAREHOLDERS

The shareholders of GrameenPhone contribute their unique, in-depth experience in both telecommunications and development.

The international shareholder brings technological and business management expertise while the local shareholder provides a presence throughout Bangladesh and a deep understanding of its economy. Both are dedicated to Bangladesh and its struggle for

economic progress and have a deep commitment to GrameenPhone and its mission to provide affordable telephony to the entire population of Bangladesh

- Telenor
- Grameen Telecom

2.4.1 About Telenor

Telenor AS is the leading Telecommunications Company of Norway listed in the Oslo and NASDAQ Stock Exchanges. It owns 62% shares of GrameenPhone Ltd. Telenor has played a pioneering role in development of cellular communications.

It has substantial international operations in mobile telephony, satellite operations and pay Television services In addition to Norway and Bangladesh, Telenor owns GSM companies in Denmark, Austria, Hungary, Russia, Ukraine, Montenegro, Thailand, Malaysia and Pakistan.

Telenor uses the expertise it has gained in its home and international markets for the development of emerging markets like Bangladesh Group revenues for 2005 reached NOK 68.9 billion - a growth of 14 per cent compared to 2004. At year-end 2005, Telenor employed 27,600 people (man-years) - 16,700 of whom were employed outside Norway.

2.4.2 About Grameen Telecom

Grameen Telecom Corporation, which owns 38% of the shares of GrameenPhone, is a not-for-profit company and works in close collaboration with Grameen Bank. The internationally reputed bank for the poor has the most extensive rural banking network and expertise in microfinance. It understands the economic needs of the rural population, in particular the women from the poorest households.

Grameen Telecom, with the help of Grameen Bank, administers the Village Phone Program, through which GrameenPhone provides its services to the fast growing rural customers. Grameen Telecom trains the operators, supplies them with handsets and handles all service-related issues.

Grameen Bank currently covers more than 67,000 villages which are serviced by 2121 bank branches all over the countryside. As of may 2006, the bank had 6.33 million borrowers, 97 percent of whom were women.

Grameen Telecom's objectives are to provide easy access to GSM cellular services in rural Bangladesh, creating new opportunities for income generation through self- employment by providing villagers with access to modern information and communication based. [10]

2.4.3 CSR at Grameenphone:

GrameenPhone started its journey 10 years back with a belief that "Good development is good business". Since its inception, GrameenPhone has been driven to be inspiring and leading by example, when it comes to being involved in the community. At GrameenPhone we believe that, sustainable development can only be achieved through long term economic growth. Therefore, as a leading corporate house in Bangladesh we intend to deliver the best to our customers, business partners, stakeholders, employees and society at large by 'being a partner in development.

GrameenPhone defines CSR as 'a complimentary combination of ethical and responsible corporate behavior as well as a commitment towards generating greater good in society as a whole by addressing the development needs of the country.

To interact effectively and responsibly with the society and to contribute to the socio-economic development of Bangladesh. GP has adopted a holistic approach to CSR, i.e. Strategic and Tactical. Through this approach GP aims to, on the one hand involve itself with the larger section of the society and to address diverse segments of the stakeholder demography, and on the other remain focused in its social investment to generate greater impact for the society.

GrameenPhone focuses its CSR involvement in three main areas - Health, Education and Empowerment. We aim to combine all our CSR initiatives under these three core areas to enhance the economic and social growth of Bangladesh.

We believe that Corporate Social Responsibility is a journey along which we will create a positive difference in the community and the development of the country; thus meeting the expectations of our customers and stakeholders.

2.5 ABOUT SPONSORSHIP AND GRAMEENPHONE

Grameenphone's objective in engaging in sponsorships is to create mutual benefit for our partners. GrameenPhone is happy to be able to work with a number of important projects and events and position the company as a good corporate citizen.

What makes GrameenPhone stand out from the others and makes it a distinct market leader? The answer is probably allied with the varied activities GrameenPhone engages in and for the company's wide contribution to society. Sponsorship is one of the many wings of GrameenPhone that has been patronizing and supporting various entities for different noble causes. Moreover, we recognize the responsibility of a good corporate citizen and are ready to attend to stakeholder needs in every way possible.

2.5.1 Widest Network Coverage

The Grameenphone network now covers more than 95 percent of the country's population, up from around 50 percent two years earlier. During the same period, the company also introduced a range of enabling services and the entire network is now EDGE/GPRS enabled Grameenphone has greatly benefited from Telenor Group's, with its 12 mobile operations worldwide, aggregated purchasing power This has enabled the company to rapidly extend its network coverage and upgrade its network. Group cost-saving initiatives have also allowed Grameenphone to reduce tariffs substantially, thus making mobile communication affordable for a wider community in Bangladesh, especially those who have little to spend on communication.

Over the years, the shareholders have re-invested nearly all of their earnings to expand coverage and increase capacity of the network. The cumulative investments up to December 2006 stood at about BDT 76 billion, making Grameenphone one of the largest private sector investments in the country.

2.5.2 Committed Customer Service

Grameenphone has always been committed to provide quality after-sales service to its customers. It was the first company to set up a 24-hour Call Center in the country in 1999. In order to make customer service more easily accessible, the Grameenphone Customer Service desk concept was developed in 2005. There are now more than 600 Grameenphone Customer Service desks in operation around the country. These service desks have remarkably reduced travel time for customers from as much as eight hours to a maximum of one hour for any after-sales service. The flagship Grameenphone Centers were also launched last year to provide a "one-stop solution" for all customers. The centers are designed to increase customer satisfaction by integrating all sales and after-sales services in an open, friendly and comfortable environment. Presently, there are 80 Grameenphone Centers in operation around the country.

2.5.3 Contribution to growth

The telecommunication industry in Bangladesh is now estimated to represent more than one percent of the country's GDP. Since commercial operations began in March 1997 and up to December 2006, Grameenphone has contributed over BDT 67 billion to the country's National Exchequer in direct and indirect taxes. Grameenphone's annual revenues surpassed BDT 45 billion in 2006, and the total contribution to the National Exchequer, including all taxes and VAT from the services, was more than BDT 20 billion during the year.

Grameenphone directly employs more than 5,000 people and it is estimated that another 100,000 people are directly dependant on the business, working for the vendors, suppliers and retailers. In addition, there are now over 280,000 Village Phone operators earning a living through the Village Phone Program.

A study published in 2005 by the London Business School established a clear link between economic growth and mobile phone penetration in developing nations. The study showed that for the period from 1996 to 2003, a developing country with 10 more mobile phones per 100 people enjoyed per capita GDP growth that was 0.6 percentage points higher than in an

otherwise identical country. The benefits brought by the mobile phone include a reduction of the number of middle-men, higher profitability for businesses and improved contact between family and friends.

2.6 GRAMEENPHONE AND ITS TECHNOLOGY

Telecommunications are an essential part of a country's infrastructure. Grameen Phone's Global System for mobile communication (GSM) technology is the most widely accepted digital system in the world, currently used by approximate 2bn in 216 countries. GSM brings the most advanced developments in cellular technology at a reasonable cost by spurring severe among manufacturers and driving down the cost of equipment Thus, consumers get the best for the least. GSM is a living, growing technology with different level of adoptions, pattern of use and approaches to service provisions in different areas of the world

The success of GSM is that its development was founded on the delivery of a specific user benefit - international roaming. The demands of international roaming had profound changes on GSM's architecture and mandated an open future-proof standard that ensured interoperability, without stifling competition, and innovation among suppliers. This lowered barriers to entry, promoted compatibility between systems which, in turn, lowered development osts and set the stage for better choice and innovation. The unparalleled economics of scale and competition that resulted brought convenience and falling prices to manufacturers, network operators and consumers.

The adoption of a digital system offered improved mobility, spectrum efficiency, better quality transmission and new services over the first generation systems. The use of Very Large Scale Integration (VLSI) microprocessor technology and other low cost 32 IC architectures paved the way for more efficient and affordable pocket-sized mobile phones. This resulted in a profound change in users' mobile communication style from vehicular-based to personal, opportunity-based communications. Although GSM is only one of the pieces in the cluster of current and future telecommunications networks, its ability to provide anytime, and almost anywhere, communications has resulted in tremendous economic and social consequences.

- 12 -

2.7 SERVICES

GrameenPhone considers its employees to be one of its most important assets. GP has an extensive employee benefit scheme in place including Gratuity, Provident Fund, Group Insurance, Family Health Insurance, Transportation Facility, Day Care Centre, Children's Education Support, and Higher Education Support for employees, in-house medical support and other initiatives

2.8 PURPOSES

Grameenphone has dual purpose.
- To receive an economic return on its investments.
- To contribute to the economic developments of Bangladesh where telecommunications can play a critical role

This is why Grameen Phone in collaboration with Grameen bank is aiming to place one phone in each village to contribute significantly to the economic uplifts of those villages. Grameen Phone's basic strategy is coverage of both urban and rural areas In contrast to the island strategy followed by some companies which involves connecting isolated island of urban coverage through transmission link. Grameen Phone builds continuous coverage cell after cell, while the intensity of coverage may vary from area to area depending on market conditions, the basic strategy of cell to cell coverage is applied throughout Grameen phone network.

Grameen Phone is more than just about phones to its employee. The sense of purpose gives them the dedication and the drive producing the biggest coverage and subscriber base in the country. Grameen Phone knows that the talents and energy of its employees are critical to its operation and treats them accordingly Grameen Phone believes in services, a service that leads to good business and good developments. Telephony helps people work together raising their productivity. This gain in productivity is development, which in turn enables them to afford a telephone service; generating a good business thus development and business go together.

By bringing electronic connectivity to rural Bangladesh, Grameen Phone is delivering the digital revolution to the doorsteps of the poor and unconnected.

2.9 NETWORK

Meanwhile Grameenphone built a healthy and robust infrastructure in terms of telecommunication network which is expanded at a record pace every year as well. The Radio in terms of coverage and capacity Transmission and Switching network in terms of number of base station, connecting transmission line. switching system (MSC) and so on

2.9.1 Switching Network

The switching capacity has been strengthened with 27 Mobile switching centers 42 Base Station Controller and other equipments added to in 06 divisional cities. Grameenphone is also offering a different type of services to the valued subscribers continuously by deploying different service equipment SMSC, VMSC, EDGE and so on.

2.9.2 Transmission Network

Bangladesh is located at the Ganges delta basin so the landscape of Bangladesh is dominated by the rivers and channel. Therefore an important part of the infrastructure is based on radio resources (Microwave Links) owned by Grameen phone. Grameenphone built a strong infrastructure by taking lease dark fibers from the Bangladesh Railway around 2000 km. The second tier backbone covers approximate 1200 km of new fiber optic cable was laid apart from leased optical fiber from Bangladesh Railway to enhance the capacity and to ensure higher redundancy in transmission end.

2.9.3 Radio network

It has built the largest network with the widest coverage. Nearly 80 percent of population has now been brought under the coverage of the GP network, which covers more than 450 Upazilas of 61 districts. Almost 3600 base stations are operating around the country.

CHAPTER 3

OVERVIEW OF GSM NETWORK

Grameenphone is using GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM) technology for providing network services to its customers. This technology was launched in Europe in 900 MHz frequency in the year of 1985. In the year 1991, 1800 MHz frequency band of GSM technology was introduced.

3.1 GSM NETWORK COMPONENTS

The GSM network is divided into two systems. Each of these systems is comprised of a number of functional units which are individual components of the mobile network. The two systems are:

- Switching System (SS)
- Base Station System (BSS)
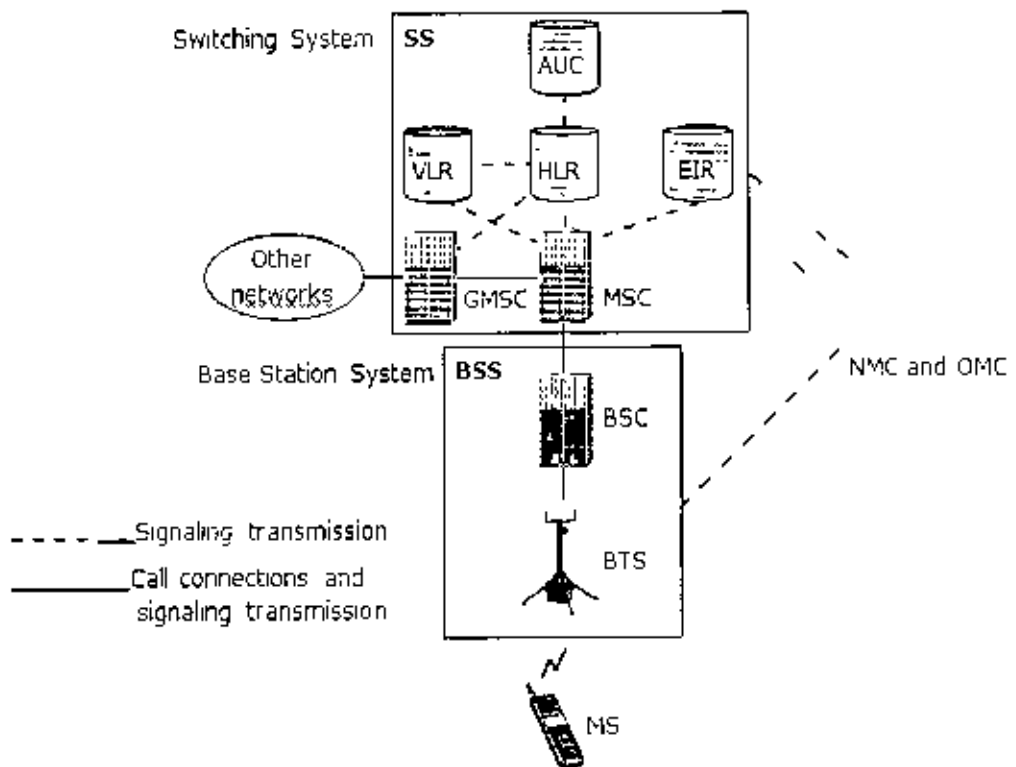
Figure 3.1: GSM System model

3.2 GSM TECHNOLOGY

3.2.1 General Information

GSM is also known as Global System for Mobile Communications, or simply Global System for Mobile. A technology started development in 1985 by a French company formerly known as Groupe Special Mobile. Its main competitor is CDMA, currently in use by Bell Mobility, Telus Mobility and Mobility Canada carriers.

Currently, only two main carriers in Canada are operating GSM networks, Microcell (Fido, Cityfone) and Rogers Wireless. Fido was the first carrier to start utilising this technology, followed by Rogers Wireless mainstream around 2001. Several companies in the United States have adopted GSM and it's spreading fast among AT&T Wireless, T-Mobile.

GSM operates on 4 different frequencies worldwide. However, only two are which are used in Canada, which are GSM-850 and GSM-1900.GSM-850 and GSM-1900 which operate at 1.9Ghz.

GSM calls are either based on data or voice. Voice calls use audio codecs called half-rate, full-rate and enhanced full-rate. Data calls can turn the cell phone into a modem operating at 9600 bps. An extended GSM feature is high speed circuit switched data, allowing the phone to transmit upto around 40 kbps.

Cell horizontal radius varies depending on antenna height, antenna gain and propagation conditions from a couple of hundred meters to several tens of kilometers. The longest distance the GSM specification supports in practical use is 35 kilometres (22 mi). There are also several implementations of the concept of an extended cell, where the cell radius could be double or even more, depending on the antenna system, the type of terrain and the timing advance.

Indoor coverage is also supported by GSM and may be achieved by using an indoor picocell base station, or an indoor repeater with distributed indoor antennas fed through power splitters, to deliver the radio signals from an antenna outdoors to the separate indoor distributed antenna system. These are typically deployed when a lot of call capacity is needed indoors, for example in shopping centers or airports. However, this is not a

prerequisite, since indoor coverage is also provided by in-building penetration of the radio signals from nearby cells.

The modulation used in GSM is Gaussian minimum-shift keying (GMSK), a kind of continuous-phase frequency shift keying. In GMSK, the signal to be modulated onto the carrier is first smoothed with a Gaussian low-pass filter prior to being fed to a frequency modulator, which greatly reduces the interference to neighboring channels (adjacent channel interference). [2]

3.3 NETWORK STRUCTURE
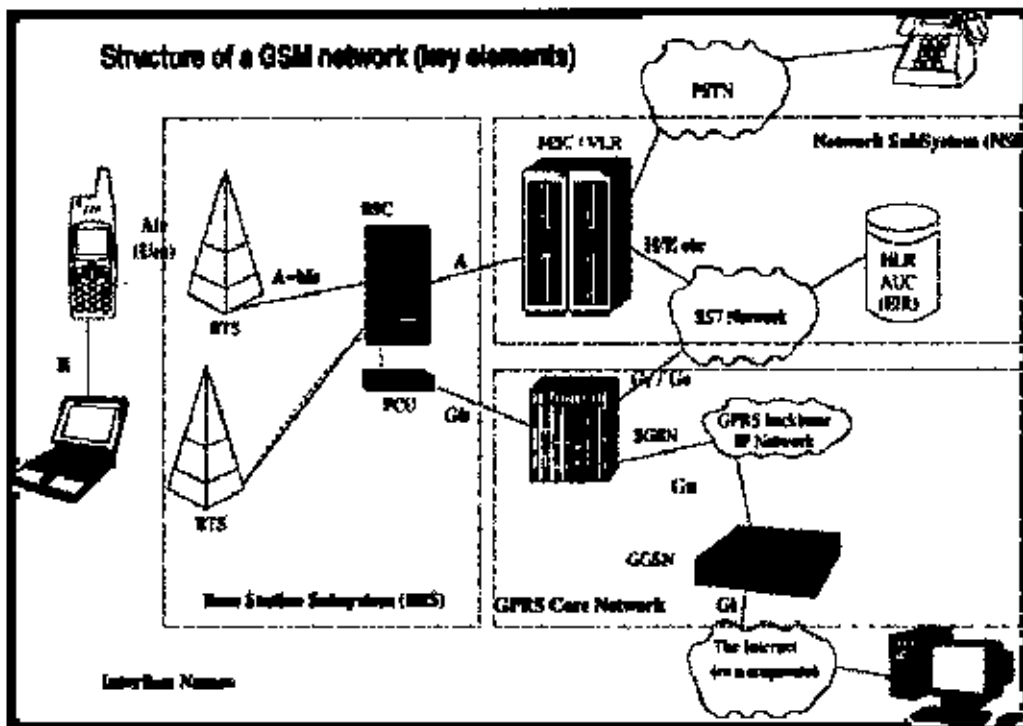
Figure 3 2· The structure of a GSM network

3.4 NETWORK ELEMENTS – AN OVERVIEW
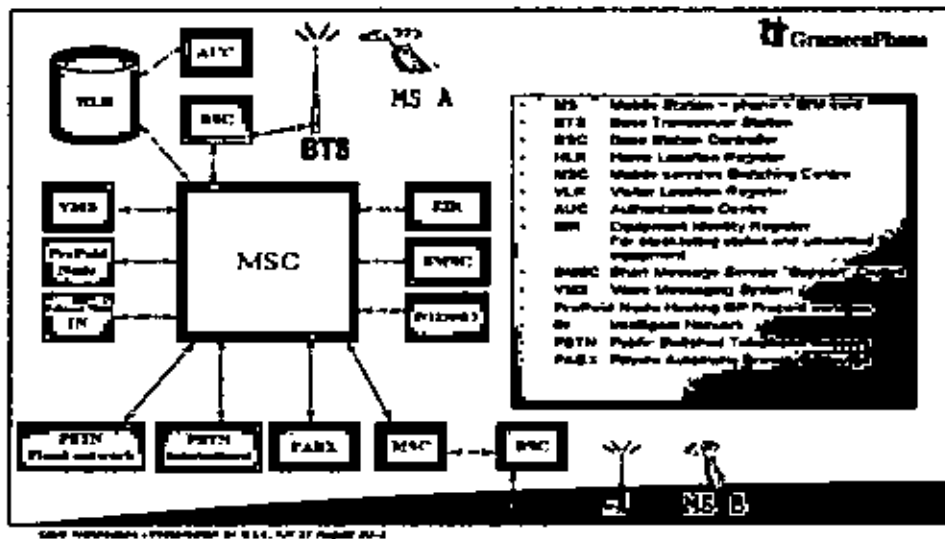
Figure 3.3: Different Elements of GSM network

The network behind the GSM system seen by the customer is large and complicated in order to provide all of the services which are required. It is divided into a number of sections and these are each covered in separate articles.

- The Base Station Subsystem (the base stations and their controllers).
- The Network and Switching Subsystem (the part of the network most similar to a fixed network). This is sometimes also just called the core network.
- The GPRS Core Network (the optional part which allows packet based Internet connections).
- All of the elements in the system combine to produce many GSM services such as voice calls and SMS

3.4.1 Mobile Station (MS)

- MS consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM)
- The SIM provides personal mobility, so that the user can have access to subscribed services irrespective of a specific terminal. By inserting the SIM card into a GSM terminal, the user is able to receive and make calls at that terminal, and receive other subscribed services. Without the SIM, the terminal will not work.

- 19 -

- The mobile equipment is uniquely identified by the International Mobile Equipment Identity (IMEI).
- The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other information.
- The IMEI and the IMSI are independent, thereby allowing personal mobility.
- The SIM card may be protected against unauthorized use by a password or personal identity number (PIN).

MS's main task

- In **BUSY** mode

    - Transmit measure reports to BTS every 480 ms
    - Measurements from neighbour cells.

