ANALYSIS OF PERFORMANCE & DEVELOPMENT OF QUALITY IMPROVEMENT PLAN FOR NEW BTS (BASE TRANSCEIVER STATION) OF A MOBILE OPERATOR IN BANGLADESH

GAZI SAHARUL HABIB

DEPARTMENT OF INDUSTRIAL & PRODUCTION ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY
DHAKA-1000, BANGLADESH

September 2008

ANALYSIS OF PERFORMANCE & DEVELOPMENT OF QUALITY IMPROVEMENT PLAN FOR NEW BTS (BASE TRANSCEIVER STATION) OF A MOBILE OPERATOR IN BANGLADESH

BY

GAZI SAHARUL HABIB

A THESIS PRESENTED TO THE INDUSTRIAL AND PRODUCTION ENGINEERING DEPARTMENT IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING IN ADVANCED ENGINEERING MANAGEMENT

DEPARTMENT OF INDUSTRIAL & PRODUCTION ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY
DHAKA-1000, BANGLADESH

September 2008

CERTIFICATE OF APPROVAL

The thesis titled 'Analysis of Performance & Development of Quality Improvement Plan for New BTS (Base Transceiver Station) of a Mobile Operator in Bangladesh' submitted by Gazi Saharul Habib, Student No. 040308156 (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.

BOARD OF EXAMINERS

1. Dr. M. Ahsan Akhter Hasin
   Professor & Head
   Dept. of IPE, BUET, Dhaka — Chairman (Supervisor)

2. Dr. A.K.M. Masud
   Associate Professor
   Dept. of IPE, BUET, Dhaka — Member

3. Mr. Md. Zafar Ullah
   Senior Assistant Chief
   Planning Commission
   GOB — Member

CANDIDATE'S DECLARATION

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.

Gazi Saharul Habib

ACKNOWLEDGEMENTS

I express my deepest sense of indebtness, heartiest thanks and gratefulness to my project supervisor Ahsan Akhtar Hasin, Professor, Department of IndusTrial & Production Engineering, BUET, for providing the guidance, overall supervision & constructive criticism throughout the progress of this research.

I would also like to thank all the employees of Network Management department, Technical Operation, GrameenPhone Ltd. for providing necessary information and data for analysis part of my project.

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.

ABSATRACT

GrameenPhone Ltd. Is the largest mobile phone operator in Bangladesh with more than 20 million subscribers and around 12000 Base Stations at 6000 locations all over the country? The quality of the network is largely depends upon the quality of Newly on Air sites. With the huge implementation pace the quality of newly on Air sites are creating some concerns.

After getting on Air of a site it passes through Stability Period for at least 72 hours. During this period the base Station is checked for two important quality parameters a. PCM quality & Cell quality. A good quality site must pass these parameters. My focus in this thesis is to improve the quality of newly on Aired sites.

In this thesis, I studied & analyze the overall planning, Implementation and acceptance process. I studied STP data & TR feedback & develop statistical Process control system using Control Chart, Pareto analysis, Cause-Effect diagram. I identify the root causes of different kinds of problems those are responsible for poor quality and provide suggestion for the solutions. Overall I develop a model for quality improvement keeping the roll out pace on going.

TABLE OF CONTENTS

CHAPTER 4: ANALYSIS OF PERFORMANCE FOR NEW BTS

CHAPTER 5 : CONCLUSION AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

The grameenphone is one of the largest mobile operators in Bangladesh with a considerable percentage of market shares alone. The company already entered into 11 years of its successful operation in Bangladesh & became one of the main drive forces of Bangladesh economy.

As grameenphone is basically a service providing organization, the success of the company is dependent on customer satisfaction which is again dependent on the quality & efficiency of the service. Besides direct customer support & care (which is taken care by Customer Relation Division), Technical Division is the concerned division which is responsible for the quality & efficiency of the overall service Whenever a New BTS come on Air it instantly carrying traffic. So, the quality of New on Air site is very important for our valued customer satisfaction. Current protocol to get site on Air is as described in the following figure 1.1.

Grameenphone has almost 12000 base stations at 6000 locations all over the country. To face the huge competition at telecom industry by rival other 4 mobile operators she may have to increase her base stations rapidly to almost double within next 2 years to comply with consumers needs. To keep the status of the current market leader in future, she has to keep her service standard to the customer satisfaction level. To meet that the quality of new on air base station has to be top class.