- In **IDLE** mode

    - Find the strongest cell and listen to the system info in BCCH
    - Listen for Paging in correct Paging group in BCCH
    - Do location update
    - At end of timer (4 hour) – T3212
    - When MS is coming into a new LA.
    - Do HO when ordered from BSC.
    - Code/decode/modulate/demodulate/cipher/decipher speech/data

3.4.2 Base Station Subsystem

The Base Station Subsystem (BSS) is the section of a traditional cellular telephone network which is responsible for handling traffic and signaling between a mobile phone and the Network Switching Subsystem. The BSS carries out transcoding of speech channels, allocation of radio channels to mobile phones, paging, quality management of transmission and reception over the Air interface and many other tasks related to the radio network.[3]
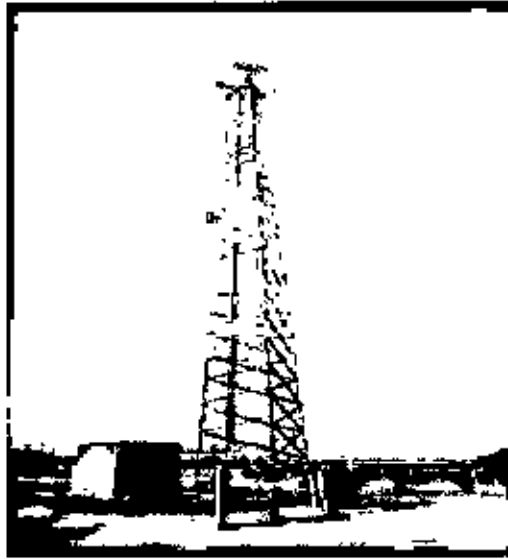
Figure 3.4: A typical GSM Base Station

3.4.3 BTS (Base Transceiver Station)

The Base Transceiver Station, or BTS, contains the equipment for transmitting and receiving of radio signals (transceivers), antennas, and equipment for encrypting and decrypting communications with the Base Station Controller (BSC). Typically a BTS for anything other than a picocell will have several transceivers (TRXs) which allow it to serve several different frequencies and different sectors of the cell (in the case of sectorised base stations). A BTS is controlled by a parent BSC via the Base Station Control Function (BCF). The BCF is implemented as a discrete unit or even incorporated in a TRX in compact base stations. The BCF provides an Operations and Maintenance (O&M) connection to the Network Management System (NMS), and manages operational states of each TRX, as well as software handling and alarm collection.
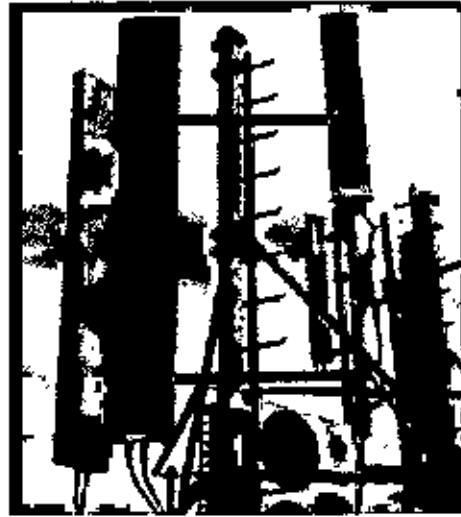
Figure 3.5: Base Transceiver Station Antenna

The functions of a BTS vary depending on the cellular technology used and the cellular telephone provider. There are vendors in which the BTS is a plain transceiver which receives information from the MS (Mobile Station) through the Um (Air Interface) and then converts it to a TDM ("PCM") based interface, the Abis, and sends it towards the BSC. There are vendors which build their BTSs so the information is preprocessed, target cell lists are generated and even intracell handover (HO) can be fully handled. The advantage in this case is less load on the expensive Abis interface.

The BTSs are equipped with radios that are able to modulate layer 1 of interface Um; for GSM 2G+ the modulation type is GMSK, while for EDGE-enabled networks it is GMSK and 8-PSK.

Antenna combiners are implemented to use the same antenna for several TRXs (carriers), the more TRXs are combined the greater the combiner loss will be. Up to 8:1 combiners are found in micro and pico cells only.

Frequency hopping is often used to increase overall BTS performance; this involves the rapid switching of voice traffic between TRXs in a sector. A hopping sequence is followed by the TRXs and handsets using the sector. Several hopping sequences are available, and the sequence in use for a particular cell is continually broadcast by that cell so that it is known to the handsets

- 22 -

A TRX transmits and receives according to the GSM standards, which specify eight TDMA timeslots per radio frequency. A TRX may lose some of this capacity as some information is required to be broadcast to handsets in the area that the BTS serves. This information allows the handsets to identify the network and gain access to it. This signalling makes use of a channel known as the BCCH (Broadcast Control Channel).

- The BTS corresponds to the transceivers and antennas used in each cell of the network
- It handles the radio-link protocols with the Mobile Station.
- A BTS may be placed in the center of a cell (omni-directional) or shooting in one or more specific directions (sectorized). Its transmitting power defines the size of a cell.
- Each BTS has typically between one and sixteen transceivers depending on the density of users in the cell.
- In a large urban area, there will potentially be a large number of BTSs deployed, thus the requirements for a BTS are ruggedness, reliability, portability, and minimum cost. [4]

3.4.4 Brief Description of a Base Station

A typical base station consists of following equipments

- Base station cabinet
- Power system equipments like – Rectifier, MDB and Bus bar
- Transmission equipments – Indoor and outdoor unit
- Battery for backup power
- GSM antenna
- Microwave antenna for point to point air connection with other base station

CHAPTER 4

FAULTS AND MANAGEMENT PROCESS

4.1 TYPES OF FAULTS IN NETWORK

Network elements of a base station are running for 24 hours. These are mainly electronic devices. But there are electrical and mechanical elements also to run the base station. These network elements have different life time. Moreover, regular preventive maintenance and health checking is performed to avoid any fault. But inspite some hardware faults occur.

Besides the hardware faults, there are dependency on some external parameters also like the external power from different utility service provider, environmental condition etc.

Considering these things, total faults happening in the base stations can be categorized into 5 major categories. These are-

1.   Base station hardware faults
2.   External power problem
3.   Internal power problem
4.   Low capacity microwave
5.   High capacity microwave

4.2 SHORT DESCRIPTION OF MAJOR FAULTS

4.2.1 Base Transceiver Station (BTS) hardware faults

We know that there is a base station cabinet which is mainly responsible for handling the major part of GSM technology. This cabinet consists of different replaceable units, cables, connectors etc.

Following faults may happen for the cabinet:

- BTS Hardware Problem- hardware may gone faulty at any time or malfunction
- BTS Software Problem- different units of the BTS cabinets are operated by software which may be corrupted at any time
- BTS Configuration Problem- this is also one kind of software problem. But here the difference is configuration of the cabinet may be changed for some reasons which result faults.
- BSC-BTS Synchronization Problem- we know that the BTS is controlled by remotely located Base Station Controller (BSC). Timing synchronization between BSC and BTS may happen resulting BTS faults.
- Automatic Reset- the cabinet may take reset due to various technical reasons which results outage or malfunctioning for a short period.

4.2.2 External Power Problem

- Mains Fail- If external power is not available for a long period, site may go down due to this problem. Normally battery backup is available for around 8 hours in every site. Also auto generator is there in some very remote or critical sites. But in some cases, power is not available for longer period, also generator malfunctions in some cases.
- Power Problem at the link site- Every site is connected to a remote or link site for transmission connectivity. So if power problem occurs at that site and go down for that reason, this site will also go down.
- Generator problem- In some sites, no commercial power is available and solely depend on generator. This is a mechanical device and may go faulty for various reasons. Moreover, automatic transfer system (ATS) is required for power switching between battery and generator. Sometimes, this ATS malfunction which cause site down. Moreover, to start the generator, a battery is required which sometimes don't function properly. As a result, the generator fails to start.
- Low fuel problem- Generators need fuel to run and this needs to be refueled before being empty. Normally the generators are fuelled maintaining a schedule. But sometimes high consumption of fuel may occur which brings abnormal situation. As a result, site may go down for failure of running the generator.

4.2.3. Internal Power Problem

- MDB Breaker Trip- Sometimes due to high voltage problem, transient current or circuit brakers internal problem, Main Distribution Brakers went tripped. This cause commercial power unavailable for the site until anyone attend and rectify the fault.

- Controller card problem- Rectifier is used in a base station to provide DC power to the telecom equipments. These rectifier consists different components, controller card is one of the basis component which sometimes don't work for which power is not fed to the equipments which cause site down.

- LVD problem- Low voltage disconnect (LVD) is a system

- Module Fail- Main part of the rectifier system is its modules. Function of the modules is to charge the batteries when external power is available. But sometimes, these modules don't work for which batteries are not being charged properly. For this reason, proper backup power is not obtained when mains fail occurs for longer period.

- Battery Breaker Tripped- This is one kind of MDB trip. Difference is this the DC braker for the battery. This sometimes got tripped due to abnormal situation. For this reason, site goes down immediately when mains fail occur.

- Load Breaker Tripped- DC power is fed to the equipments through different circuit breakers. Sometimes, these CBs also got tripped causing site down immediately.

- High Temperature- Telecom equipments are temperature sensitive and perform efficiently until certain temperature. These equipment generate heat which increase the temperature inside the room. To ensure cooling, air conditioner is placed in every site. But due to different reasons, these units go faulty which make high temperature. For this reason, GSM or transmission equipment goes down.

4.2.4. High Capacity problem

•   Environmental Problem- High capacity microwave transmission links are normally used for long distance transmission. Link is designed is such a way that it can sustain the attenuation due to a certain rainfall or fog. If rainfall or fog density is much denser than the design value, link doesn't function properly which causes a good number of sites down or poor performing.

•   Cable/connector faulty- Indoor units of the microwave links (MW) links are connected to the outdoor units or antennas through cable, connectors. Performance of these cable, connectors may deteriorate in time of period or due to poor workmanship during installation. Also water may enter inside the cable, connector if taping is not done properly.

•   ADM Card Faulty- High capacity microwave links and optical fibers are terminated through Add Drop Mulitiplexing or MUX equipments. It consists lots of different cards. Any of these cards may go fault at any time which cause huge impact on the network.

•   ADM Pigtail Faulty- Cards of the ADMs are connected to the indoor units or Optical Distribution Frame (ODF) of fiber optic through cables which are known as pigtails. These pigtails may go faulty which disrupt the connectivity causing site down.

•   Fiber Cut- Optical fiber passes through the railway tracks or highway. Lots of activities are always going on along these routes. Though fiber is laid maintaining a certain depth under the ground level, fiber sometimes gone cut. In most of the cases, traffic is protected providing ring solution. In that case, no customer is suffered. But in some cases, ring can't provided which causes site down. No. of site down due to fiber cut is normally huge.

•   Configuration Problem- High capacity links and MUX equipments are needed to configured by software.   Switching is done automatically also depending on the configuration file. Sometimes this configuration file may go corrupted which may cause site down.

•   ODF; Port Faulty- Optical fiber is terminated in the optical distribution frame (ODF). Ports of these ODFs may go faulty for various reasons. These also cause disruption of the respective links causing traffic outage.

4.2.5 Low Capacity Microwave

- Cable, connector Problem- Indoor units of the microwave links (MW) links are connected to the outdoor units or antennas through cable, connectors. Performance of these cable, connectors may deteriorate in time of period or due to poor workmanship during installation. Also water may enter inside the cable, connector if taping is not done properly.

- Environmental Problem-Low capacity microwave link are designed is such a way that it can sustain the attenuation due to a certain rainfall or fog. If rainfall or fog density is much denser than the design value, link doesn't function properly which causes a good number of sites down or poor performing.

- IDU Problem- Indoor units of the links may go faulty for different reasons at any time which cause outage of the links causing site down connected to that links.

- ODU Problem - Outdoor units of the links may go faulty for different reasons at any time which cause outage of the links causing site down connected to that links.

- Tributary port problem- Any BTS is connected to the switches (BSC) through tributary ports or PCM connectors. These have to be made manually where workmanship in involved. Also quality of the cable and connectors play a vital role. So the respective port connected by these connectors/cables may go faulty which will cause site down.

- Interference Problem- Frequency interference may occur if any neighbouring link is configured with the same frequency. In that case the link may go down or performance may be affected severely.

- LOS Break – Line of sight between two ends of a microwave link has to be clear. But normally in the big cities especially Dhaka, always construction of high rise buildings is going on which may disrupt the LOS.

4.3 FAULT MANAGEMENT PROCESS

We can see that the GSM communication depends on huge number of equipments and factors for which different types of faults are happening at every moment. So a proper fault management process is required to be maintained to restore the faults within the shortest possible time to minimize customer sufferings.

Grameenphone has a strong management process for this purpose. For managing the access network fault, Regional Operation and maintenance team is responsible with the help of Network Management team. Engineers of NM are monitoring the whole network on 24x7 basis. If any access network related fault appears, they communicate it to the respective ROM engineers through different channels like over phone, SMS, e-mail etc. The escalation period and mode depend on the severity of the fault.

After getting the notification from NM, field engineers take necessary action to restore the fault. Flow diagram of the fault management process is given in the following page:

.

Fault Management Process
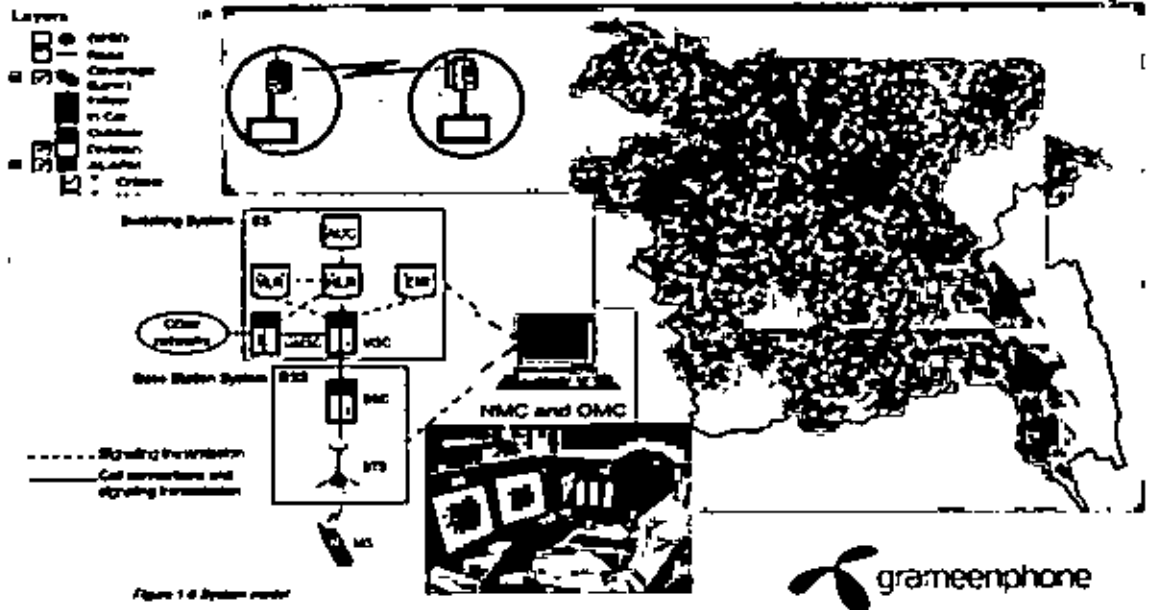
Figure 4.1: Fault Management Process

Fault Management Process

grameenphone
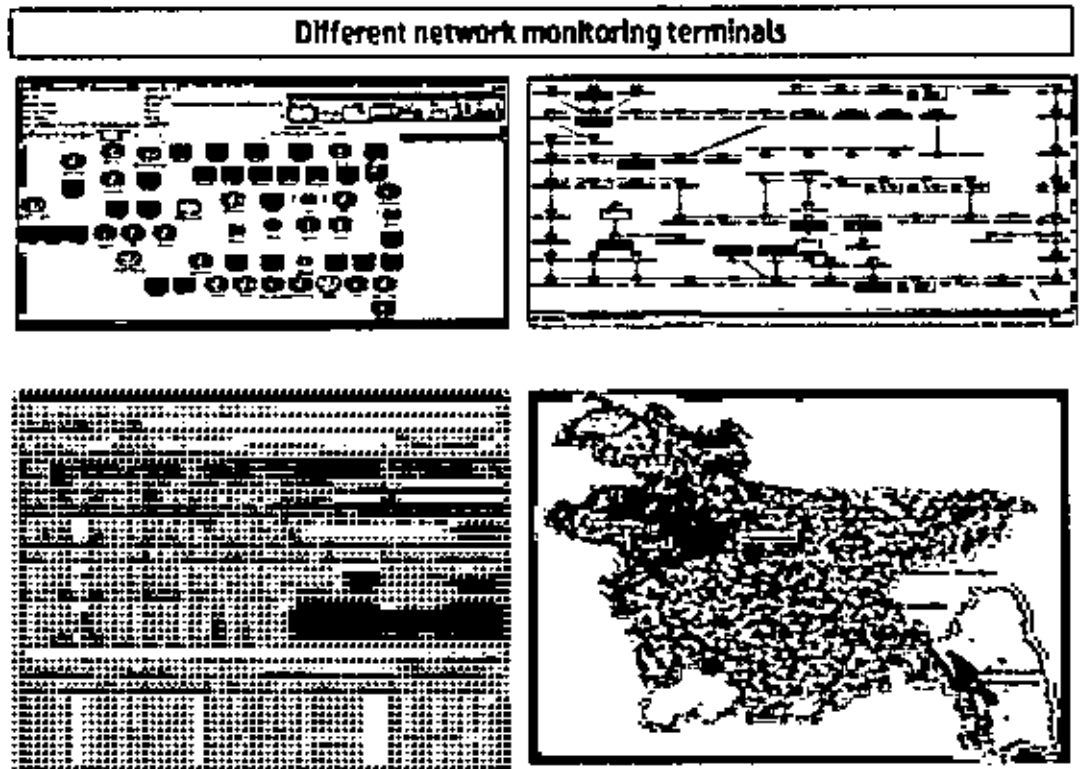
Figure 4.2: Different terminals for fault monitoring

4.4 FAULT ESCALATION FROM NM TO ROM

From the above two figures of Fault Management Process, we can see that from a central monitoring point, whole network is being monitored on 24x7 basis using different terminals for different types of faults. If any fault occurs, that is being reported and displayed in the terminals. Network Management (NM) engineers immediately inform the field engineers about the fault through different channels like over phone, SMS and e-mail. This is called Trouble Report (TR). A TR is issued for every fault where it is outage or quality issue.

4.5 FAULT CLEAR

Regional O&M engineers immediately rush to the site normally. Before leaving for the site, both NM and ROM engineers want to be sure about the fault for which site down has been occurred. This is required because ROM engineers have to carry spare hardware, portable generator. necessary tools etc. with them before leaving to rectify the fault ASAP but within the SLA.