After completion of commissioning the site acceptance team accepts the site and immediately go for traffic. Grameenphone NIC (Network Integration Center) department monitor the status of every site for 72 hours after given on air. This is called Stability Test Period shortly termed as STP. They check 2 important parameters a) PCM performance & b) Cell performance & these two parameters are directly related to network quality.
My project directly aims at in depth analyze the PCM & Cell performance of cluster of sites (per week on air) during STP, finding out the root causes, suggesting statistical quality control &

providing clear guidelines to keep the standard of new on air sites at international level with respect to the coming & ongoing rollout pace.

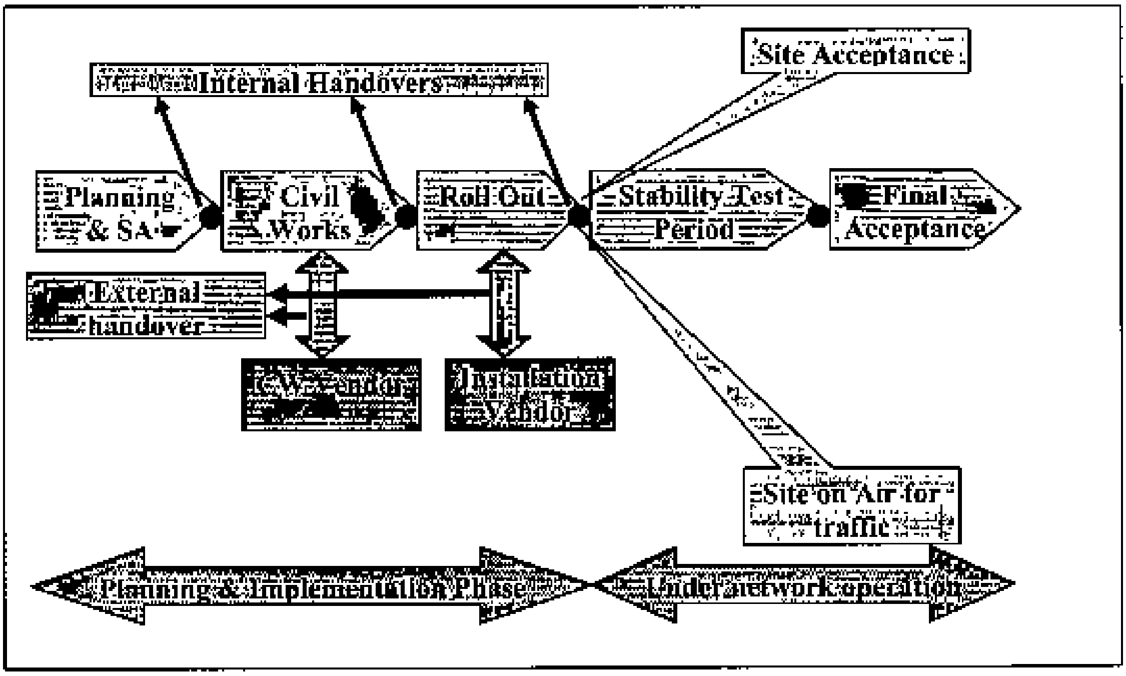


Figure 1.1 Handover Protocol of New BTS

1.2. OBJECTIVE WITH SPECIFIC AIM AND POSSIBLE OUTCOMES

The main objectives of this study are

- Study and analyze the overall planning & implementation process for new BTS
- Analyze the work and current performances of different interfaces.
- Develop statistical Process control system for required interfaces.
- Identify and suggest for removing the root causes of different types of problems.
- Develop a model for quality improvement keeping the roll out pace on going.

The main outcomes of this study are

- A comprehensive guideline for improving performance of the integrated system.
- Reduction of faults of newly commissioned sites to reduce the OPEX as well as to increase customer satisfaction.

1.3 METHODOLOGY

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

- Study and analyze the overall planning & implementation process for a new BTS that come on air.
- Analyze the work of different interfaces.
- Analyze Stability Test Procedure for grameenphone for New BTS.
- Collect the STP report of sites coming every week and analyze the report.
- Develop statistical Process Control Plan.
- Analyze the TR feedback and root cause analysis of different types of problems.
- Develop a model for quality improvement keeping the roll out pace on going.
- Recommendations for improvement.