After rectifying the fault, Field engineers inform NM to be confirmed about the status of the fault. If NM confirms that the fault has been cleared. then the TR is closed. But if the fault still exists, then the fault may be escalated to 2nd line expertise team or vendor The flow chart is mentioned in figure 4.3.

```
┌─────────────────────────────────────┐
│   Fault appeared and Displayed at NMS │
└─────────────────────────────────────┘
                  │
                  ▼
┌─────────────────────────────────────┐
│  Issuance of TR and Inform to responsible │
│ Regional Team leader by SMS and/or Phone call │
└─────────────────────────────────────┘
                  │
                  ▼
┌─────────────────────────────────────┐
│  Attend the fault at site by Field Engineer │
└─────────────────────────────────────┘
                  │
                  ▼
            ◇ Rectification done ◇ ───NO───→ ┌────────┐
                  │                           │   NM   │
                 YES                          └────────┘
                  │                                │
                  ▼                                ▼
       ┌──────────────────┐              ◇ 2nd Line Group to rectify ◇ ──NO──→
       │  NM monitors status │                    │
       │    of the fault     │                   YES        ┌────────┐
       └──────────────────┘                       │         │ Vendor │
                  │                                │         └────────┘
                  OK                               │
                  ▼                                ▼
       ┌──────────────────┐                 Confirm with
       │   Confirm with    │ ←──────────────── NM/ROM
       │     NM/ROM        │
       └──────────────────┘
                  │
                  ▼
            ◇ Fault Cleared ◇
                  │
                 YES
                  ▼
           ┌────────────┐
           │  TR Closed │
           └────────────┘
```
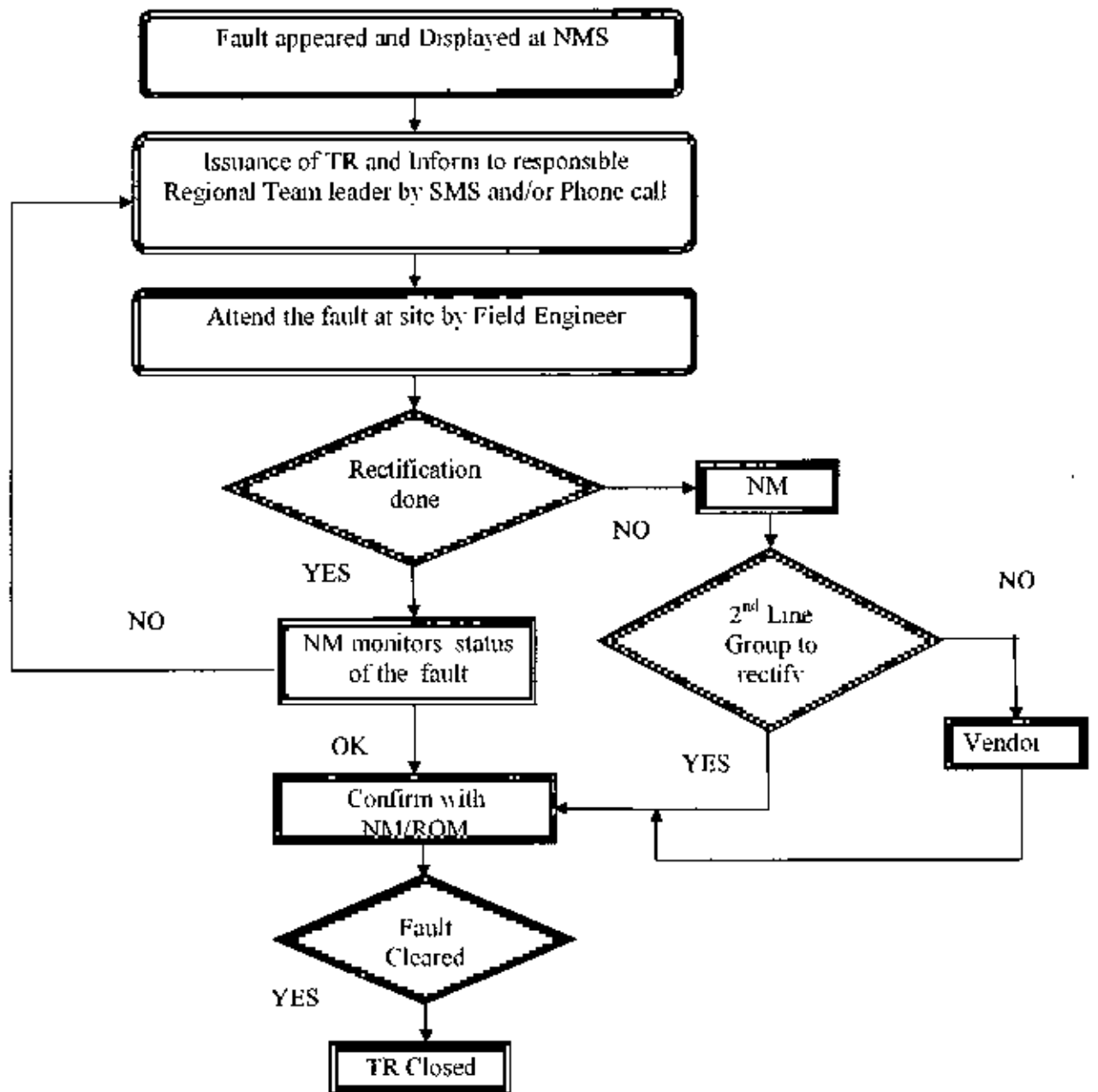
Figure 4.3: Fault monitoring, escalation and clear work flow

CHAPTER 5

STATISTICAL PROCESS CONTROL (SPC)

5.1 DEFINITION OF SPC

Statistical Process Control (SPC) is an effective method of monitoring a process through the use of control charts. By collecting data from samples at various points within the process, variations in the process that may affect the quality of the end product or service can be detected and corrected, thus reducing waste and as well as the likelihood that problems will be passed on to the customer. With its emphasis on early detection and prevention of problems, SPC has a distinct advantage over quality methods, such as inspection, that apply resources to detecting and correcting problems in the end product or service.

In addition to reducing waste, SPC can lead to a reduction in the time required to produce the product or service from end to end. This is partially due to a diminished likelihood that the final product will have to be reworked, but it may also result from using SPC data to identify bottlenecks, wait times, and other sources of delays within the process. Process cycle time reductions coupled with improvements in yield have made SPC a valuable tool from both a cost reduction and a customer satisfaction standpoint.

Statistical process control (SPC) involves using statistical techniques to measure and analyze the variation in processes. Most often used for manufacturing processes, the intent of SPC is to monitor product quality and maintain processes to fixed targets. Statistical quality control refers to using statistical techniques for measuring and improving the *quality* of processes and includes SPC in addition to other techniques, such as sampling plans, experimental design, variation reduction, process capability analysis, and process improvement plans.

SPC is used to monitor the consistency of processes used to manufacture a product as designed. It aims to get and keep processes under control. No matter how good or bad the design, SPC can ensure that the product is being manufactured as designed and intended.

Thus, SPC will not improve a poorly designed product's reliability, but can be used to maintain the consistency of how the product is made and, therefore, of the manufactured product itself and its as-designed reliability.

A primary tool used for SPC is the *control chart*, a graphical representation of certain descriptive statistics for specific quantitative measurements of the manufacturing process. The control chart is one of the seven basic tools of quality control (along with the histogram, Pareto chart, check sheet, cause-and-effect diagram, flowchart, and scatter diagram). In statistical process control, the control chart, also known as the 'Shewhart chart' or 'process-behavior chart' is a tool to determine whether a manufacturing or business process is in a state of statistical control or not. If the chart indicates that the process being monitored is not in control, the pattern it reveals can help determine the source of variation to be eliminated to bring the process back into control. A control chart is a specific kind of run chart.

These descriptive statistics are displayed in the control chart in comparison to their "in-control" sampling distributions. The comparison detects any unusual variation in the manufacturing process, which could indicate a problem with the process. Several different descriptive statistics can be used in control charts and there are several different types of control charts that can test for different causes, such as how quickly major vs. minor shifts in process means are detected. Control charts are also used with product measurements to analyze process capability and for continuous process improvement efforts. [1]

5.2 BENEFITS OF SPC

- Provides surveillance and feedback for keeping processes in control.
- Signals when a problem with the process has occurred.
- Detects assignable causes of variation.
- Accomplishes process characterization.
- Reduces need for inspection.
- Monitors process quality.
- Provides mechanism to make process changes and track effects of those changes.
- Once a process is stable (assignable causes of variation have been eliminated), provides process capability analysis with comparison to the product tolerance.

5.3 BASIC TOOLS OF QUALITY

- Pareto Principle
- Scatter Plots.
- Control Chart.
- Flow Charts/ Process Map.
- Cause effect, Fishbone, Ishikawa diagram.
- Histogram or Bar Graph.
- Checklists & Check sheet.

5.3.1 Pareto Principle

A Pareto chart looks like a cumulative bar graph. The lengths of the bars represent frequency or cost (time or money), and are arranged with longest bars on the left and the shortest to the right. The longest bar represents the most vital cause.

This is graphical tool for ranking causes from most significant to least significant. It depicts a series of vertical bars lined up lined up in a descending order – from high to low – to reflect frequency, importance, or priority. The following is an example (Table 5.1 and Figure 5.1) of a Pareto analysis of problems that occurred in products from lathe machine workshop.

Table 5.1. Frequency of areas of complaints

Areas of complaints	Frequency	Percent	Cummulative percentage
Wrong dimension	49	49	49
Surface areas	20	20	69
Broken	15	15	84
Wrong material	10	10	94
Others	6	6	100

Based on this table, a Pareto chart is prepared, as given in Figure 5.1 [1]
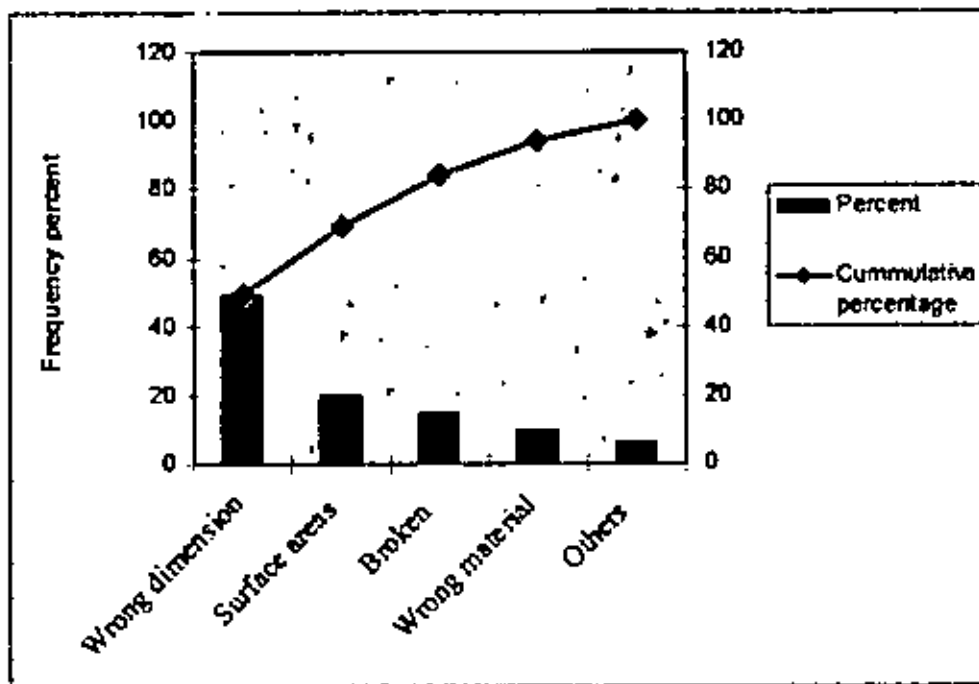
Figure 5.1: Pareto diagram for complaints regarding TV delivery to households

80/20 rule

The Pareto principle (also known as the 80-20 rule, the law of the vital few and the principle of factor sparsity) states that, for many events, 80% of the effects come from 20% of the causes. Business management thinker Joseph M. Juran suggested the principle and named it after Italian economist Vilfredo Pareto, who observed that 80% of income in Italy went to 20% of the population. It is a common rule of thumb in business; e.g., "80% of your sales comes from 20% of your clients."

It is worthy of note that some applications of the Pareto principle appeal to a pseudo-scientific "law of nature" to bolster non-quantifiable or non-verifiable assertions that are "painted with a broad brush". The fact that hedges such as the 90/10, 70/30, and 95/5 "rules" exist is sufficient evidence of the non-exactness of the Pareto principle. On the other hand, there is adequate evidence that "clumping" of factors does occur in most phenomena

The Pareto principle is only tangentially related to Pareto efficiency, which was also introduced by the same economist, Vilfredo Pareto. Pareto developed both concepts in the context of the distribution of income and wealth among the population.

The observation was in connection with income and wealth. Pareto noticed that 80% of Italy's wealth was owned by 20% of the population. He then carried out surveys on a variety of other countries and found to his surprise that a similar distribution applied.

It also applies to a variety of more mundane matters: one might guess approximately that we wear our 20% most favored clothes about 80% of the time, perhaps we spend 80% of the time with 20% of our acquaintances, etc.

The Pareto principle has many applications in quality control. It is the basis for the Pareto chart, one of the key tools used in total quality control and six sigma. The Pareto principle serves as a baseline for ABC-analysis and XYZ-analysis, widely used in logistics and procurement for the purpose of optimizing stock of goods, as well as costs of keeping and replenishing that stock .

In computer science the Pareto principle can be applied to optimization efforts.

The Pareto principle was a prominent part of the 2007 bestseller . The 4-Hour Workweek by Tim Ferriss. Ferriss recommended firing the 80% of your customers who take up the majority of your time and focusing on the 20% who make up the majority of your profits

ITW practices the 80/20 rule in all of its businesses. [7]

5.3.2 Scatter Plot

A **scatter graph** or **scatter plot** is a type of display that contains one or more **scatter plots** each of which use Cartesian coordinates to display values for two variables for a set of data. The data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis.

A scatter plot only specifies variables or independent variables when a variable exists that are under the control of the experimenter. If a parameter exists that is systematically incremented and/or decremented by the experimenter, it is called the *control parameter* or

independent variable and is customarily plotted along the horizontal axis The measured or dependent variable is customarily plotted along the vertical axis. If no dependent variable exists, either type of variable can be plotted on either axis or a scatter plot will illustrate only the degree of correlation (not causation) between two variables.

A scatter plot can suggest various kinds of correlations between variables with a certain confidence level. Correlations may be positive (rising), negative (falling), or null (uncorrelated). If the pattern of dots slopes from lower left to upper right, it suggests a positive correlation between the variables being studied. If the pattern of dots slopes from upper left to lower right, it suggests a negative correlation. A line of best fit can be drawn in order to study the correlation between the variables. An equation for the correlation between the variables can be determined by established best-fit procedures. For a linear correlation, the best-fit procedure is known as linear regression and is guaranteed to generate a correct solution in a finite time. Unfortunately, no universal best-fit procedure is guaranteed to generate a correct solution for arbitrary relationships. One of the most powerful aspects of a scatter plot, however, is its ability to show nonlinear relationships between variables. Furthermore, if the data is represented by a mixture model of simple relationships, these relationships will be visually evident as superimposed patterns. [5]

Old Faithful Eruptions
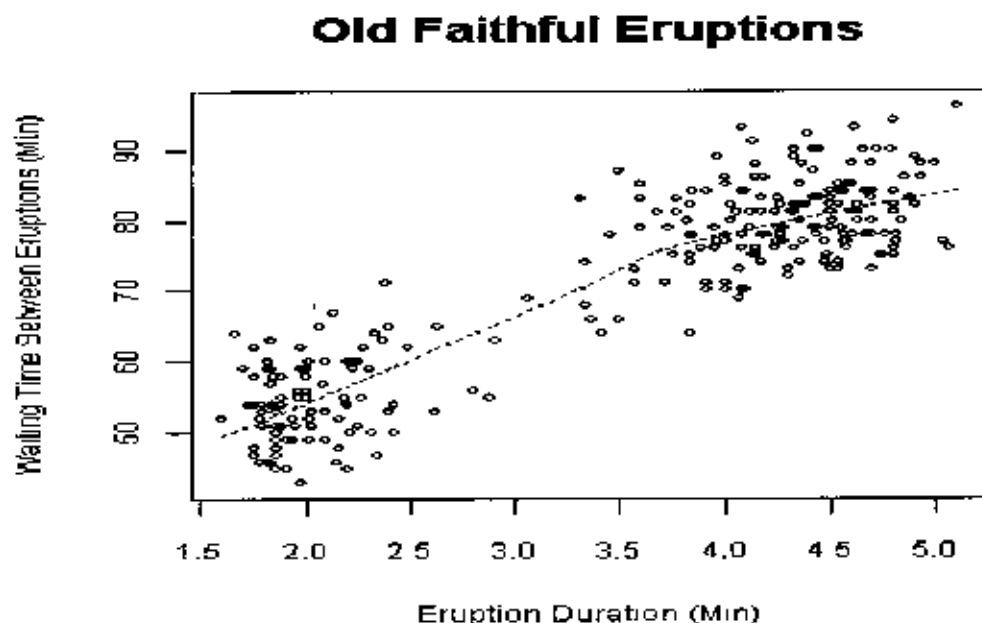
Figure 5.2. Graphical display for Scatter plot

5.3.3 Control Chart

Variations:

Different types of control charts can be used, depending upon the type of data. The two broadest groupings are for variable data and attribute data.

- **Variable data** are measured on a continuous scale. For example: time, weight, distance or temperature can be measured in fractions or decimals. The possibility of measuring to greater precision defines variable data.

- **Attribute data** are counted and cannot have fractions or decimals. Attribute data arise when you are determining only the presence or absence of something, success or failure, accept or reject, correct or not correct.

Details:

A control chart consists of the following:

- Points representing averages of measurements of a quality characteristic in samples taken from the process versus time.
- A centre line, drawn at the process mean.
- Upper and lower control limits ("natural process limits") that indicate the threshold at which the process output is considered statistically unlikely.

It is expected that the quality characteristics remain within these two limits.

A center line (CL), which is basically the target mean value of the quality characteristics. It is expected that the values of quality characteristics remain randomly on both side of the mean, or centre line.

Description:

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw

- 40 -

conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.
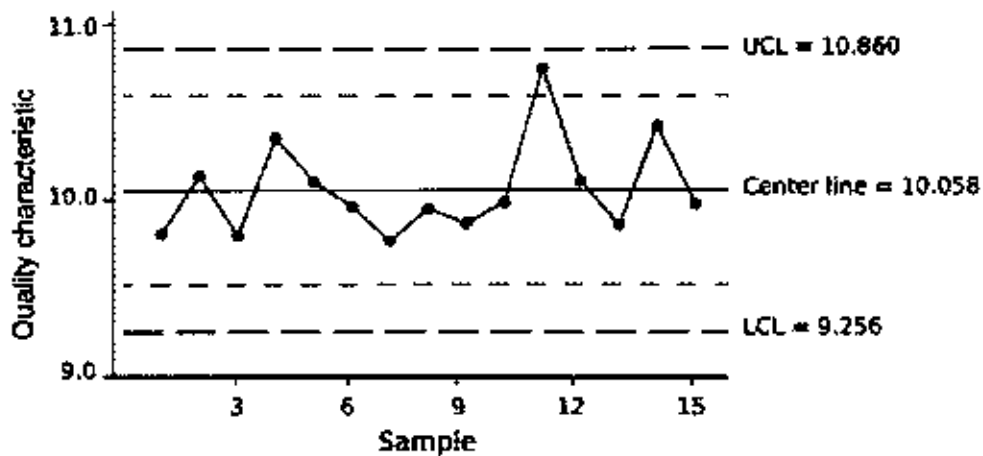
Figure 5.3: A typical control chart

As per theory of normal disturbance, if all the plotted fall within the limits, the process is in control, statically in the 'acceptance' zone. Any point plotted outside the limits would mean, the process is in the 'rejection' zone. Too many points outside the limit would mean the process is out of control. When this condition occurs, investigation is necessary for identifying (assignable) reasons/causes behind, for subsequent intervention or corrective action.

When to Use a Control Chart:

• When controlling ongoing processes by finding and correcting problems as they occur.

• When predicting the expected range of outcomes from a process.

• When determining whether a process is stable (in statistical control).

• When analyzing patterns of process variation from special causes (non-routine events) or common causes (built into the process).

• When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process

Control Chart Basic Procedure:

• Choose the appropriate control chart for your data.

• Determine the appropriate time period for collecting and plotting data.

• Collect data, construct your chart and analyze the data.

• Look for "out-of-control signals" on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected

Out-of-control signals:

• A single point outside the control limits. In Figure 5 4, point sixteen is above the UCL (upper control limit).

• Two out of three successive points are on the same side of the centerline and farther than 2σ from it. In Figure 5.4, point 4 sends that signal.

• Four out of five successive points are on the same side of the centerline and farther than 1σ from it. In Figure 5.4, point 11 sends that signal.

• A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. In Figure 5.4, point 21 is eighth in a row above the centerline.

• Obvious consistent or persistent patterns that suggest something unusual about your data and your process.
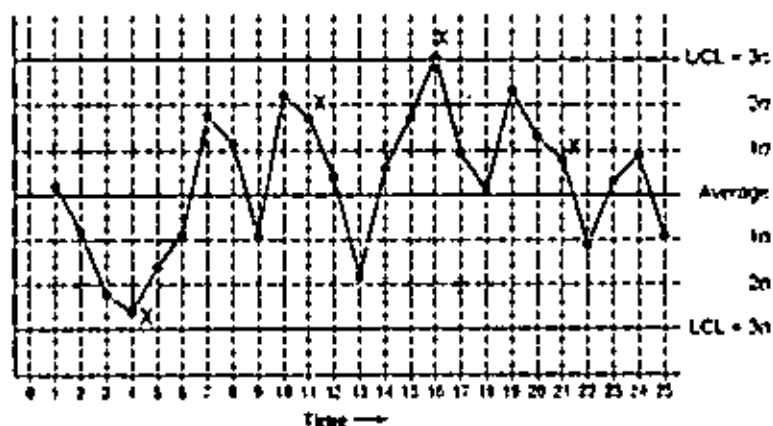
Figure 5.4: Control Chart: Out-of-Control Signals

- Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.
- When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits. [6]

5.3.3.1 Types of Control Chart: [1]

Table 5.2: List of different types of Control Chart

Chart	Process observation	Process observations relationships	Process observations type	Size of shift to detect
Xbar R chart	Quality characteristic measurement within one subgroup	Independent	Variables	Large ($\geq 1.5\sigma$)
Xbar S chart	Quality characteristic measurement within one subgroup	Independent	Variables	Large ($\geq 1.5\sigma$)
Shewhart individuals	Quality characteristic measurement for one	Independent	Variables	Large ($\geq 1.5\sigma$)

- 43 -

control chart	observation			
Three-way chart	Quality characteristic measurement within one subgroup	Independent	Variables	Large (≥ 1.5σ)
p-chart	Fraction nonconforming within one subgroup	Independent	Attributes	Large (≥ 1.5σ)
np-chart	Number nonconforming within one subgroup	Independent	Attributes	Large (≥ 1.5σ)
c-chart	Number of nonconformance's within one subgroup	Independent	Attributes	Large (≥ 1.5σ)
u-chart	Nonconformance's per unit within one subgroup	Independent	Attributes	Large (≥ 1.5σ)

5.3.3.2 X-bar/R chart:

An X-bar/R chart is a specific member of a family of control charts. A control chart is a tool used in quality control, specifically SPC or statistical process control, as originally developed by Walter A. Shewhart at Western Electric in 1924 to improve the quality of telephones.

A control chart is a plot of measurements of a product on two special scales, usually located above and below each other and running horizontally. X-Bar/R charts consist of two charts, both with the same horizontal axis denoting the sample number.