CHAPTER 2

OVERVIEW OF THE GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

2.1 HISTORY OF GSM

During the early 1980s, analog cellular telephone systems were experiencing rapid growth in Europe, particularly in Scandinavia and the United Kingdom, but also in France and Germany. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only was the mobile equipment limited to operation within national boundaries, which in a unified Europe were increasingly unimportant, but there was also a very limited market for each type of equipment, so economies of scale and the subsequent savings could not be realized.

The Europeans realized this early on, and in 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Groupe Spécial Mobile (GSM) to study and develop a pan-European public land mobile system. The proposed system had to meet certain criteria

- Good subjective speech quality
- Low terminal and service cost
- Support for international roaming
- Ability to support handheld terminals
- Support for range of new services and facilities
- Spectral efficiency
- ISDN compatibility

In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase 1 of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by 1993 there were 36 GSM networks in 22 countries. Although standardized in Europe, GSM is not only a European standard. Over 200 GSM networks (including DCS1800 and PCS1900) are operational in 110 countries around the world. In the beginning of 1994, there were 1.3 million subscribers worldwide, which had grown to more than 55 million by October 1997. With North America making a delayed entry into the GSM field with a derivative of GSM called PCS1900, GSM systems exist on every continent, and the acronym GSM now aptly stands for Global System for Mobile communications. [5]

2.2 ARCHITECTURE OF THE GSM NETWORK

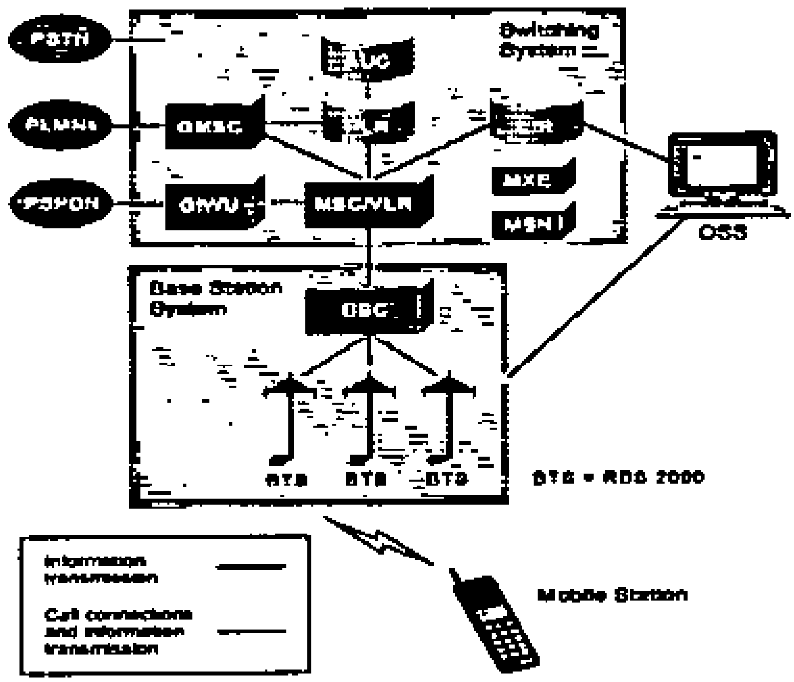


Figure 2.1 Overview architecture of a GSM network

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure 1 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts. The Mobile Station is carried by the subscriber. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. Not shown is the Operations and Maintenance Center, which oversees the proper operation and setup of the network. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface.

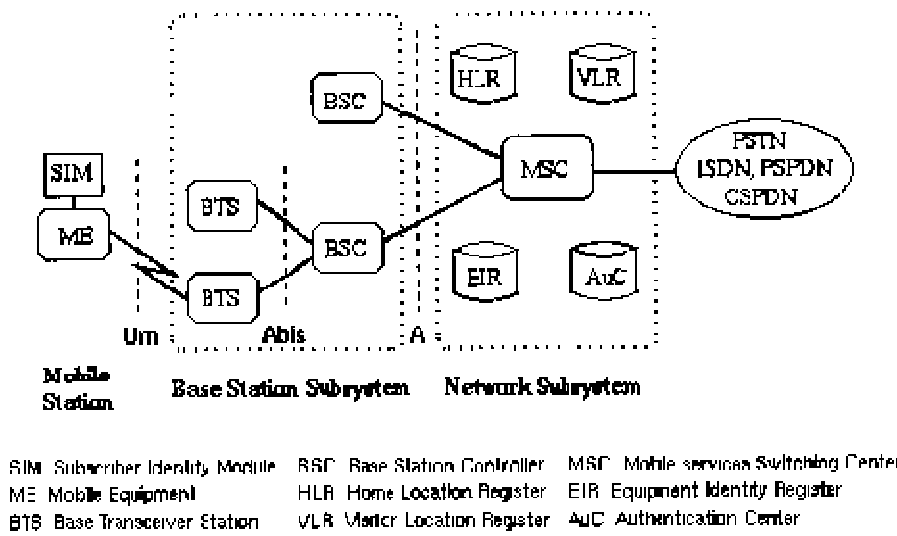


Figure 2.2 General architecture of a GSM network [2]

2.2.1 Mobile Station (MS)

The mobile station (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 another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services.

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.

2.2.2 Base Station Subsystem (BSS)

The Base Station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). The Base Transceiver Station houses the radio tranceivers that define a cell and handles the radio-link protocols with the Mobile Station. 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.
The Base Station Controller manages the radio resources for one or more BTSs. It handles radio-channel setup, frequency hopping, and handovers, as described below. The BSC is the connection between the mobile station and the Mobile service Switching Center (MSC).

2.2.3 Network Subsystem

The central component of the Network Subsystem is the Mobile services Switching Center (MSC). It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. These services are provided in conjunction with several functional entities, which together form the Network Subsystem. The MSC provides the connection to the fixed networks (such as the PSTN or ISDN). Signaling between functional entities in the Network Subsystem uses Signaling System Number 7 (SS7), used for trunk signaling in ISDN and widely used in current public networks.
The Home Location Register (HLR) and Visitor Location Register (VLR), together with the MSC, provide the call-routing and roaming capabilities of GSM. The HLR contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile. The location of the mobile is typically in the form of the signaling address of the VLR associated with the mobile station. The actual routing procedure will be described later. There is logically one HLR per GSM network, although it may be implemented as a distributed database.
The Visitor Location Register (VLR) contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. Although each functional entity can be implemented as an independent unit, all manufacturers of switching equipment to date implement the VLR together with the MSC, so that the geographical area controlled by the

MSC corresponds to that controlled by the VLR, thus simplifying the signaling required. Note that the MSC contains no information about particular mobile stations --- this information is stored in the location registers.

The other two registers are used for authentication and security purposes. The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where each mobile station is identified by its International Mobile Equipment Identity (IMEI). An IMEI is marked as invalid if it has been reported stolen or is not type approved. The Authentication Center (AuC) is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and encryption over the radio channel.

2.3 RADIO LINK ASPECTS

The International Telecommunication Union (ITU), which manages the international allocation of radio spectrum (among many other functions), allocated the bands 890-915 MHz for the uplink (mobile station to base station) and 935-960 MHz for the downlink (base station to mobile station) for mobile networks in Europe. Since this range was already being used in the early 1980s by the analog systems of the day, the CEPT had the foresight to reserve the top 10 MHz of each band for the GSM network that was still being developed. Eventually, GSM will be allocated the entire 2x25 MHz bandwidth.

2.3.1 Multiple Access And Channel Structure

Since radio spectrum is a limited resource shared by all users, a method must be devised to divide up the bandwidth among as many users as possible. The method chosen by GSM is a combination of Time- and Frequency-Division Multiple Access (TDMA/FDMA). The FDMA part involves the division by frequency of the (maximum) 25 MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart. One or more carrier frequencies are assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme. The fundamental unit of time in this TDMA scheme is called a burst period and it lasts 15/26 ms (or approx. 0.577 ms). Eight burst periods are grouped into a TDMA frame (120/26 ms, or approx 4.615 ms), which forms the basic unit for the definition of logical channels. One physical channel is one burst period per TDMA frame.