The vertical axis on the top chart depicts the sample means (X-Bar) for a series of lots or subgroup samples. It has a centerline represented by Xdoublebar, which is simply the overall process average, as well as two horizontal lines, one above and one below the centerline, known as the upper control limit or UCL and lower control limit or LCL, respectively. These lines are drawn at a distance of plus and minus three standard deviations (that is, standard deviations of the sampling distribution of sample means) from the process average. In practice, tabulated constants are available to determine the control limits, or they are automatically calculated by the SPC software used.

The bottom chart has the range (R) of each subgroup plotted on the vertical axis. Like an X-Bar chart, R charts have a centerline and two control limits. However, for sample sizes below 7, the LCL is zero.

The purpose of any control chart is to help determine if variations in measurements of a product are caused by small, normal variations that cannot be acted upon ("common causes"), or by some larger "special cause" that can be acted upon or fixed. The type of chart to be used is based on the nature of the data.

The X-bar/R chart is normally used for numerical data that is captured in subgroups in some logical manner – for example 3 production parts measured every hour. A special cause such as a broken tool will then show up as an abnormal pattern of points on the chart.

5.3.3.3 P-chart:

In industrial statistics, the **p-chart** is a type of control chart that is very similar to the X-bar chart except that the statistic being plotted is the sample proportion rather than the sample mean. Since the proportion deals with the percentage of successes, clearly the appropriate data for p-charts needs to be attribute data where the outcomes for each trial can be classified as either a success or a failure (conform or non-conform, yes or no, etc.). The subgroup size should ideally be equal, although unequal sample sizes can be accommodated.

It's Characteristics:

- The "p" comes from use of the proportion of nonconforming items
- Need a good definition of nonconforming items – usually a categorical definition
- Can be of equal or unequal subgroups
- Normally need large subgroups – can even be up to total for the period

Control limits for the p-chart are calculated on the basis of the binomial distribution.

The control limits for this chart type can be determined by the formula:

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

5.3.3.4 NP-chart:

In industrial statistics, the **np-chart** is a type of control chart that is very similar to the p-chart except that the statistic being plotted is a number count rather than a sample proportion of items. For example, an np-chart often shows the number of nonconforming items in each sample. Since we are counting failures or successes, clearly the appropriate data for np-charts need to be attribute data. The subgroup size must be constant, as comparisons of counts would otherwise be meaningless.

It's Characteristics.

- The "np" stands for the number of conforming items, which can be expressed as n (sample size) times p (proportion of nonconforming items).
- Need a good definition of nonconforming items – usually a categorical definition.
- Subgroup size must be constant.
- Normally need large subgroups – can even be up to total for the period.

Control limits for the np-chart are calculated on the basis of the binomial distribution.

The control limits for this chart type can be determined by the formula: .

$$n\bar{p} \pm 3\sqrt{\frac{n\bar{p}(1-\bar{p})}{n}}$$

5.3.3.5 C-Chart:

A C chart is a data analysis technique for determining if a measurement process has gone out of statistical control. The C chart is sensitive to changes in the number of defective items in the measurement process. The "C" in C CONTROL CHART stands for "counts" as in defectives per lot. The C control chart consists of:

Vertical axis = the number defective for each sub-group.

Horizontal axis = sub-group designation.

The C chart assumes that each sub-group has an equal sample size (this sample size does not need to be specified). A sub-group is typically a time sequence (e.g., the number of

defectives in a daily production run where each day is considered a sub-group). If the times are equally spaced, the horizontal axis variable can be generated as a sequence

In addition, horizontal lines are drawn at the mean number of defectives and at the upper and lower control limits.

The control limits for this chart type can be determined by the formula

Center Line is calculated as:

$$\bar{c} = \frac{\sum_{j=1}^{m}(count)_j}{m}$$

Where m is the number of groups included in the analysis.

UCL, LCL (Upper and Lower Control Limit):

$$UCL = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL = MAX\left[0, \bar{c} - 3\sqrt{\bar{c}}\right]$$

5.3.3.6 U Chart:

U chart generates a (Poisson) proportion control chart. A U chart is a data analysis technique for determining if a measurement process has gone out of statistical control. The U chart is sensitive to changes in the normalized number of defective items in the measurement process. Normalized means that the number of defectives is divided by the unit area.). The "U" Nin U chart stands for "units" as in defectives per lot The U control chart consists of:

Vertical axis = the normalized number of defectives
Horizontal axis = sub-group designation.

The control limits for this chart type can be determined by the formula:

- 47 -

The average count of occurrences of criteria of interest in sample of items

$$u_j = \frac{(count)_j}{n_j}$$

Where nj is the sample size (number of units) of group j.

Center Line is calculated as:

$$\bar{u} = \frac{\sum_{j=1}^{m}(count)_j}{m}$$

where nj is the sample size (number of units) of group j, and m is the number of groups included in the analysis.

UCL, LCL (Upper and Lower Control Limit):

$$UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{n_j}}$$

$$LCL = MAX\left[0, \bar{u} - 3\sqrt{\frac{\bar{u}}{n_j}}\right]$$

5.3.4 Flowchart

A flowchart is one of the seven basic tools of quality control, which also includes the histogram, Pareto chart, check sheet, control chart, cause-and-effect diagram, and scatter diagram. They are commonly used in business/economic presentations to help the audience visualize the content better, or to find flaws in the process. Alternatively, one can use Nassi-Shneiderman diagrams.

A **flowchart** (also spelled **flow-chart** and **flow chart**) is a schematic representation of an algorithm or a process. This is alternatively known as Run chart, Route sheet, Process Map. Flowcharts are useful tool foe examining how various steps are related to each other. By studying these charts individuals and teams can often uncover potential source of trouble and/ or identify steps to be taken to improve or error-proof a process.

Process flow chat focuses on the specific processes that raw materials, parts and sub-assemblies follow as they move through the plant. This chart is a useful diagnosis tool and can be used to improve the performances at each step in the operations. Indeed the standard step in analyzing any production is to map the flows.

A complete diagnosis of a sub-system certainly requires information on its input side and output side, because, the sub-system may interact or may be affected by the preceding part or operations and requirement/constraints in the succeeding operation. Thus, a complete view of a process flow helps an analyst to pin point the exact location, or source of disturbance.

A flowchart is described as "cross-functional" when the page is divided into different "lanes" describing the control of different organizational units. A symbol appearing in a particular "lane" is within the control of that organizational unit. This technique allows the analyst to locate the responsibility for performing an action or making a decision correctly, allowing the relationship between different organizational units with responsibility over a single process. The following figure shows a brief schematic view of a process chart.
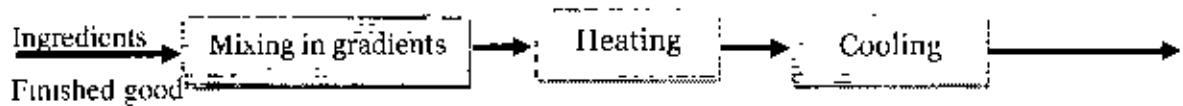
Figure 5.5: Schematic diagram of a process chart

5.3.5 Cause effect, Fishbone, Ishikawa diagram

The **Ishikawa diagram** (or **fishbone diagram** or also **cause-and-effect diagram**) is the brainchild of Kaoru Ishikawa, who pioneered quality management processes in the Kawasaki shipyards, and in the process became one of the founding fathers of modern management. It is simply a diagram that shows the causes of a certain event. It was first used in the 1960s, and is considered one of the seven basic tools of quality management, along with the histogram, Pareto chart, check sheet, control chart, flowchart, and scatter diagram. See Quality Management Glossary. It is known as a fishbone diagram because of its shape, similar to the side view of a fish skeleton.
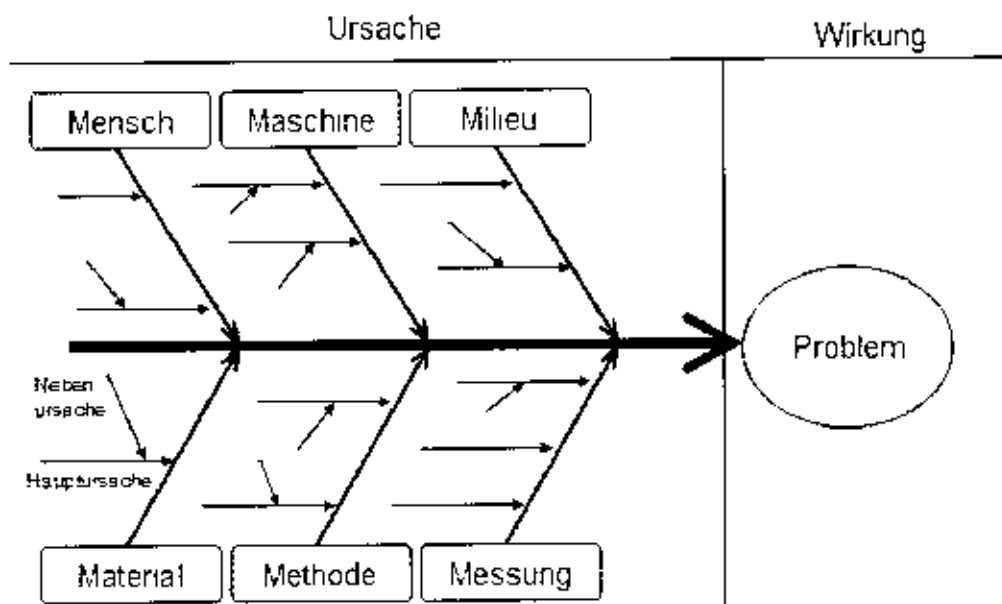
Figure 5.6: Graphical display of Cause effect diagram

5.3.6 Histogram or Bar Graph

In statistics, a **histogram** is a graphical display of tabulated frequencies. It shows what proportion of cases fall into each of several categories. A histogram differs from a bar chart in that it is the area of the bar that denotes the value, not the height, a crucial distinction when the categories are not of uniform width (Lancaster, 1974). The categories are usually specified as non-overlapping intervals of some variable. The categories (bars) must be adjacent.

The word histogram is derived from Greek: histos 'anything set upright' (as the masts of a ship, the bar of a loom, or the vertical bars of a histogram); gramma 'drawing, record, writing'. The histogram is one of the seven basic tools of quality control, which also include the Pareto chart, check sheet, control chart, cause-and-effect diagram, flowchart, and scatter diagram. A generalization of the histogram is kernel smoothing techniques. This will construct a very smooth probability density function from the supplied data

Examples

As an example we consider data collected by the U.S. Census Bureau on time to travel to work. The census found that there were **124 million people** who work outside of their homes. This rounding is a common phenomenon when collecting data from people.

Histogram of travel time, US 2000 census. Area under the curve equals the total number of cases. This diagram uses Q/width from the table.

Table 5.2: Data of US worker who traveler to go for work

Data by absolute numbers			
Interval	Width	Quantity	Quantity/width
0	5	4180	836
5	5	13687	2737
10	5	18618	3723
15	5	19634	3926
20	5	17981	3596
25	5	7190	1438
30	5	16369	3273
35	5	3212	642
40	5	4122	824
45	15	9200	613
60	30	6461	215
90	60	3435	57
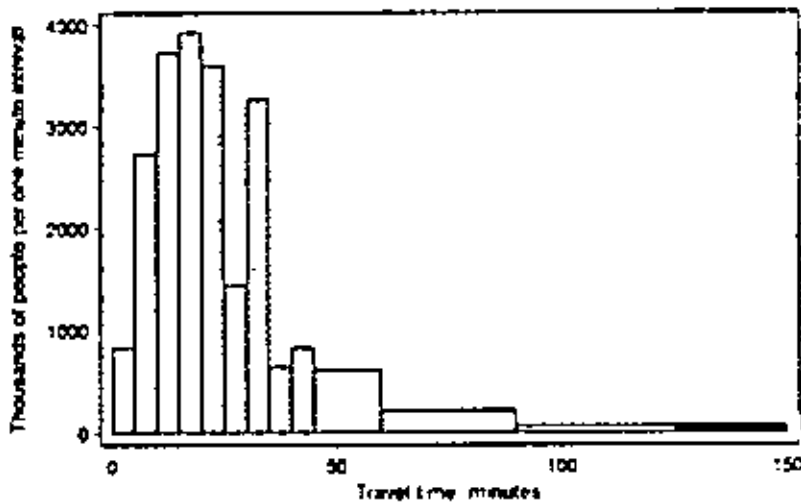
Figure 5.7: Histogram for the workers who travel to go for work

This histogram shows the number of cases per unit interval so that the height of each bar is equal to the proportion of total people in the survey who fall into that category. The area under the curve represents the total number of cases (124 million). This type of histogram shows absolute numbers. [9]

5.3.7 Check sheet

The **check sheet** is a simple document that is used for collecting data in real-time and at the location where the data is generated. The document is typically a blank form that is designed for the quick, easy, and efficient recording of the desired information, which can be either quantitative or qualitative. When the information is quantitative, the checksheet is sometimes called a tally sheet.

A defining characteristic of a check sheet is that data is recorded by making marks ("checks") on it. A typical check sheet is divided into regions, and marks made in different regions have different significance. Data is read by observing the location and number of marks on the sheet. 5 Basic types of Check Sheets:

- **Classification**: A trait such as a defect or failure mode must be classified into a category.
- **Location**: The physical location of a trait is indicated on a picture of a part or item being evaluated.
- **Frequency**: The presence or absence of a trait or combination of traits is indicated. Also number of occurrences of a trait on a part can be indicated.
- **Measurement Scale**: A measurement scale is divided into intervals, and measurements are indicated by checking an appropriate interval.
- **Check List:** The items to be performed for a task are listed so that, as each is accomplished, it can be indicated as having been completed.[8]

The table below shows a check sheet used to collect data on telephone interruptions. The tick marks were added as data was collected over several weeks. [1]

Table 5.3: Check sheet for data collection of telephonic interruptions

Telephone Interruptions

Reason	Day					
	Mon	Tues	Wed	Thurs	Fri	Total
Wrong number	⊞	‖	‖	⊞	⊞ ‖	20
Info request	‖	‖	‖	‖	‖	10
Boss	⊞	‖	⊞ ‖	‖	‖‖‖	19
Total	12	6	10	8	13	49

- 54 -

PROCESS ANALYSIS FOR NO. OF FAULTS

6.1 ANALYSIS OF NO OF FAULTS USING C-CHART

In this chapter, we will analyse the process for total and all category wise faults. Data has been taken and compiled from the daily outage report published by Network Management department. Period of data is 1st to 30th October, 2007. As mentioned before, faults have been taken for the sites of Dhaka region.

Table 6.1: List of outage related network faults under Dhaka region [11]

Sl.	DATE	Total fault	No. of fault-ITS HW	No. of fault-EXP	No. of fault-Int Power	No. of fault-LCMW	No of fault-HCMW
1	1-Oct-07	124	4	80	14	25	1
2	2-Oct-07	123	2	80	3	36	2
3	3-Oct-07	144	6	82	13	39	4
4	4-Oct-07	68	6	1	15	45	1
5	5-Oct-07	71	6	8	11	40	6
6	6-Oct-07	58	6	4	12	35	1
7	7-Oct-07	218	5	182	15	14	2
8	8-Oct-07	108	3	84	3	14	4
9	9-Oct-07	42	2	24	10	2	4
10	10-Oct-07	130	6	88	7	26	3
11	11-Oct-07	128	2	78	4	37	7
12	12-Oct-07	123	3	82	10	24	4
13	13-Oct-07	136	4	79	5	42	6
14	14-Oct-07	78	1	46	7	23	1
15	15-Oct-07	147	1	85	7	45	9
16	16-Oct-07	145	5	74	13	47	7
17	17-Oct-07	122	1	83	15	19	4
18	18-Oct-07	136	3	70	10	46	7
19	19-Oct-07	117	1	82	8	19	7
20	20-Oct-07	134	3	96	12	18	5
21	21-Oct-07	74	3	21	2	42	6
22	22-Oct-07	132	6	74	7	43	4
23	23-Oct-07	150	7	80	14	46	3
24	24-Oct-07	122	2	79	10	28	3
25	25-Oct-07	131	1	72	11	42	5
26	26-Oct-07	148	1	81	15	48	3
27	27-Oct-07	113	4	75	4	27	3
28	28-Oct-07	109	2	68	3	31	5
29	29-Oct-07	127	2	86	7	25	7
30	30-Oct-07	125	3	89	13	18	2
Sum		3583	101	2133	279	944	126

6.2 ANALYSIS OF TOTAL FAULTS USING C-CHART

It was a challenging task for the author to analyse the service oriented process using any charts from different control charts. Every control chats were look into in details but only C control chart best fitted for the analysis. Now all data will be analysed using C-chart and find out the status of the system whether it is under control or not.

First, the analysis will be done for total faults. After that, for all the 5 categories, the process will be checked.

Table 6.2: Fault Analysis using C-chart- Total faults

SL	DATE	No. of total fault	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	124	119.43	152.2	0
2	2-Oct-07	123	119.43	152.2	0
3	3-Oct-07	144	119.43	152.2	0
4	4-Oct-07	68	119.43	152.2	0
5	5-Oct-07	71	119.43	152.2	0
6	6-Oct-07	59	119.43	152.2	0
7	7-Oct-07	218	119.43	152.2	0
8	8-Oct-07	108	119.43	152.2	0
9	9-Oct-07	42	119.43	152.2	0
10	10-Oct-07	130	119.43	152.2	0
11	11-Oct-07	128	119.43	152.2	0
12	12-Oct-07	123	119.43	152.2	0
13	13-Oct-07	136	119.43	152.2	0
14	14-Oct-07	78	119.43	152.2	0
15	15-Oct-07	147	119.43	152.2	0
16	16-Oct-07	145	119.43	152.2	0
17	17-Oct-07	122	119.43	152.2	0
18	18-Oct-07	136	119.43	152.2	0
19	19-Oct-07	117	119.43	152.2	0
20	20-Oct-07	134	119.43	152.2	0
21	21-Oct-07	74	119.43	152.2	0
22	22-Oct-07	132	119.43	152.2	0
23	23-Oct-07	150	119.43	152.2	0
24	24-Oct-07	122	119.43	152.2	0
25	25-Oct-07	131	119.43	152.2	0
26	26-Oct-07	148	119.43	152.2	0

27	27-Oct-07	113	119.43	152.2	0
28	28-Oct-07	109	119.43	152.2	0
29	29-Oct-07	127	119.43	152.2	0
30	30-Oct-07	125	119.43	152.2	0
Sum		3583			

Calculation of parameters of C-Chart for all faults of the system:

Calculation of all the parameters of C-Chart for all 5 types of faults has been shown. These have been computed as given below:

$C\ bar = CL = 3583/30 = 119.43$

$UCL = 119.43 + 3\sqrt{119.43} = 152.2$

$LCL = 119.43 - 3\sqrt{119.43} = 86.64$

In this case, target of the department is to reduce the no. of faults as much as possible. If there would be zero fault, then the system would be perfect. For this reason, in this case study, for all types of faults and analysis, LCL has always been considered as zero.

All the data has been plotted and the chart is like below:
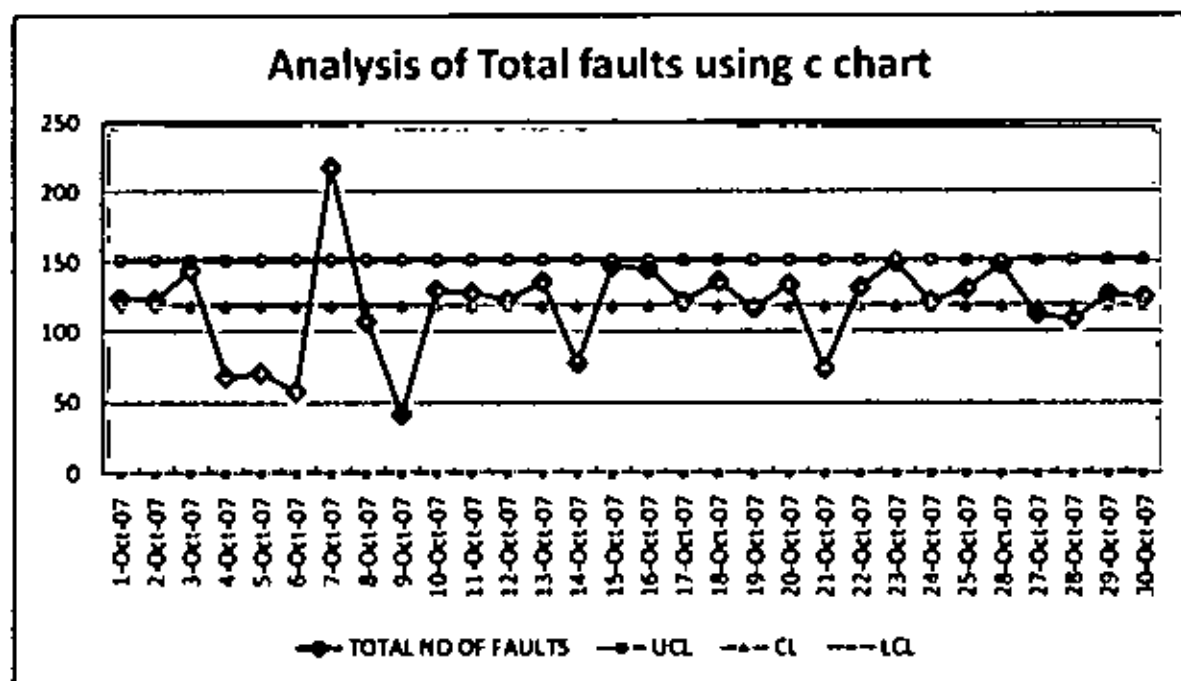
Figure 6.1: Analysis of total faults using C-chart

Comments: From figure 6.1, it is clear that the system is out of control. On 7th Oct, total no. of faults was over the UCL. If we see the corresponding table, we can see that on this particular day. total 218 no. of faults occurred which is abnormal compare to other day's faults.