Channels are defined by the number and position of their corresponding burst periods. All these definitions are cyclic, and the entire pattern repeats approximately every 3 hours. Channels can be divided into dedicated channels, which are allocated to a mobile station, and common channels, which are used by mobile stations in idle mode.

2.3.1.1 Traffic Channels

A traffic channel (TCH) is used to carry speech and data traffic. Traffic channels are defined using a 26-frame multi frame, or group of 26 TDMA frames. The length of a 26-frame multi frame is 120 ms, which is how the length of a burst period is defined (120 ms divided by 26 frames divided by 8 burst periods per frame). Out of the 26 frames, 24 are used for traffic, 1 is used for the Slow Associated Control Channel (SACCH) and 1 is currently unused (see Figure 2c). TCHs for the uplink and downlink are separated in time by 3 burst periods, so that the mobile station does not have to transmit and receive simultaneously, thus simplifying the electronics.

In addition to these full-rate TCHs, there are also half-rate TCHs defined, although they are not yet implemented. Half-rate TCHs will effectively double the capacity of a system once half-rate speech coders are specified (i.e., speech coding at around 7 kbps, instead of 13 kbps). Eighth-rate TCHs are also specified, and are used for signalling. In the recommendations, they are called Stand-alone Dedicated Control Channels (SDCCH).

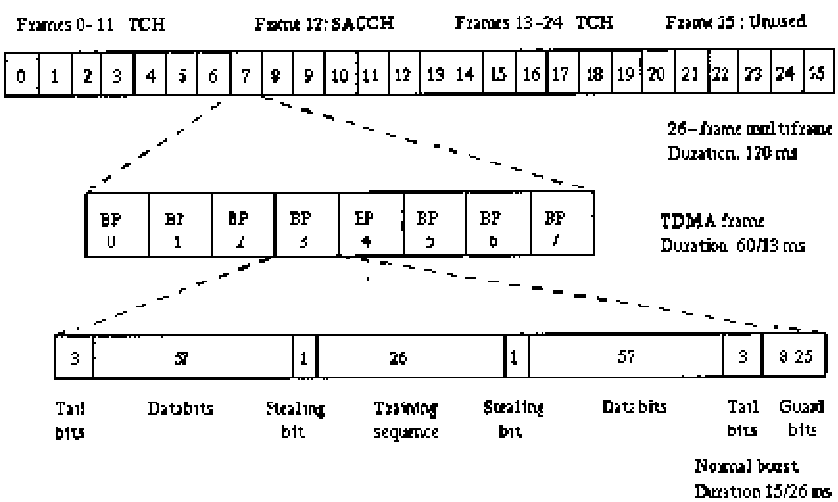


Figure 2.3 Organization of bursts, TDMA frames and multi frames for speech & data [2}

2.3.1.2 Control Channels

Common channels can be accessed both by idle mode and dedicated mode mobiles. The common channels are used by idle mode mobiles to exchange the signaling information required to change to dedicated mode. Mobiles already in dedicated mode monitor the surrounding base stations for handover and other information. The common channels are defined within a 51-frame multi frame, so that dedicated mobiles using the 26-frame multi frame TCH structure can still monitor control channels. The common channels include

Broadcast Control Channel (BCCH)

Continually broadcasts, on the downlink, information including base station identity, frequency allocations, and frequency-hopping sequences.

Frequency Correction Channel (FCCH) and **Synchronization Channel (SCH)**

Used to synchronize the mobile to the time slot structure of a cell by defining the boundaries of burst periods, and the time slot numbering. Every cell in a GSM network broadcasts exactly one FCCH and one SCH, which are by definition on time slot number 0 (within a TDMA frame).

Random Access Channel (RACH)

Slotted Aloha channel used by the mobile to request access to the network.

Paging Channel (PCH)

Used to alert the mobile station of an incoming call.

Access Grant Channel (AGCH)

Used to allocate an SDCCH to a mobile for signaling (in order to obtain a dedicated channel), following a request on the RACH.

2.3.1.3 Burst Structure

There are four different types of bursts used for transmission in GSM. The normal burst is used to carry data and most signalling. It has a total length of 156.25 bits, made up of two 57 bit information bits, a 26 bit training sequence used for equalization, 1 stealing bit for each information block (used for FACCH), 3 tail bits at each end, and an 8.25 bit guard sequence, as shown in Figure 2 The 156.25 bits are transmitted in 0.577 ms, giving a gross bit rate of 270.833 kbps.

The F burst, used on the FCCH, and the S burst, used on the SCH, have the same length as a normal burst, but a different internal structure, which differentiates them from normal bursts (thus allowing synchronization). The access burst is shorter than the normal burst, and is used only on the RACH. [2]

2.3.2 Speech Coding

GSM is a digital system, so speech which is inherently analog, has to be digitized. The method employed by ISDN, and by current telephone systems for multiplexing voice lines over high speed trunks and optical fiber lines, is Pulse Coded Modulation (PCM). The output stream from PCM is 64 kbps. too high a rate to be feasible over a radio link. The 64 kbps signal, although simple to implement, contains much redundancy. The GSM group studied several speech coding algorithms on the basis of subjective speech quality and complexity (which is related to cost, processing delay, and power consumption once implemented) before arriving at the choice of a Regular Pulse Excited -- Linear Predictive Coder (RPE--LPC) with a Long Term Predictor loop. Basically, information from previous samples, which does not change very quickly, is used to predict the current sample. The coefficients of the linear combination of the previous samples, plus an encoded form of the residual, the difference between the predicted and actual sample, represent the signal. Speech is divided into 20 millisecond samples, each of which is encoded as 260 bits, giving a total bit rate of 13 kbps. This is the so-called Full-Rate speech coding. Recently, an Enhanced Full-Rate (EFR) speech coding algorithm has been implemented by some North American GSM1900 operators. This is said to provide improved speech quality using the existing 13 kbps bit rate. [2]

2.3.3 Channel Coding And Modulation

Because of natural and man-made electromagnetic interference, the encoded speech or data signal transmitted over the radio interface must be protected from errors. GSM uses convolutional encoding and block interleaving to achieve this protection. The exact algorithms used differ for speech and for different data rates The method used for speech blocks will be described below.

Recall that the speech codec produces a 260 bit block for every 20 ms speech sample. From subjective testing, it was found that some bits of this block were more important for perceived speech quality than others. The bits are thus divided into three classes

- Class Ia 50 bits - most sensitive to bit errors
- Class Ib 132 bits - moderately sensitive to bit errors
- Class II 78 bits - least sensitive to bit errors

Class Ia bits have a 3 bit Cyclic Redundancy Code added for error detection. If an error is detected, the frame is judged too damaged to be comprehensible and it is discarded. It is replaced by a slightly attenuated version of the previous correctly received frame. These 53 bits, together with the 132 Class Ib bits and a 4 bit tail sequence (a total of 189 bits), are input into a 1/2 rate convolutional encoder of constraint length 4 Each input bit is encoded as two output bits, based on a combination of the previous 4 input bits. The convolutional encoder thus outputs 378 bits, to which are added the 78 remaining Class II bits, which are unprotected. Thus every 20 ms speech sample is encoded as 456 bits, giving a bit rate of 22.8 kbps.

To further protect against the burst errors common to the radio interface, each sample is interleaved. The 456 bits output by the convolutional encoder are divided into 8 blocks of 57 bits, and these blocks are transmitted in eight consecutive time-slot bursts. Since each time-slot burst can carry two 57 bit blocks, each burst carries traffic from two different speech samples.

Recall that each time-slot burst is transmitted at a gross bit rate of 270.833 kbps. This digital signal is modulated onto the analog carrier frequency using Gaussian-filtered Minimum Shift Keying (GMSK). GMSK was selected over other modulation schemes as a compromise between spectral efficiency, complexity of the transmitter, and limited spurious emissions. The complexity of the transmitter is related to power consumption, which should be minimized for the mobile station. The spurious radio emissions, outside of the allotted bandwidth, must be strictly controlled so as to limit adjacent channel interference, and allow for the co-existence of GSM and the older analog systems (at least for the time being). [2]

2.3.4 Multipath Equalization

At the 900 MHz range, radio waves bounce off everything - buildings, hills, cars, airplanes, etc. Thus many reflected signals, each with a different phase, can reach an antenna. Equalization is used to extract the desired signal from the unwanted reflections. It works by finding out how a known transmitted signal is modified by multipath fading, and constructing an inverse filter to extract the rest of the desired signal. This known signal is the 26-bit training sequence transmitted in the middle of every time-slot burst. The actual implementation of the equalizer is not specified in the GSM specifications.