If we exclude the faults of this day, C-chart parameters are calculated as

C bar=CL= 3365/29 = 0.075

UCL=0 075+3$\sqrt{0.075\ (1-0.075)/1510}$ = 0.099

LCL= 0

Calculation for the whole month excluding the abnormal high faults of 7th Oct is given in Table 6.3 in the next page.

6.3 ANALYSIS OF TOTAL FAULTS EXCLUDING 7TH OCT

Here analysis has been done for total faults but excluding all the faults of 7th Oct. This is to see whether the process was out of control only for this day's abnormal number of faults or there are other reasons also for taking the process out of control.

Table 6.3: Analysis of total fault using excluding abnormal high fault of 7th Oct

SL	DATE	Total Fault excluding 7th Oct	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	124	116.03	148.35	0
2	2-Oct-07	123	116.03	148.35	0
3	3-Oct-07	144	116.03	148.35	0
4	4-Oct-07	68	116.03	148.35	0
5	5-Oct-07	71	116.03	148.35	0
6	6-Oct-07	58	116.03	148.35	0
7	8-Oct-07	108	116.03	148.35	0
8	9-Oct-07	42	116.03	148.35	0
9	10-Oct-07	130	116.03	148.35	0
10	11-Oct-07	128	116.03	148.35	0
11	12-Oct-07	123	116.03	148.35	0
12	13-Oct-07	136	116.03	148.35	0
13	14-Oct-07	78	116.03	148.35	0
14	15-Oct-07	147	116.03	148.35	0
15	16-Oct-07	145	116.03	148.35	0
16	17-Oct-07	122	116.03	148.35	0
17	18-Oct-07	136	116.03	148.35	0
18	19-Oct-07	117	116.03	148.35	0
19	20-Oct-07	134	116.03	148.35	0
20	21-Oct-07	74	116.03	148.35	0
21	22-Oct-07	132	116.03	148.35	0
22	23-Oct-07	150	116.03	148.35	0
23	24-Oct-07	122	116.03	148.35	0
24	25-Oct-07	131	116.03	148.35	0
25	26-Oct-07	148	116.03	148.35	0
26	27-Oct-07	113	116.03	148.35	0
27	28-Oct-07	109	116.03	148.35	0
28	29-Oct-07	127	116.03	148.35	0
29	30-Oct-07	125	116.03	148.35	0
	Sum	3365			

If we plot the above result in the chart, we can see that the system is quite under control
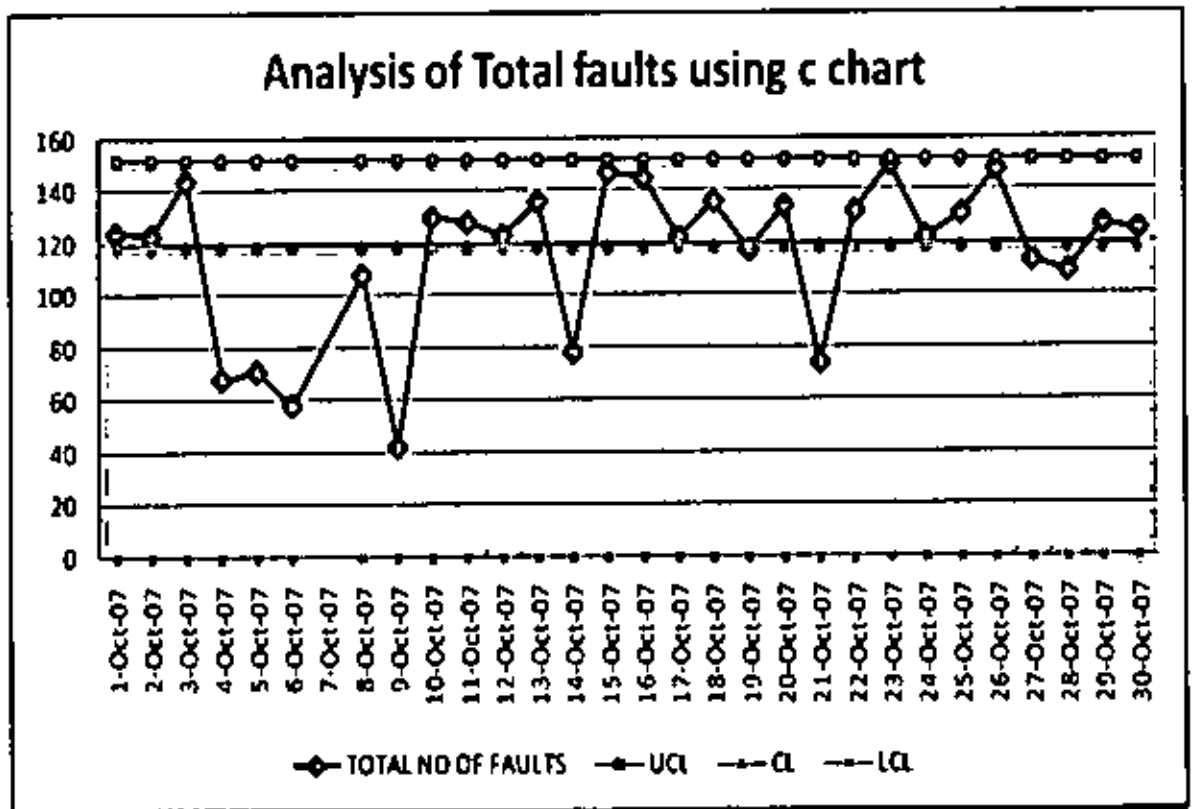
Figure 6.2: Analysis of total faults using C-chart excluding the high faults of 7th Oct

6.4 ANALYSIS OF BTS HW FAULTS USING C-CHART

In this chapter, analysis has been done to see the status of the process for the said period in respect to Base Transceiver Station (BTS) hard ware (HW) faults.

Table 6.4: Analysis of BTS HW faults using C-chart

SL	DATE	No. of BTS faults	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	4	3.37	8.87	0
2	2-Oct-07	2	3.37	8.87	0
3	3-Oct-07	6	3.37	8.87	0
4	4-Oct-07	6	3.37	8.87	0
5	5-Oct-07	6	3.37	8.87	0
6	6-Oct-07	6	3.37	8.87	0
7	7-Oct-07	5	3.37	8.87	0
8	8-Oct-07	3	3.37	8.87	0
9	9-Oct-07	2	3.37	8.87	0
10	10-Oct-07	6	3.37	8.87	0
11	11-Oct-07	2	3.37	8.87	0
12	12-Oct-07	3	3.37	8.87	0
13	13-Oct-07	4	3.37	8.87	0
14	14-Oct-07	1	3.37	8.87	0
15	15-Oct-07	1	3.37	8.87	0
16	16-Oct-07	5	3.37	8.87	0
17	17-Oct-07	1	3.37	8.87	0
18	18-Oct-07	3	3.37	8.87	0
19	19-Oct-07	1	3.37	8.87	0
20	20-Oct-07	3	3.37	8.87	0
21	21-Oct-07	3	3.37	8.87	0
22	22-Oct-07	6	3.37	8.87	0
23	23-Oct-07	7	3.37	8.87	0
24	24-Oct-07	2	3.37	8.87	0
25	25-Oct-07	1	3.37	8.87	0
26	26-Oct-07	1	3.37	8.87	0
27	27-Oct-07	4	3.37	8.87	0
28	28-Oct-07	2	3.37	8.87	0
29	29-Oct-07	2	3.37	8.87	0
30	30-Oct-07	3	3.37	8.87	0
Sum		101			

C bar=CL= 101/30 = 3.37

UCL=3.37+3√3.37= 8.87

LCL= 0

All the data has been plotted and the chart is like below:
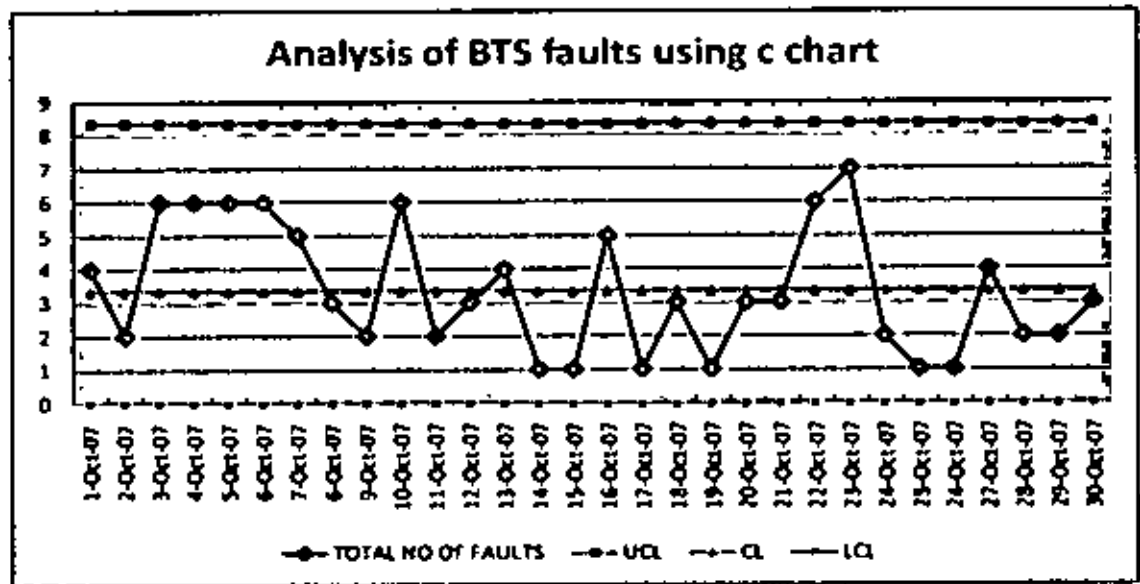
Figure 6.3: Analysis of BTS HW faults using C-chart

Comments: From the above graph, it is clear that the system is under total control. In no days under this sample period, no. of faults related to the BTS hardware problem went beyond UCL.

6.5 ANALYSIS OF EXTERNAL POWER FAULTS USING C-CHART

External power is the highest contributor among all the 5 major categories of faults. In this chapter, analysis has been done using C-chart to see the status of the process for this type of fault.

Table 6.5: Analysis of BTS HW faults using C-chart

SL	DATE	External Power fault	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	80	74.37	100.24	0
2	2-Oct-07	104	74.37	100.24	0
3	3-Oct-07	98	74.37	100.24	0
4	4-Oct-07	1	74.37	100.24	0
5	5-Oct-07	8	74.37	100.24	0
6	6-Oct-07	4	74.37	100.24	0
7	7-Oct-07	182	74.37	100.24	0
8	8-Oct-07	84	74.37	100.24	0
9	9-Oct-07	24	74.37	100.24	0
10	10-Oct-07	89	74.37	100.24	0
11	11-Oct-07	103	74.37	100.24	0
12	12-Oct-07	82	74.37	100.24	0
13	13-Oct-07	79	74.37	100.24	0
14	14-Oct-07	46	74.37	100.24	0
15	15-Oct-07	85	74.37	100.24	0
16	16-Oct-07	74	74.37	100.24	0
17	17-Oct-07	83	74.37	100.24	0
18	18-Oct-07	103	74.37	100.24	0
19	19-Oct-07	82	74.37	100.24	0
20	20-Oct-07	96	74.37	100.24	0
21	21-Oct-07	21	74.37	100.24	0
22	22-Oct-07	74	74.37	100.24	0
23	23-Oct-07	80	74.37	100.24	0
24	24-Oct-07	79	74.37	100.24	0
25	25-Oct-07	72	74.37	100.24	0
26	26-Oct-07	81	74.37	100.24	0
27	27-Oct-07	75	74.37	100.24	0
28	28-Oct-07	68	74.37	100.24	0
29	29-Oct-07	86	74.37	100.24	0
30	30-Oct-07	89	74.37	100.24	0
Sum		2231			

Calculation of parameters of C-Chart for external power faults:

Calculation of all the parameters of C-Chart for external power faults has been shown in the table above. These have been computed as given below:

C bar=CL= 2231/30 = 74.37
UCL=74.37+3√74.37= 100.24
LCL= 0

All the data has been plotted and the chart is like below:
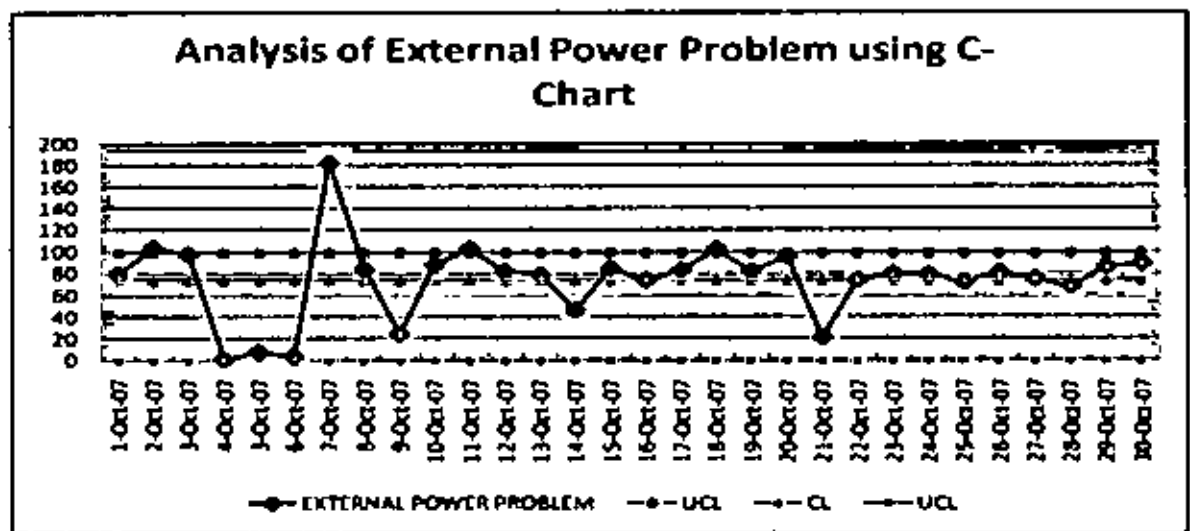
Figure 6.4: Analysis of external power faults using C-chart

Comment: From the above chart, we can see that the system went out of the UCL, hugely on 7th Oct. Total number of faults on this particular day was 182 which is really abnormal compare to other days. It's nearest no. of faults occurred on 2nd Oct which was 104.

Investigating this day's power situation of Dhaka region, it was found that huge load shading occurred due to low production of the power generation authority (PDB) on that day. That's why, for long time, these 1510 sites had to depend on auto generator and battery. We have some portable generators to provide backup power during this type of situation. But the number of auto generator as well as the manpower is limited. Engineers put priority on the high priority sites like the critical transmission points, coverage sites etc.

During the analysis for all faults, we found that system went out of control on the same day i.e, on 7th Oct. Though we will do the analysis for other remaining faults, at this moment,

we can assume that the abnormal number of external power faults of this day is responsible for taking the system out of control.

6.6 ANALYSIS OF INTERNAL POWER FAULTS USING C-CHART

In this chapter, C-chart analysis has been done for the internal power faults. These are the faults which occur inside the rectifier or the air conditioners.

Table 6.6: List of internal power faults with C-Chart parameters

SL	DATE	No. of internal power fault	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	14	9.30	18.45	0
2	2-Oct-07	3	9.30	18.45	0
3	3-Oct-07	13	9.30	18.45	0
4	4-Oct-07	15	9.30	18.45	0
5	5-Oct-07	11	9.30	18.45	0
6	6-Oct-07	12	9.30	18.45	0
7	7-Oct-07	15	9.30	18.45	0
8	8-Oct-07	3	9.30	18.45	0
9	9-Oct-07	10	9.30	18.45	0
10	10-Oct-07	7	9.30	18.45	0
11	11-Oct-07	4	9.30	18.45	0
12	12-Oct-07	10	9.30	18.45	0
13	13-Oct-07	5	9.30	18.45	0
14	14-Oct-07	7	9.30	18.45	0
15	15-Oct-07	7	9.30	18.45	0
16	16-Oct-07	12	9.30	18.45	0
17	17-Oct-07	15	9.30	18.45	0
18	18-Oct-07	10	9.30	18.45	0
19	19-Oct-07	8	9.30	18.45	0
20	20-Oct-07	12	9.30	18.45	0
21	21-Oct-07	2	9.30	18.45	0
22	22-Oct-07	7	9.30	18.45	0
23	23-Oct-07	14	9.30	18.45	0
24	24-Oct-07	10	9.30	18.45	0
25	25-Oct-07	11	9.30	18.45	0
26	26-Oct-07	15	9.30	18.45	0
27	27-Oct-07	4	9.30	18.45	0
28	28-Oct-07	3	9.30	18.45	0
29	29-Oct-07	7	9.30	18.45	0
30	30-Oct-07	13	9.30	18.45	0
Sum		279			

Calculation of parameters of C-Chart for internal power faults:

Calculation of all the parameters of C-Chart for internal power faults has been shown in the table above. These have been computed as given below:

C bar=CL= 279/30 = 9.30
UCL=9.30+3√9.30 = 18.45
LCL= 0

All the data has been plotted and the chart is like below:
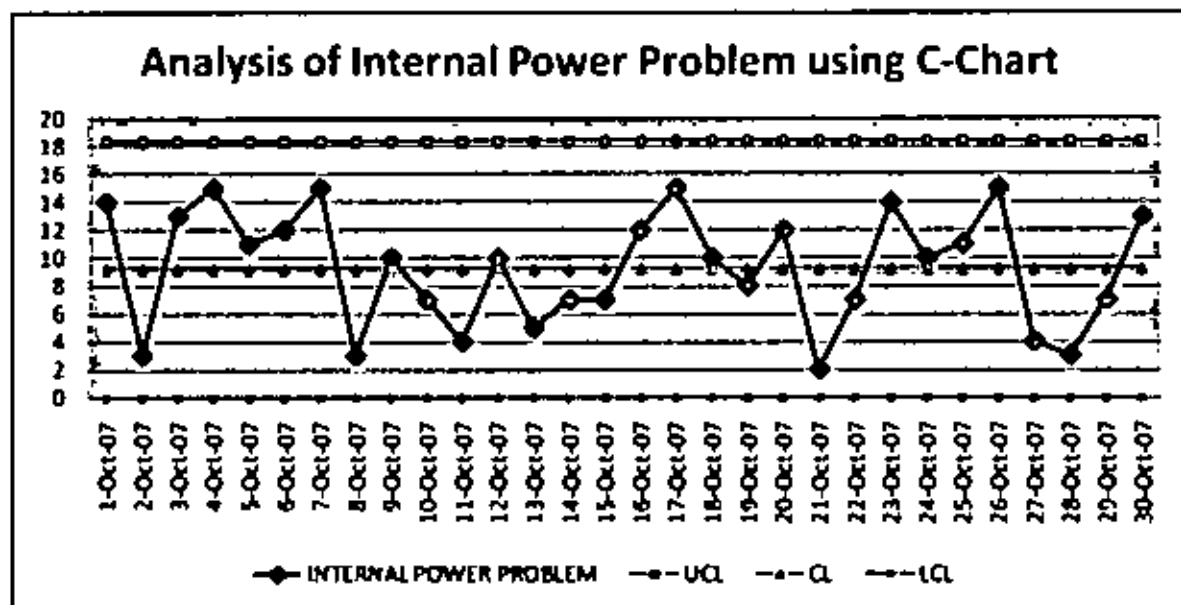
Figure 6.5: Analysis of internal power faults using C-chart

Comments: From figure 6.5, it is clear that the system is under total control. In no days under this sample period, no. of faults related to the internal power problem went beyond UCL.

6.7 ANALYSIS OF LOW CAPACITY MW FAULTS USING C-CHART

Low capacity microwave is another major category of fault contributor in the GSM network. In this chapter, analysis has been done to check the status of the process for this type of fault.