2.3.5 Frequency Hopping

The mobile station already has to be frequency agile, meaning it can move between transmit, receive, and monitor time slot within one TDMA frame, which normally are on different frequencies. GSM makes use of this inherent frequency agility to implement slow frequency hopping, where the mobile and BTS transmit each TDMA frame on a different carrier frequency. The frequency hopping algorithm is broadcast on the Broadcast Control Channel. Since multipath fading is dependent on carrier frequency, slow frequency hopping helps alleviate the problem. In addition, co-channel interference is in effect randomized.

2.3.6 Discontinuous Transmission

Minimizing co-channel interference is a goal in any cellular system. since it allows better service for a given cell size. or the use of smaller cells, thus increasing the overall capacity of the system. Discontinuous transmission (DTX) is a method that takes advantage of the fact that a person speaks less that 40 percent of the time in normal conversation. by turning the transmitter off during silence periods. An added benefit of DTX is that power is conserved at the mobile unit.

The most important component of DTX is, of course, Voice Activity Detection. It must distinguish between voice and noise inputs, a task that is not as trivial as it appears, considering background noise. If a voice signal is misinterpreted as noise, the transmitter is turned off and a very annoying effect called clipping is heard at the receiving end. If, on the other hand, noise is misinterpreted as a voice signal too often, the efficiency of DTX is dramatically decreased. Another factor to consider is that when the transmitter is turned off, there is total silence heard at the receiving end, due to the digital nature of GSM. To assure the receiver that the connection is not dead, comfort noise is created at the receiving end by trying to match the characteristics of the transmitting end's background noise.

2.3.7 Discontinuous Reception

Another method used to conserve power at the mobile station is discontinuous reception. The paging channel, used by the base station to signal an incoming call, is structured into sub-channels. Each mobile station needs to listen only to its own sub-channel. In the time between successive paging sub-channels, the mobile can go into sleep mode, when almost no power is used.

2.3.8 Power Control

There are five classes of mobile stations defined, according to their peak transmitter power, rated at 20, 8, 5, 2, and 0.8 watts. To minimize co-channel interference and to conserve power, both the mobiles and the Base Transceiver Stations operate at the lowest power level that will maintain an acceptable signal quality. Power levels can be stepped up or down in steps of 2 dB from the peak power for the class down to a minimum of 13 dBm (20 mill watts).
The mobile station measures the signal strength or signal quality (based on the Bit Error Ratio), and passes the information to the Base Station Controller, which ultimately decides if and when the power level should be changed. Power control should be handled carefully, since there is the possibility of instability. This arises from having mobiles in co-channel cells alternately increase their power in response to increased co-channel interference caused by the other mobile increasing its power. This in unlikely to occur in practice but it is (or was as of 1991) under study.

2.4 COMMUNICATION MANAGEMENT

The Communication Management layer (CM) is responsible for Call Control (CC), supplementary service management, and short message service management. Each of these may be considered as a separate sub layer within the CM layer. Call control attempts to follow the ISDN procedures specified in Q.931, although routing to a roaming mobile subscriber is obviously unique to GSM. Other functions of the CC sub layer include call establishment, selection of the type of service (including alternating between services during a call), and call release. [2]

2.4.1 Call Routing

Unlike routing in the fixed network, where a terminal is semi-permanently wired to a central office, a GSM user can roam nationally and even internationally. The directory number dialed to reach a mobile subscriber is called the Mobile Subscriber ISDN (MSISDN), which is defined by the E.164 numbering plan. This number includes a country code and a National Destination Code which identifies the subscriber's operator. The first few digits of the remaining subscriber number may identify the subscriber's HLR within the home PLMN.

An incoming mobile terminating call is directed to the Gateway MSC (GMSC) function. The GMSC is basically a switch which is able to interrogate the subscriber's HLR to obtain routing information, and thus contains a table linking MSISDNs to their corresponding HLR. A simplification is to have a GSMC handle one specific PLMN. It should be noted that the GMSC function is distinct from the MSC function, but is usually implemented in an MSC.