Table: 6.7: List of Low capacity MW faults with C-Chart parameters

SL	DATE	No. of LCMW fault	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	25	31.47	48.30	0
2	2-Oct-07	36	31.47	48.30	0
3	3-Oct-07	39	31.47	48.30	0
4	4-Oct-07	45	31.47	48.30	0
5	5-Oct-07	40	31.47	48.30	0
6	6-Oct-07	35	31.47	48.30	0
7	7-Oct-07	34	31.47	48.30	0
8	8-Oct-07	14	31.47	48.30	0
9	9-Oct-07	7	31.47	48.30	0
10	10-Oct-07	26	31.47	48.30	0
11	11-Oct-07	37	31.47	48.30	0
12	12-Oct-07	24	31.47	48.30	0
13	13-Oct-07	42	31.47	48.30	0
14	14-Oct-07	23	31.47	48.30	0
15	15-Oct-07	45	31.47	48.30	0
16	16-Oct-07	47	31.47	48.30	0
17	17-Oct-07	19	31.47	48.30	0
18	18-Oct-07	46	31.47	48.30	0
19	19-Oct-07	19	31.47	48.30	0
20	20-Oct-07	15	31.47	48.30	0
21	21-Oct-07	47	31.47	48.30	0
22	22-Oct-07	43	31.47	48.30	0
23	23-Oct-07	46	31.47	48.30	0
24	24-Oct-07	28	31.47	48.30	0
25	25-Oct-07	42	31.47	48.30	0
26	26-Oct-07	45	31.47	48.30	0
27	27-Oct-07	27	31.47	48.30	0
28	28-Oct-07	32	31.47	48.30	0
29	29-Oct-07	25	31.47	48.30	0
30	30-Oct-07	18	31.47	48.30	0
Sum		944			

Calculation of parameters of C-Chart for Low capacity MW faults:

Calculation of all the parameters of C-Chart for Low capacity MW_faults has been shown in the table above. These have been computed as given below:

C bar=CL= 944/ 30 = 31.47

UCL=31.47 +3 $\sqrt{31.47}$ = 48.30

LCL= 0

All the data has been plotted and the chart is like below:

Figure 6.6: Analysis of Low Capacity MW faults using C-chart

Comments: From the above table, it is clear that the system is under total control. In no days under this sample period, no. of faults related to the low capacity MW problem went beyond UCL.

6.8 ANALYSIS OF HIGH CAPACITY MW FAULTS USING C-CHART

Impact of high capacity MW faults is huge. In this chapter, C-chart analysis has been done for this type of fault. Using the equation, here CL= 4.20, UCL=10.35 and LCL=0.

Table 6.8: List of High capacity MW faults with C-chart parameters

Sl.	DATE	No. of HCMW fault	C bar = CL	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	1	4.20	10.35	0
2	2-Oct-07	2	4.20	10.35	0
3	3-Oct-07	4	4.20	10.35	0
4	4-Oct-07	1	4.20	10.35	0
5	5-Oct-07	6	4.20	10.35	0
6	6-Oct-07	1	4.20	10.35	0
7	7-Oct-07	2	4.20	10.35	0
8	8-Oct-07	4	4.20	10.35	0
9	9-Oct-07	4	4.20	10.35	0
10	10-Oct-07	3	4.20	10.35	0
11	11-Oct-07	7	4.20	10.35	0
12	12-Oct-07	4	4.20	10.35	0
13	13-Oct-07	6	4.20	10.35	0
14	14-Oct-07	1	4.20	10.35	0
15	15-Oct-07	9	4.20	10.35	0
16	16-Oct-07	7	4.20	10.35	0
17	17-Oct-07	4	4.20	10.35	0
18	18-Oct-07	7	4.20	10.35	0
19	19-Oct-07	7	4.20	10.35	0
20	20-Oct-07	5	4.20	10.35	0
21	21-Oct-07	6	4.20	10.35	0
22	22-Oct-07	4	4.20	10.35	0
23	23-Oct-07	3	4.20	10.35	0
24	24-Oct-07	3	4.20	10.35	0
25	25-Oct-07	5	4.20	10.35	0
26	26-Oct-07	3	4.20	10.35	0
27	27-Oct-07	3	4.20	10.35	0
28	28-Oct-07	5	4.20	10.35	0
29	29-Oct-07	7	4.20	10.35	0
30	30-Oct-07	2	4.20	10.35	0
Sum		126			

Calculation of parameters of C-Chart for high capacity MW faults:

Calculation of all the parameters of C-Chart for high capacity MW_faults has been shown in the table above. These have been computed as given below:

C bar=CL= 126/ 30 = 4.20
UCL=4.20+3√4.20 = 10.35
LCL= 0

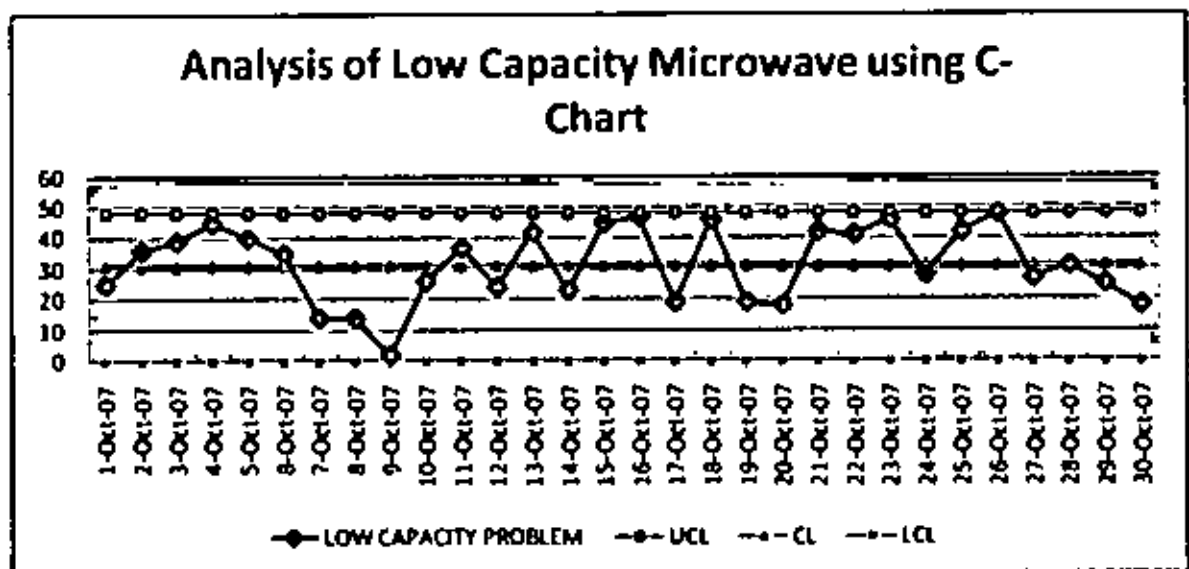All the data has been plotted and the chart is like below:
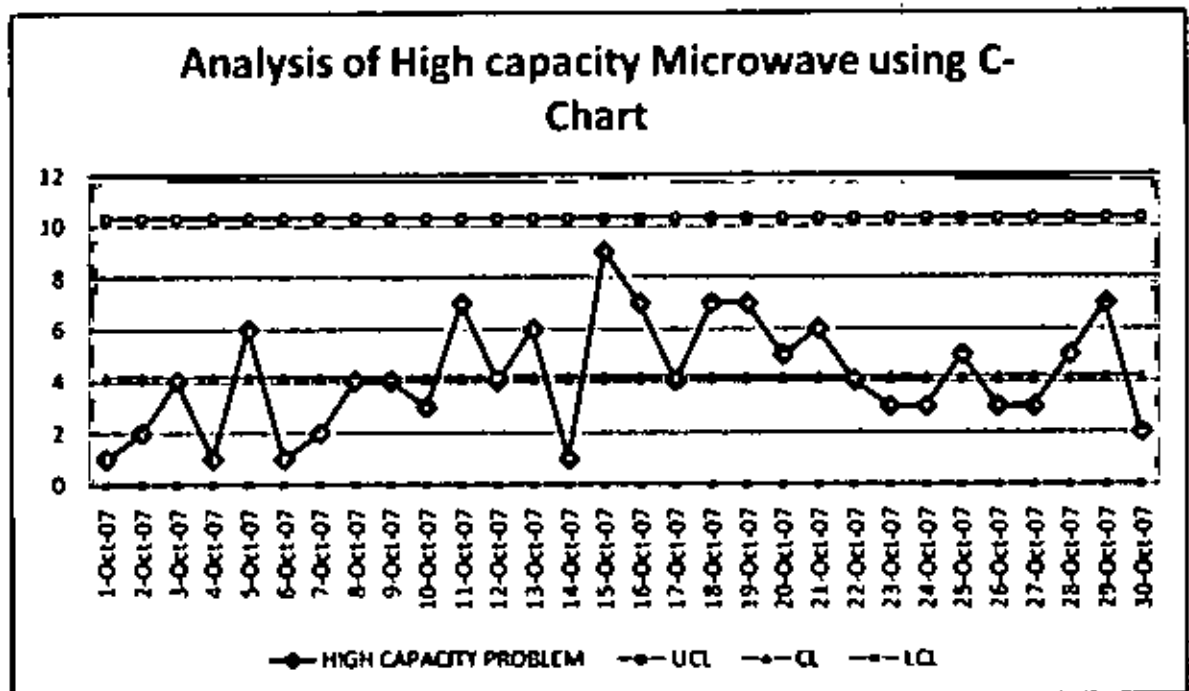
Figure 6.7: Analysis of High Capacity MW faults using C-chart

Comments: From the above table, it is clear that the system is under total control. In no days under this sample period, no. of faults related to the high capacity MW problem went beyond UCL.

CHAPTER 7

PROCESS ANALYSIS FOR MTTR OF VARIOUS TYPES OF FAULTS

7.1 DEFINITION OF TWO OPERATIONAL KPI: SLA AND MTTR

Service Level Agreement (SLA): When a fault occurs in the network, it needs to be cleared within a specific period of time by the concerned department. This amount of time has been set considering the impact of the fault, practical requirement of time, previous history etc. An agreement is prepared with the stakeholders for all types of faults stating how much time is required to rectify the specific faults. This time is mentioned as the SLA. For example, if a fault for low capacity microwave occurs in the network, NM will notify the ROM engineers and ROM engineers has to rectify the fault within 6 hours of notification. If ROM engineer fail to rectify it within this timeline, SLA for handling this fault will be treated as failed otherwise achieved. SLA report on different frequencies is published to see the organizational performances.

Mean Time To Restore (MTTR): From the definition of SLA, we can see that a fault has to cleared within a timeline. Actual time required to clear a fault is known as the Mean Time To Restore (MTTR). Normally in Management, this KPI is known as Mean time to repair instead of restore. But in telecommunication, network or service restoration is the same as repair for the factory process. Report on MTTR is also published on different frequencies to measure the organizational performances.

- Time required to restore a fault
- MTTR target time varies for different faults
- Unit of MTTR is hour
- Value of MTTR is measured by the duration of fault (clear time-event time) divided by no. of faults

7.2 ANALYSIS OF BTS HW M.T.T.R USING C-CHART

Data for MTTR of BTS HW faults are shown Table 7.1. Here total restoration time has been calculated by multiplying the no. of faults of each day with the MTTR of that day for all faults. Total restoration time is the cumulative restoration time for the whole period i.e, from 1st to 30th October. C bar has been calculated by total restoration time divided by the total no. of faults for the sample period of Oct'07.

Hence C bar = CL = 92.94/101 = 0.92 hours

Then UCL comes from the equation UCL = C bar + $3\sqrt{C}$ bar
$$>> UCL = 3.80 \text{ hours}$$

LCL has been considered as zero since the target is to clear any fault within the shortest possible time which means zero time.

Table 7.1: List of MTTR for BTS HW faults [11]

SL.	DATE	No. of BTS faults	MTTR of BTS faults (hr)	Total Restoration time (hour)	C bar = CL = total restoration time/No.of fault	UCL	LCL
1	1-Oct-07	4	0.33	1.32	0.92	3.8	0
2	2-Oct-07	2	0.47	0.94	0.92	3.8	0
3	3-Oct-07	6	1.55	9.30	0.92	3.8	0
4	4-Oct-07	6	0.35	2.10	0.92	3.8	0
5	5-Oct-07	6	1.55	9.30	0.92	3.8	0
6	6-Oct-07	6	0.24	1.44	0.92	3.8	0
7	7-Oct-07	5	0.33	1.67	0.92	3.8	0
8	8-Oct-07	3	0.88	2.63	0.92	3.8	0
9	9-Oct-07	2	0.81	1.62	0.92	3.8	0
10	10-Oct-07	6	0.36	2.14	0.92	3.8	0
11	11-Oct-07	2	0.28	0.56	0.92	3.8	0
12	12-Oct-07	3	1.48	4.44	0.92	3.8	0
13	13-Oct-07	4	0.57	2.26	0.92	3.8	0
14	14-Oct-07	1	0.52	0.52	0.92	3.8	0
15	15-Oct-07	1	0.65	0.65	0.92	3.8	0
16	16-Oct-07	5	1.06	5.31	0.92	3.8	0
17	17-Oct-07	1	0.17	0.17	0.92	3.8	0
18	18-Oct-07	3	0.46	1.38	0.92	3.8	0
19	19-Oct-07	1	1.63	1.63	0.92	3.8	0
20	20-Oct-07	3	1.11	3.32	0.92	3.8	0
21	21-Oct-07	3	0.65	1.96	0.92	3.8	0
22	22-Oct-07	6	1.09	6.55	0.92	3.8	0
23	23-Oct-07	7	1.14	7.96	0.92	3.8	0
24	24-Oct-07	2	0.34	0.68	0.92	3.8	0
25	25-Oct-07	1	0.02	0.02	0.92	3.8	0
26	26-Oct-07	1	0.28	0.28	0.92	3.8	0
27	27-Oct-07	4	3.06	12.24	0.92	3.8	0
28	28-Oct-07	2	3.40	6.80	0.92	3.8	0
29	29-Oct-07	2	0.90	1.80	0.92	3.8	0
30	30-Oct-07	3	0.65	1.95	0.92	3.8	0
Sum		101		92.94			

Figure 7.1: Graphical presentation C-chart for MTTR of BTS HW faults

From the graph above, it seems that MTTR value of all days of Oct'07 for BTS HW faults fall within the UCL and LCL. It also varies in both part of the control line. This means that the system is well under control for this case.

7.3 ANALYSIS OF MTTR FOR EXTERNAL POWER RELATED FAULTS USING C-CHART:

Data for MTTR of external power faults are shown in Table 7.2. Here total restoration time has been calculated by multiplying the no. of faults of each day with the MTTR of that day for all faults. C bar has been calculated by total restoration time by the total no. of faults for the sample period of Oct'07.

Then UCL comes from the equation UCL = C bar + 3√C bar

>> UCL= 3.94 hours

LCL has been considered as zero since the target is to clear any fault within the shortest possible time which means zero time.

Table 7.2: List of MTTR for external power faults [11]

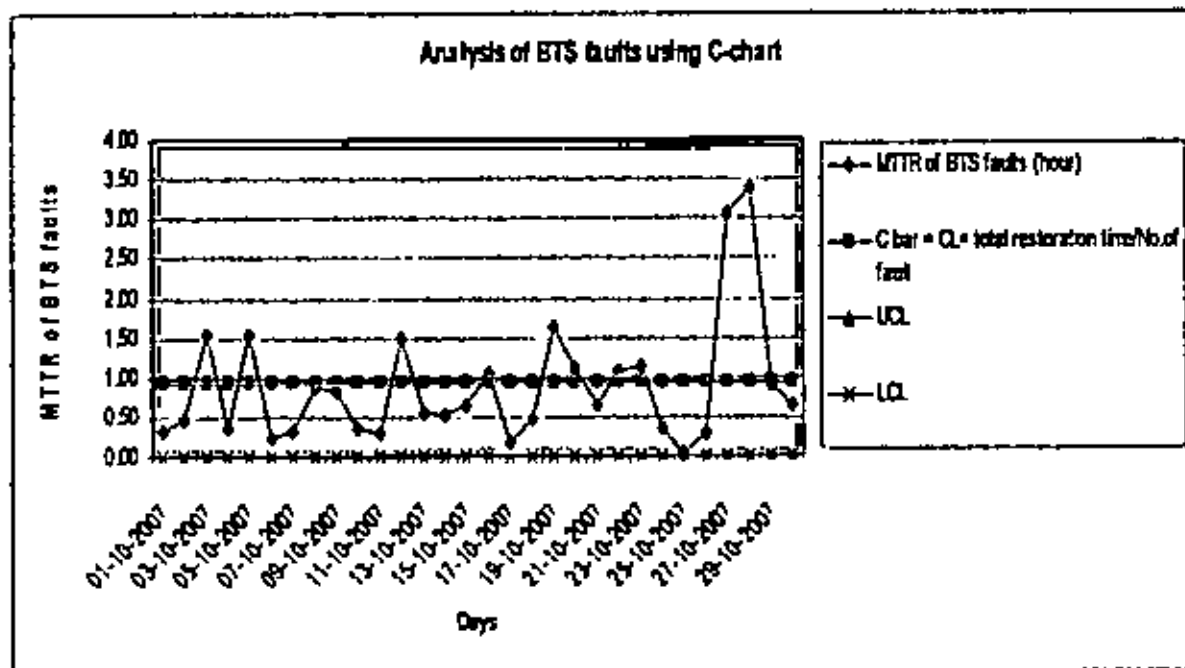| SL.	DATE	External Power fault	MTTR of EXP faults (hr)	Total restoration time (hr)	C bar = CL= total restoration time/Total no.of fault	UCL	LCL
1	1-Oct-07	80	1.26	100.80	0.97	3.94	0
2	2-Oct-07	104	1.40	145.60	0.97	3.94	0
3	3-Oct-07	98	1.32	129.36	0.97	3.94	0
4	4-Oct-07	1	0.24	0.24	0.97	3.94	0
5	5-Oct-07	8	0.24	1.92	0.97	3.94	0
6	6-Oct-07	4	1.33	5.32	0.97	3.94	0
7	7-Oct-07	182	0.91	165.46	0.97	3.94	0
8	8-Oct-07	84	0.60	50.61	0.97	3.94	0
9	9-Oct-07	24	0.70	16.65	0.97	3.94	0
10	10-Oct-07	88	0.42	36.63	0.97	3.94	0
11	11-Oct-07	103	1.73	178.04	0.97	3.94	0
12	12-Oct-07	82	0.74	60.54	0.97	3.94	0
13	13-Oct-07	79	0.57	45.07	0.97	3.94	0
14	14-Oct-07	46	0.85	38.94	0.97	3.94	0
15	15-Oct-07	85	1.00	84.78	0.97	3.94	0
16	16-Oct-07	74	0.60	44.25	0.97	3.94	0
17	17-Oct-07	83	0.48	40.04	0.97	3.94	0
18	18-Oct-07	103	0.57	58.86	0.97	3.94	0
19	19-Oct-07	82	1.17	95.77	0.97	3.94	0
20	20-Oct-07	96	1.11	106.94	0.97	3.94	0
21	21-Oct-07	21	1.59	33.35	0.97	3.94	0
22	22-Oct-07	74	1.67	123.37	0.97	3.94	0
23	23-Oct-07	80	0.04	3.20	0.97	3.94	0
24	24-Oct-07	79	0.72	57.04	0.97	3.94	0
25	25-Oct-07	72	1.12	80.64	0.97	3.94	0
26	26-Oct-07	81	0.97	78.90	0.97	3.94	0
27	27-Oct-07	75	1.02	76.82	0.97	3.94	0
28	28-Oct-07	65	1.21	82.30	0.97	3.94	0
29	29-Oct-07	86	1.13	97.15	0.97	3.94	0
30	30-Oct-07	89	1.52	135.20	0.97	3.94	0
Sum		2231		2173.83			
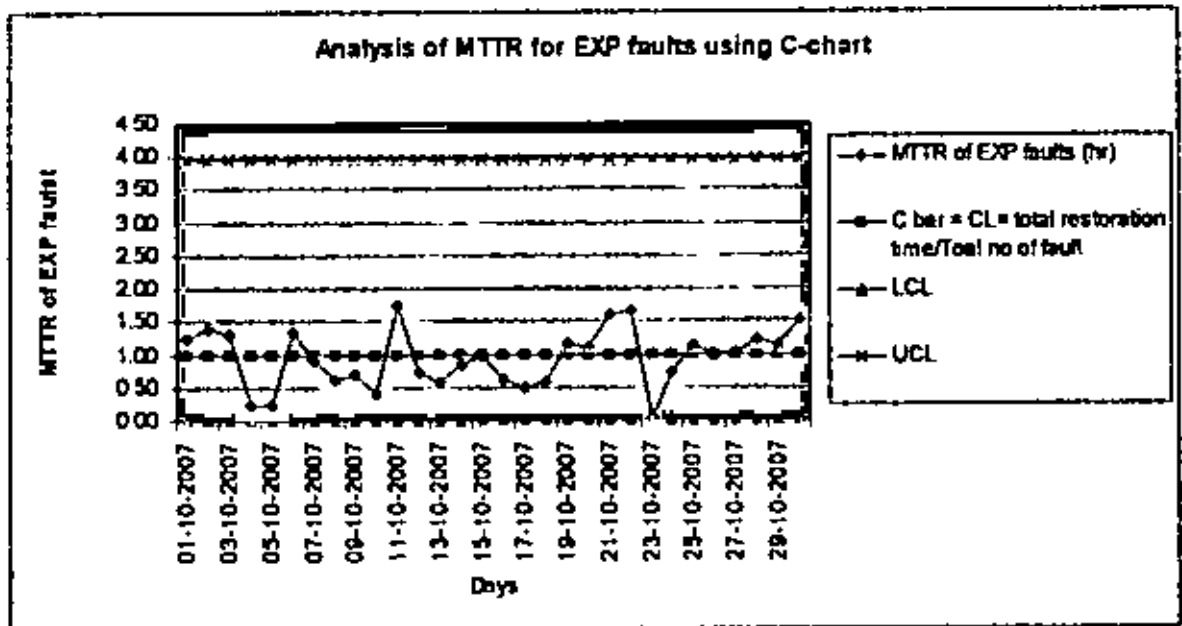
Figure 7.2: Graphical presentation of C-chart for MTTR of external power faults

From the graph above, it seems that MTTR value of all days of Oct'07 for external power faults fall within the UCL and LCL. It also varies in both part of the control line. This means that the system is well under control for this case.

7.4 ANALYSIS OF MTTR FOR INTERNAL POWER RELATED FAULTS USING C-CHART

Data for MTTR of internal power faults are shown in Table 7.3. Here total restoration time has been calculated by multiplying the no. of faults of each day with the MTTR of that day for all faults. C bar has been calculated by total restoration time by the total no. of faults for the sample period of Oct'07.

Then UCL comes from the equation UCL = C bar + 3√C bar

>> UCL= 3.14 hours

LCL has been considered as zero since the target is to clear any fault within the shortest possible time which means zero time.

- 76 -

Table 7.3: List of MTTR for internal power faults [11]

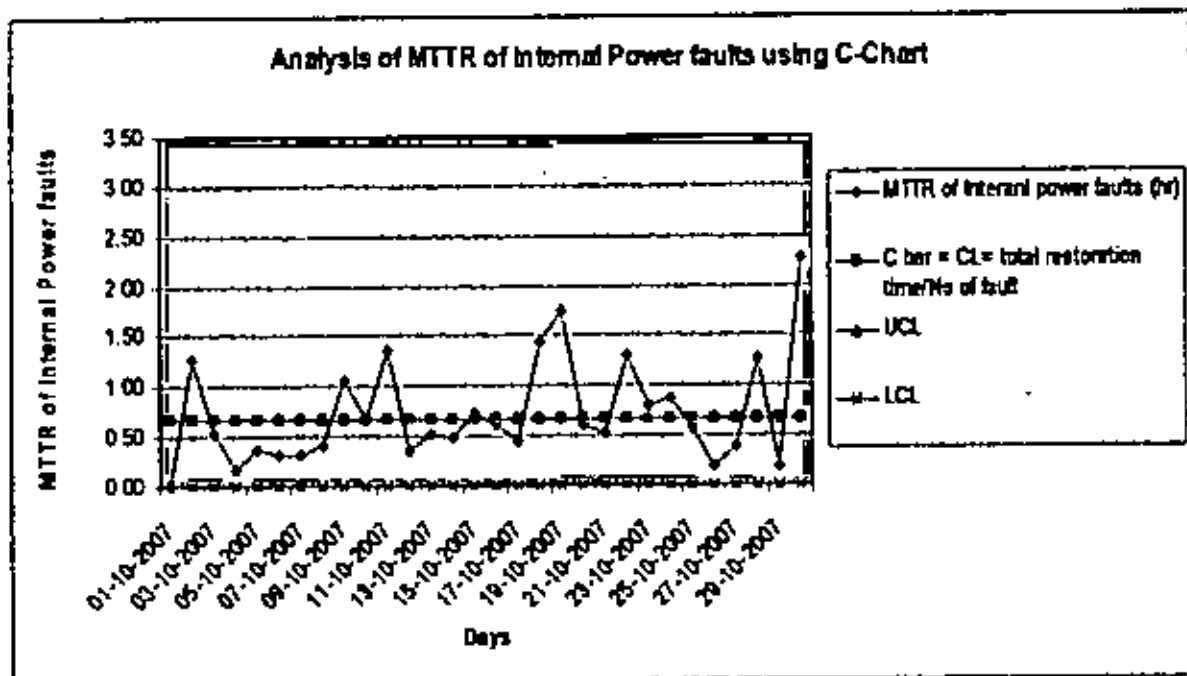| SL	DATE	No. of internal power fault	MTTR of Internal power faults (hr)	Total restoration time (hr)	C bar = CL = total restoration time/No.of fault	UCL	LCL
1	1-Oct-07	14	0.01	0.14	0.67	3.14	0
2	2-Oct-07	3	1.27	3.81	0.67	3.14	0
3	3-Oct-07	13	0.54	7.02	0.67	3.14	0
4	4-Oct-07	15	0.16	2.40	0.67	3.14	0
5	5-Oct-07	11	0.38	4.18	0.67	3.14	0
6	6-Oct-07	12	0.31	3.72	0.67	3.14	0
7	7-Oct-07	15	0.32	4.85	0.67	3.14	0
8	8-Oct-07	3	0.41	1.22	0.67	3.14	0
9	9-Oct-07	10	1.07	10.67	0.67	3.14	0
10	10-Oct-07	7	0.67	4.69	0.67	3.14	0
11	11-Oct-07	4	1.37	5.46	0.67	3.14	0
12	12-Oct-07	10	0.35	3.50	0.67	3.14	0
13	13-Oct-07	5	0.53	2.64	0.67	3.14	0
14	14-Oct-07	7	0.48	3.38	0.67	3.14	0
15	15-Oct-07	7	0.72	5.02	0.67	3.14	0
16	16-Oct-07	12	0.62	7.39	0.67	3.14	0
17	17-Oct-07	15	0.45	6.75	0.67	3.14	0
18	18-Oct-07	10	1.44	14.38	0.67	3.14	0
19	19-Oct-07	8	1.75	13.96	0.67	3.14	0
20	20-Oct-07	12	0.61	7.31	0.67	3.14	0
21	21-Oct-07	2	0.52	1.04	0.67	3.14	0
22	22-Oct-07	7	1.31	9.14	0.67	3.14	0
23	23-Oct-07	14	0.81	11.28	0.67	3.14	0
24	24-Oct-07	10	0.87	8.68	0.67	3.14	0
25	25-Oct-07	11	0.58	6.42	0.67	3.14	0
26	26-Oct-07	15	0.19	2.81	0.67	3.14	0
27	27-Oct-07	4	0.40	1.60	0.67	3.14	0
28	28-Oct-07	3	1.27	3.81	0.67	3.14	0
29	29-Oct-07	7	0.18	1.26	0.67	3.14	0
30	30-Oct-07	13	2.28	29.64	0.67	3.14	0
Sum		279		188.17			

Figure 7.3: Graphical presentation C-chart for MTTR of internal power faults

From the graph above, it seems that MTTR value of all days of Oct'07 for internal power faults fall within the UCL and LCL. It also varies in both part of the control line. This means that the system is well under control for this case.

7.5 ANALYSIS OF MTTR FOR LOW CAPACITY MW RELATED FAULTS USING C-CHART

Data for MTTR of low capacity MW faults are shown in Table 7.4. Here total restoration time has been calculated by multiplying the no. of faults of each day with the MTTR of that day for all faults. C bar has been calculated by total restoration time by the total no. of faults for the sample period of Oct'07.

Then UCL comes from the equation UCL = C bar + 3√C bar

>> UCL= 3.14 hours

LCL has been considered as zero since the target is to clear any fault within the shortest possible time which means zero time.

Table 7.4: List of MTTR for low capacity MW faults with the C chart parameters [11]

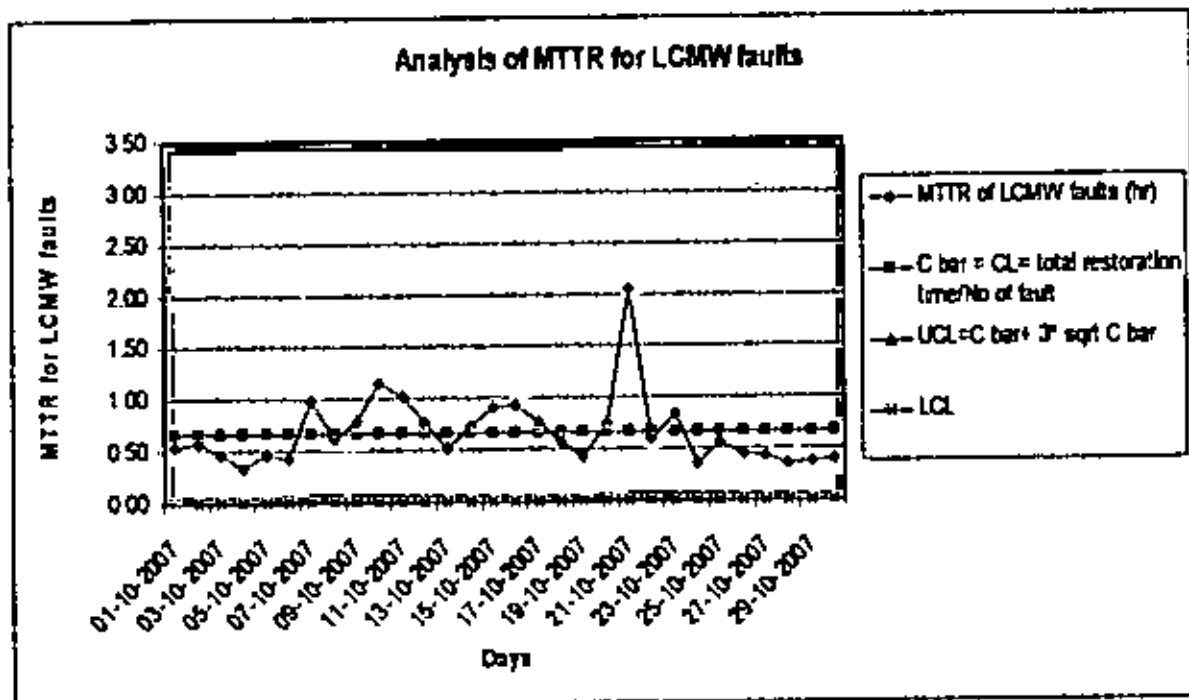| SI.	DATE	No. of LCMW fault	MTTR of LCMW faults (hr)	Total restoration time (hr)	C bar = CL= total restoration time/No.of fault	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	25	0.54	13.50	0.68	3.14	0
2	2-Oct-07	36	0.58	20.88	0.68	3.14	0
3	3-Oct-07	39	0.46	17.94	0.68	3.14	0
4	4-Oct-07	45	0.34	15.30	0.68	3.14	0
5	5-Oct-07	40	0.47	18.80	0.68	3.14	0
6	6-Oct-07	35	0.43	15.05	0.68	3.14	0
7	7-Oct-07	14	0.99	13.83	0.68	3.14	0
8	8-Oct-07	14	0.61	8.53	0.68	3.14	0
9	9-Oct-07	2	0.79	1.57	0.68	3.14	0
10	10-Oct-07	26	1.15	29.93	0.68	3.14	0
11	11-Oct-07	37	1.02	37.75	0.68	3.14	0
12	12-Oct-07	24	0.76	18.33	0.68	3.14	0
13	13-Oct-07	42	0.53	22.22	0.68	3.14	0
14	14-Oct-07	23	0.72	16.67	0.68	3.14	0
15	15-Oct-07	45	0.91	41.11	0.68	3.14	0
16	16-Oct-07	47	0.92	43.31	0.68	3.14	0
17	17-Oct-07	19	0.76	14.47	0.68	3.14	0
18	18-Oct-07	46	0.58	26.58	0.68	3.14	0
19	19-Oct-07	19	0.43	8.19	0.68	3.14	0
20	20-Oct-07	18	0.75	13.47	0.68	3.14	0
21	21-Oct-07	42	2.04	85.66	0.68	3.14	0
22	22-Oct-07	41	0.59	24.20	0.68	3.14	0
23	23-Oct-07	46	0.83	38.24	0.68	3.14	0
24	24-Oct-07	28	0.35	9.72	0.68	3.14	0
25	25-Oct-07	42	0.56	23.70	0.68	3.14	0
26	26-Oct-07	48	0.44	21.03	0.68	3.14	0
27	27-Oct-07	27	0.42	11.40	0.68	3.14	0
28	28-Oct-07	31	0.35	10.85	0.68	3.14	0
29	29-Oct-07	25	0.37	9.15	0.68	3.14	0
30	30-Oct-07	18	0.40	7.20	0.68	3.14	0
Sum		944		638.59			

Analysis of MTTR for LCMW faults

Figure 7.4: Graphical presentation C-chart for MTTR of low capacity MW faults

From the graph above, it seems that MTTR value of all days of Oct'07 for internal power faults fall within the UCL and LCL. It also varies in both part of the control line. This means that the system is well under control for this case.

7.6 ANALYSIS OF MTTR FOR HIGH CAPACITY MW RELATED FAULTS USING C-CHART

Data for MTTR of low capacity MW faults are shown in Table 7.5. Here total restoration time has been calculated by multiplying the no of faults of each day with the MTTR of that day for all faults. C bar has been calculated by total restoration time by the total no. of faults for the sample period of Oct'07.

Then UCL comes from the equation UCL = C bar + 3√C bar

>> UCL= 3.14 hours

LCL has been considered as zero since the target is to clear any fault within the shortest possible time which means zero time.

Table 7.5: List of MTTR for low capacity MW faults with the C chart parameters [11]

| SL	DATE	No. of HCMW fault	MTTR of HCMW faults (hr)	Total restoration time (hr)	C bar = CL= total restoration time/No.of fault	UCL=C bar+ 3* sqrt C bar	LCL
1	1-Oct-07	1	0.21	0.21	0.54	2.73	0
2	2-Oct-07	2	0.21	0.42	0.54	2.73	0
3	3-Oct-07	4	0.23	0.92	0.54	2.73	0
4	4-Oct-07	1	0.20	0.20	0.54	2.73	0
5	5-Oct-07	6	0.30	1.80	0.54	2.73	0
6	6-Oct-07	1	1.08	1.08	0.54	2.73	0
7	7-Oct-07	2	0.53	1.07	0.54	2.73	0
8	8-Oct-07	4	0.84	3.37	0.54	2.73	0
9	9-Oct-07	4	1.15	4.61	0.54	2.73	0
10	10-Oct-07	3	0.51	1.53	0.54	2.73	0
11	11-Oct-07	7	0.39	2.70	0.54	2.73	0
12	12-Oct-07	4	0.59	2.37	0.54	2.73	0
13	13-Oct-07	6	0.35	2.12	0.54	2.73	0
14	14-Oct-07	1	0.78	0.78	0.54	2.73	0
15	15-Oct-07	9	0.54	4.86	0.54	2.73	0
16	16-Oct-07	7	0.58	4.06	0.54	2.73	0
17	17-Oct-07	4	0.73	2.91	0.54	2.73	0
18	18-Oct-07	7	0.35	2.44	0.54	2.73	0
19	19-Oct-07	7	0.35	2.48	0.54	2.73	0
20	20-Oct-07	5	0.58	2.92	0.54	2.73	0
21	21-Oct-07	6	0.34	2.05	0.54	2.73	0
22	22-Oct-07	4	0.43	1.73	0.54	2.73	0
23	23-Oct-07	3	0.32	0.95	0.54	2.73	0
24	24-Oct-07	3	0.36	1.07	0.54	2.73	0
25	25-Oct-07	5	0.55	2.76	0.54	2.73	0
26	26-Oct-07	3	0.54	1.61	0.54	2.73	0
27	27-Oct-07	3	0.37	1.11	0.54	2.73	0
28	28-Oct-07	5	1.06	5.31	0.54	2.73	0
29	29-Oct-07	7	1.05	7.35	0.54	2.73	0
30	30-Oct-07	2	0.38	0.76	0.54	2.73	0
Sum		126		67.54			
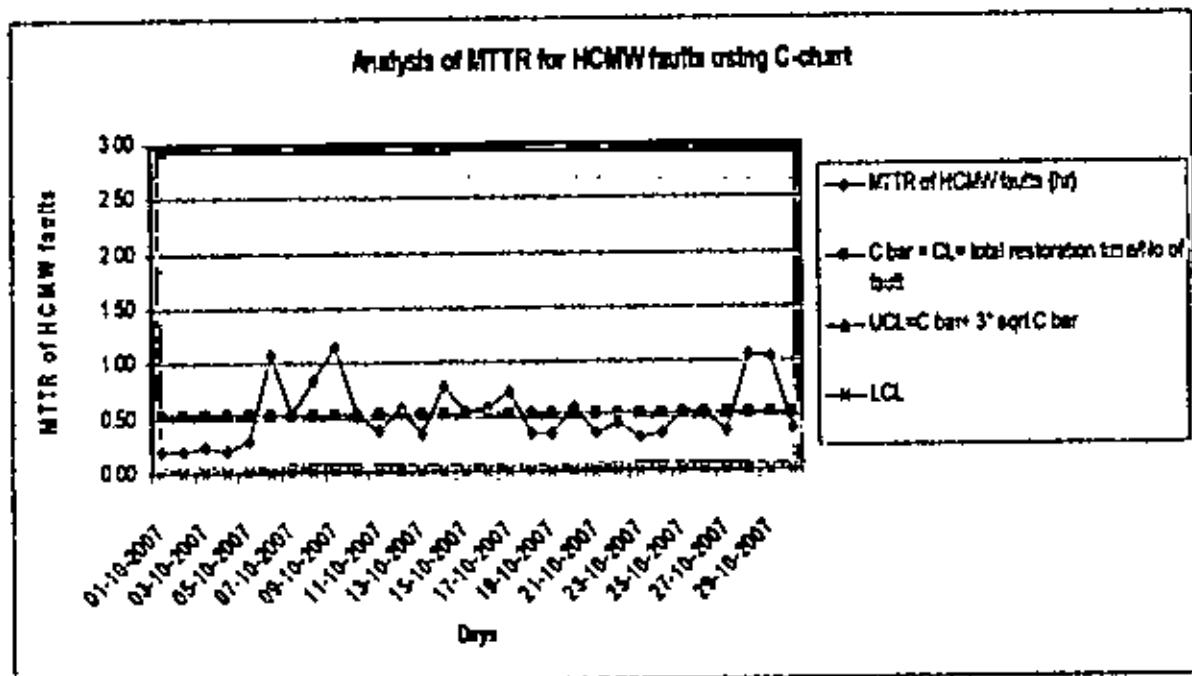
Figure 7.5: Graphical presentation C-chart for MTTR of high capacity MW faults

From the graph above, it seems that MTTR value of all days of Oct'07 for internal power faults fall within the UCL and LCL. It also varies in both part of the control line. This means that the system is well under control for this case.

CHAPTER 8

ANALYSIS OF PARETO CHART & CAUSE EFFECT DIAGRAM

8.1 PARETO ANALYSIS FOR MAIN CATEGORY

In chapter 5.3.1, we learnt about the Pareto chart and 80/20 rule. This is a popular method to find out the focus area for any organisatinal improvement.

Table 8.1: Category wise list of faults for the Oct'07 period

Sl. No.	Main Category	No of Faults	% Faults
1	BTS problem	101	3
2	External power fault	2133	60
3	Internal power fault	279	10
4	Low Capacity microwave fault	944	23
5	High Capacity microwave fault	126	4

Bar chart can be plotted for the above data to find out the focus points.
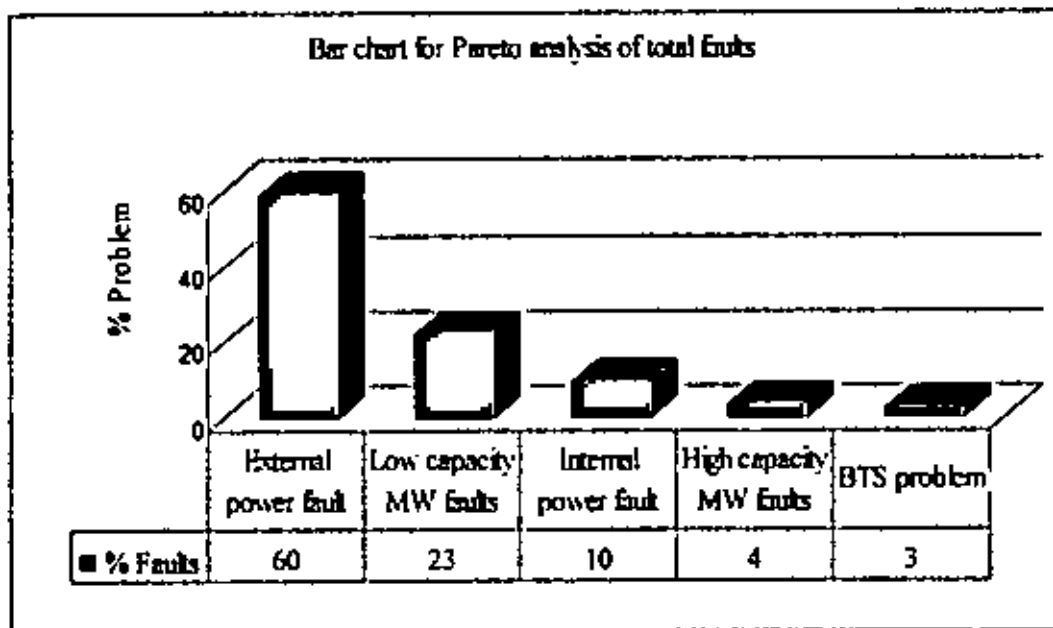
Figure 8.1: Bar chart for Pareto analysis of total faults

Comments: From the Graph it can be concluded that external power and Low capacity MW fault are the majority of the faults.

8.2 PARETO ANALYSIS FOR SUB CATEGORY

Now we will do the Pareto analysis for all the 5 categories of faults.

8.2.1 Category 1: BTS Faults

Table 8 2: Pareto analysis for BTS faults

SL No	Sub Category	Total no of faults	% faults
1	BTS Hardware Problem	73	73
2	BTS Software Problem	16	16
3	BTS Configuration Problem	6	6
4	BSC-BTS Synchronization Problem	4	4
5	Automatic Reset	2	2

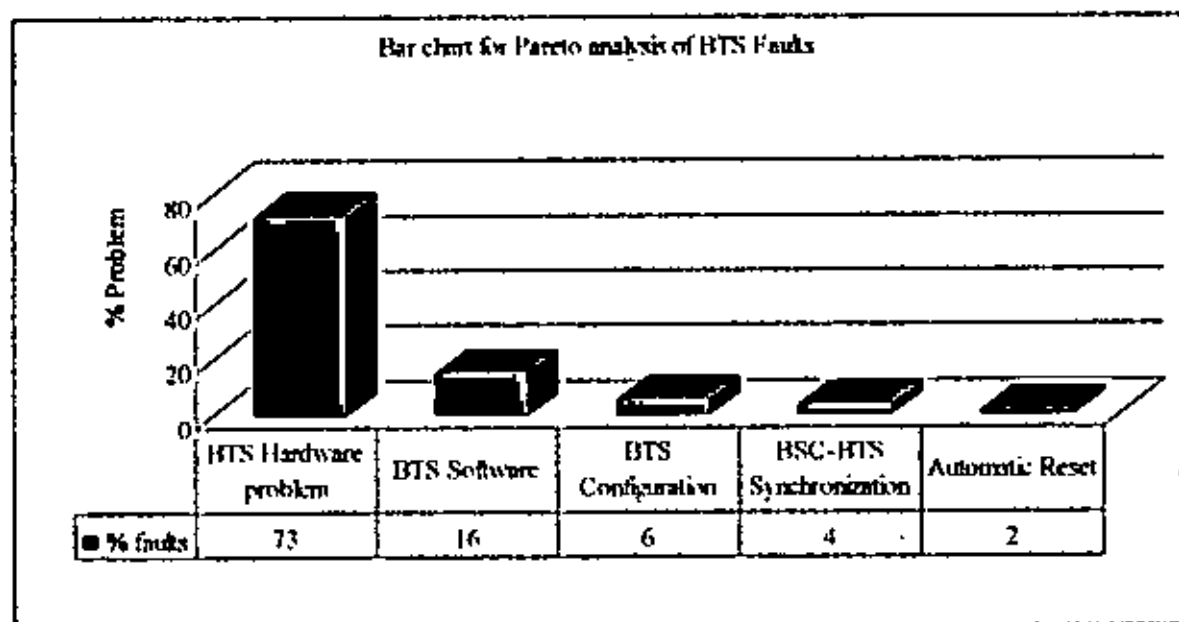Data of table 8 2 is plotted in the below bar chart.

Figure 8.2: Bar chart for Pareto analysis of BTS faults

Comments: From the Graph it can be concluded that BTS hardware and software problems contributed to the majority of the BTS faults.

8.3 CATEGORY 2: EXTERNAL POWER FAULTS

Table 8.3: Pareto analysis for external power faults

Sl.	Sub Category	No of faults	% faults
1	Mains Fail	11436	54
2	MDB Breaker Trip	513	24
3	Power Problem at the link site	278	13
4	High Temperature	114	6
5	Battery	85	3

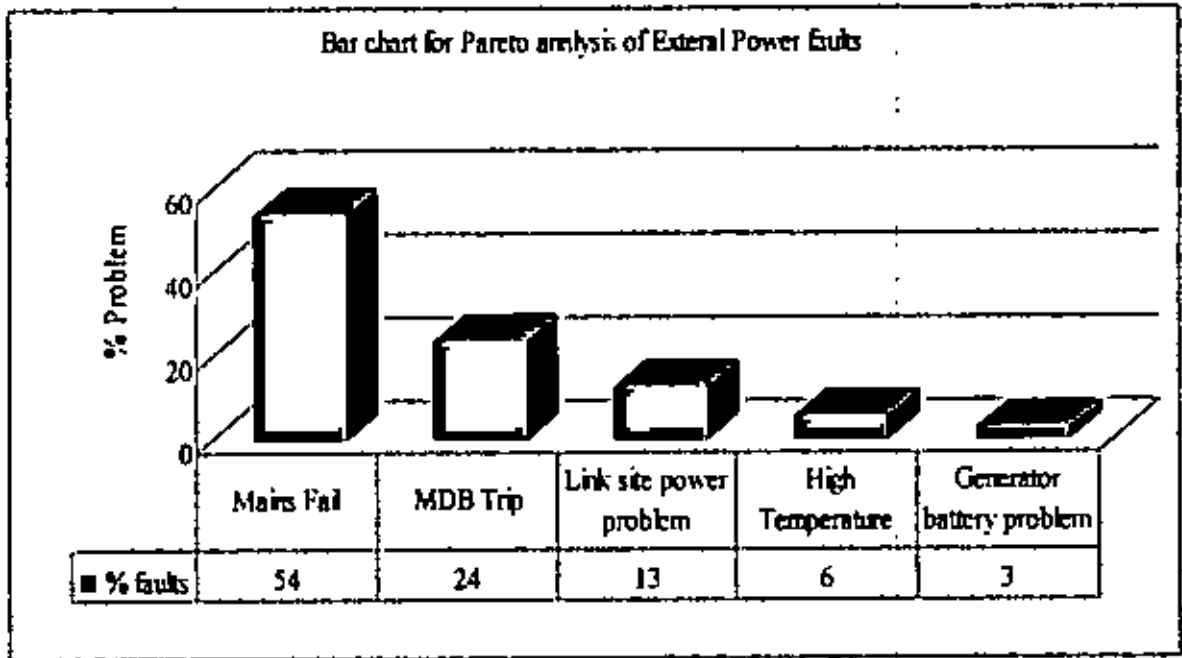Data of table 8.3 is plotted and the bar chart is found like below:

Figure 8.3: Bar chart for Pareto analysis of external power faults

Comments: From the Graph it can be concluded that Long time Mains fail and Main distribution breaker trip problems contributed to the majority of the EXP faults

8.4 CATEGORY 3: INTERNAL POWER FAULTS

Table 8.4: Reason wise no. of internal power faults

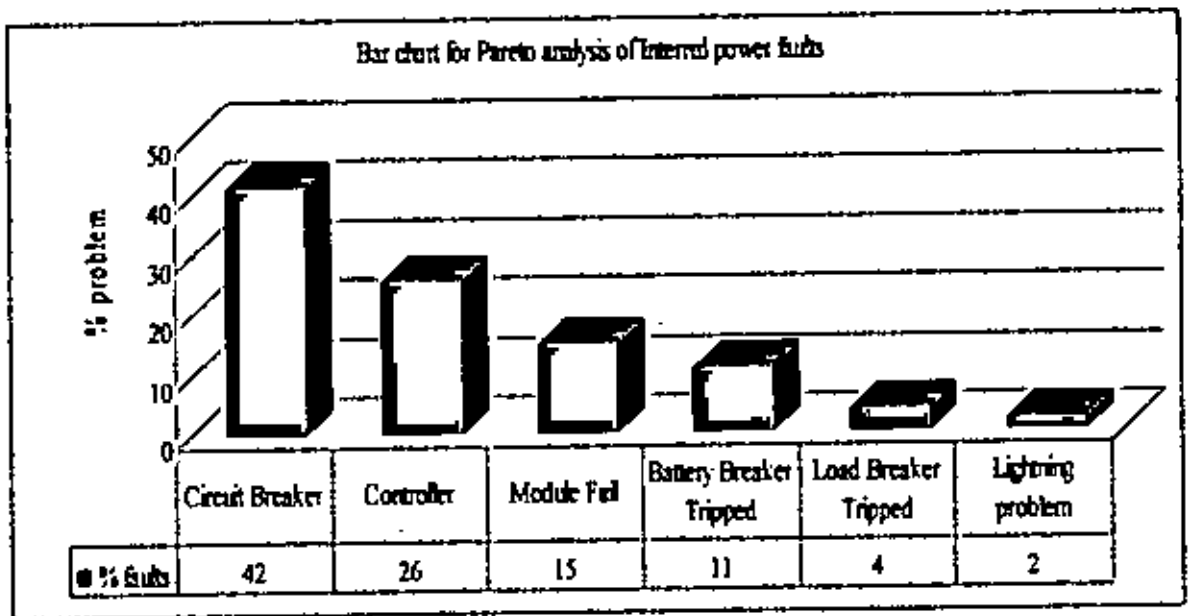| SL. No	Sub Category	No of faults	% faults
1	Circuit Breaker	113	42
2	Controller	69	26
3	Module Fail	42	15
4	Battery Breaker Tripped	30	11
5	Load Breaker Tripped	10	4
6	Lightning problem	5	2

Figure 8.4: Bar chart for Pareto analysis of internal power faults

Comments: From the Graph it can be concluded that circuit breaker and controller card problems contributed to the majority of the internal power faults

8.5 CATEGORY 4: LOW CAPACITY MICROWAVE FAULTS

Table 8.5: Reason wise no. of low capacity MW faults

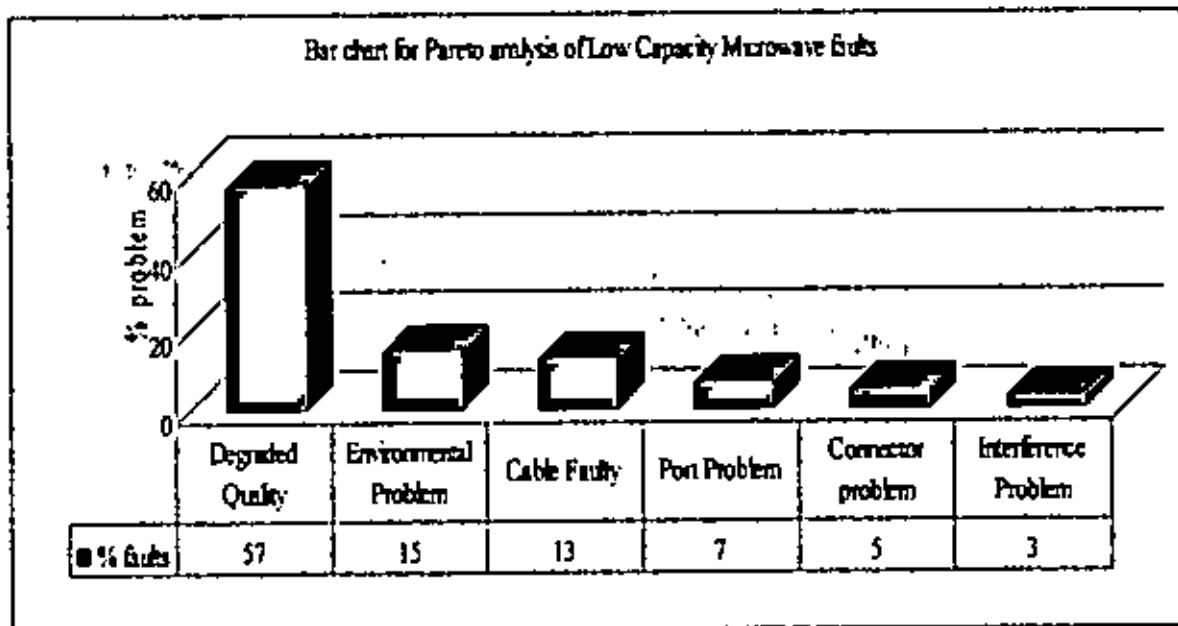| SL. No	Sub Category	No of faults	% faults
1	Degraded Quality	532	57
2	Environmental Problem	452	15
3	Cable Faulty	127	13
4	Port Problem	63	7
5	Connector problem	41	5
6	Interference Problem	29	3

Figure 8.5: Bar chart for Pareto analysis of Low Capacity Microwave faults

Comments: From the Graph it can be concluded that degraded quality, environment and Cable fault are the major roll player for Low capacity MW faults.

8.6 CATEGORY 5: HIGH CAPACITY MICROWAVE FAULTS

Table 8.6: Reason wise no. of high capacity MW faults

SL. No	Sub Category	No of faults	% faults
1	Degraded Quality	63	50
2	Equipment Problem	28	23
3	Configuration Problem	17	14
4	Environmental problem	10	8
5	Cable Faulty	5	4
6	Port Problem	3	3

Bar chart for Pareto analysis of High Capacity Microwave faults

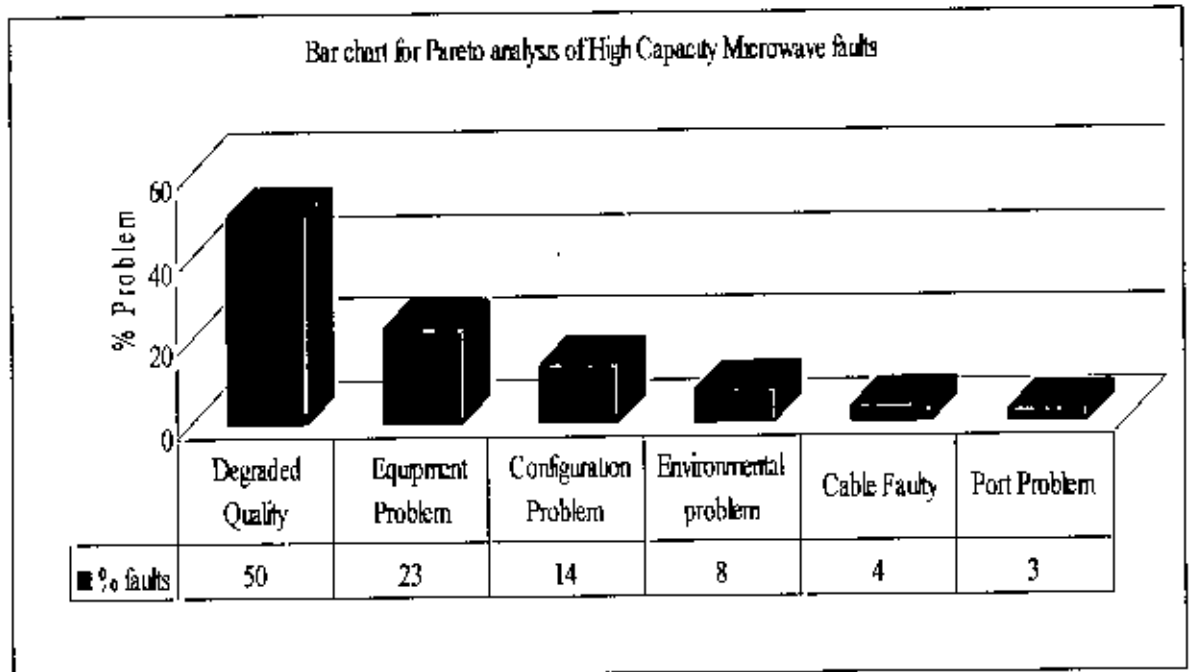| ■ % faults	Degraded Quality	Equipment Problem	Configuration Problem	Environmental problem	Cable Faulty	Port Problem
% faults	50	23	14	8	4	3

Figure 8.6. Bar chart for Pareto analysis of high capacity MW faults

Comments: From figure 8.6 it can be concluded that degraded quality, environment and configuration problem are the major roll player for high capacity MW faults.

8.7 ANALYSIS USING CAUSE EFFECT DIAGRAM

The cause-and-effect diagram can help resolve problems by helping us pinpoint the root cause and stop treating symptoms.

- It resembles skeleton of a fish.
- Emphasizes group communication and brainstorming.
- Stimulates discussion
- Leads to increased understanding of complex problems.
- Visual and presentational tool.
- Can be used to improve any product, process, or service
- Any area of the company that is experiencing a problem
- Isolates all relevant causes
- Helps bring a problem into light

- Group discussion and brainstorming.
- Finds reasons for quality variations, and the relationships between them.

8.7.1 Creating a Fishbone Diagram

- Establish problem (effect)
- State in clear terms
- agreed upon by entire group
- Problem becomes the "head" of the fish
- draw line to head ("backbone")
- Decide major causes of the problem
- By brainstorming
- If the effect or problem is part of a process the major steps in the process can be used
- Connect major causes to backbone of the fish with slanting arrows.
- Brainstorm secondary causes for each of the major causes.
- Connect these secondary causes to their respective major causes.
- Repeat steps 5 & 6 for sub-causes dividing with increased specificity.
- Analyze and evaluate causes and sub-causes.
- Decide and take action.

8.7.2 Creating Cause Effect Diagram for Total faults

Cause enumeration

- Here the Effect is "Total faults of all Sites". This Became the Head of the Fishbone.

- By Studying the STP data & Brainstorming it is found that the Major causes of the Problem are BTS, External power fault, internal power faults, Low capacity microwave. high capacity microwave.

- These major causes are connected to backbone of the fish with slanting arrows

- Secondary causes of these Major causes are identified and connected to the Major Causes in the Fishbone diagram.
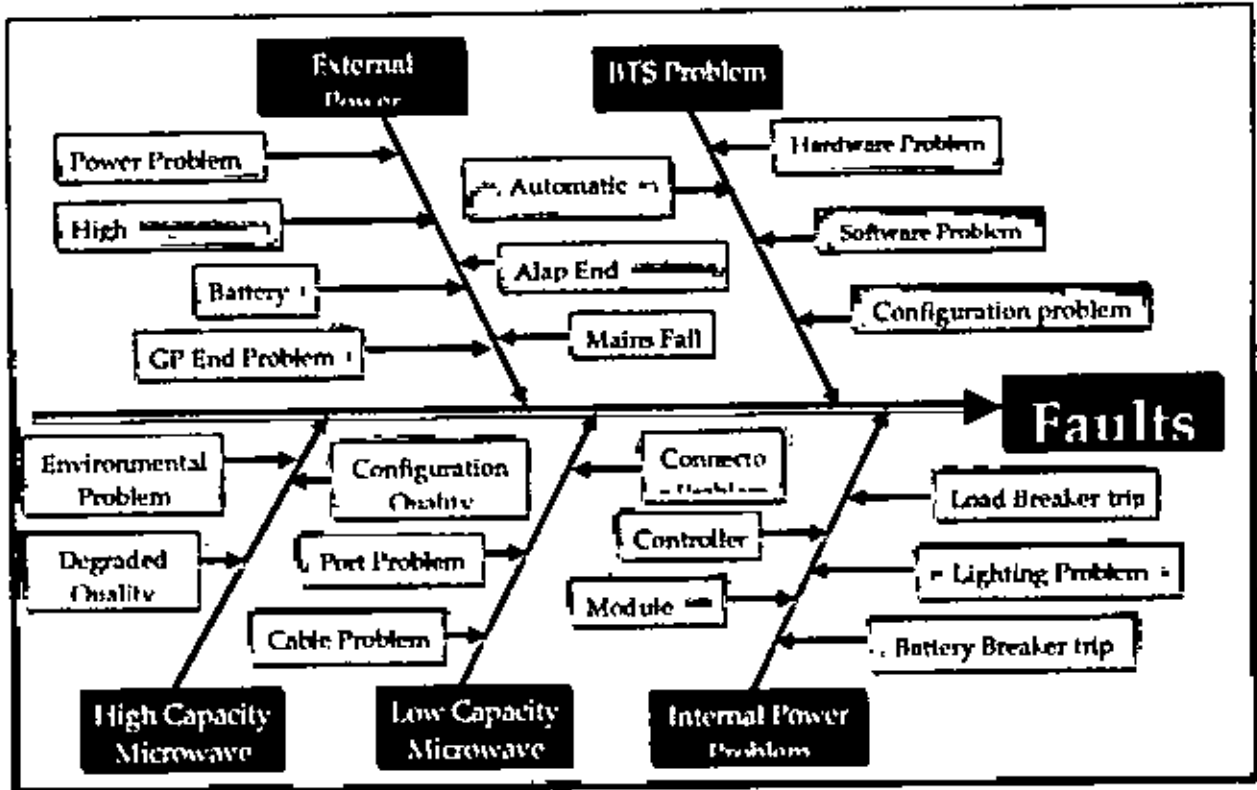
Figure 8.7: Cause enumeration diagram of total faults

8.8 PROCESS ANALYSIS

- Here the Effect is "Total faults of all Sites". This Became the Head of the Fishbone.

- By Studying the STP data & Brainstorming it is found that the exact locations are BTS, Transmission & power. Major causes of the Problem are Hardware, software, Alap end site, optical fiber, generator, equipment faulty.

- These major causes are connected to backbone of the fish with slanting arrows.

- Secondary causes of these Major causes are identified and connected to the Major Causes in the Fishbone diagram.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSION

Being the largest cellular service provider in Bangladesh. Grameenphone has the largest network among all the operators. It is really challenging to keep this huge network alive all the time. But it has to be maintained to provide uninterrupted and quality network to the customers.

Analysis has been done on the access network faults of Dhaka region for the period of 1st to 30th October'07 using different TQM tools. Focus has been given on two major KPIs-no. of faults and MTTR. Faults have been categorized in 5 major types- External Power. BTS HW, Low capacity MW, High capacity MW and Internal power.

From the Pareto Analysis, we found that only 2 or 3 causes are responsible for the faults which are occurring in the network. So if focus is given only on these factors only, huge reduction in faults can be achieved.

From the C-chart analysis for both number of faults and MTTR, it is found that the system was under control for most of the cases except exceeding the number of faults on a particular day. From the root cause analysis, it was found that abnormal external power condition for that particular day was responsible for taking the system out of control.

9.2 RECOMMENDATION

Though cellular operators are service providers, implementation of TQM can be useful and efficient for this type of organization. Hence it is recommended that TQM should be used to bring down the faults to a minimum level as well as restoration of the faults within the shortest possible time. Thus the mobile operators would be able to provide better customer service.

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