The routing information that is returned to the GMSC is the Mobile Station Roaming Number (MSRN), which is also defined by the E.164 numbering plan. MSRNs are related to the geographical numbering plan, and not assigned to subscribers, nor are they visible to subscribers.

The most general routing procedure begins with the GMSC querying the called subscriber's HLR for an MSRN. The HLR typically stores only the SS7 address of the subscriber's current VLR, and does not have the MSRN (see the location updating section). The HLR must therefore query the subscriber's current VLR, which will temporarily allocate an MSRN from its pool for the call. This MSRN is returned to the HLR and back to the GMSC, which can then route the call to the new MSC. At the new MSC, the IMSI corresponding to the MSRN is looked up, and the mobile is paged in its current location area (see Figure 2.4).

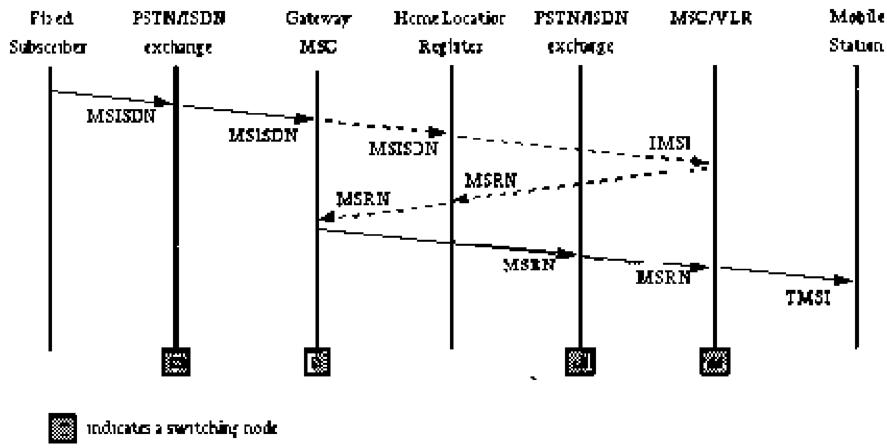


Figure 2.4 Call routing for a mobile terminating call[2]

2.5 CONCLUSION AND COMMENTS

In this chapter I have tried to give an overview of the GSM system. I believe, however, that I gave the general flavor of GSM and the philosophy behind its design. It is a standard that ensures interoperability without stifling competition and innovation among suppliers, to the benefit of the public both in terms of cost and service quality. For example, by using Very Large Scale Integration (VLSI) microprocessor technology, many functions of the mobile station can be built on one chipset, resulting in lighter, more compact and more energy-efficient terminals.

Telecommunications are evolving towards personal communication networks, whose objective can be stated as the availability of all communication services anytime, anywhere, to anyone, by a single identity number and a pocketable communication terminal. Having a multitude of incompatible systems throughout the world moves us farther away from this ideal. The economies of scale created by a unified system are enough to justify its implementation. not to mention the convenience to people of carrying just one communication terminal anywhere they go. regardless of national boundaries.

The GSM system, and its sibling systems operating at 1.8 GHz (called DCS1800) and 1.9 GHz (called GSM1900 or PCS1900, and operating in North America), are a first approach at a true personal communication system. The SIM card is a novel approach that implements personal mobility in addition to terminal mobility. Together with international roaming, and support for a variety of services such as telephony. data transfer, fax, Short Message Service, and supplementary services, GSM comes close to fulfilling the requirements for a personal communication system close enough that it is being used as a basis for the next generation of mobile communication technology in Europe, the Universal Mobile Telecommunication System (UMTS)

Another point where GSM has shown its commitment to openness, standards and interoperability is the compatibility with the Integrated Services Digital Network (ISDN) that is evolving in most indusTrial ized countries, and Europe in particular (the so-called Euro-ISDN). GSM is also the first system to make extensive use of the Intelligent Networking concept, in which services like 800 numbers are concentrated and handled from a few centralized service centers, instead of being distributed over every switch in the country. This is the concept behind the use of the various registers such as the HLR In addition, the signaling between these functional entities uses Signaling System Number 7, an international standard already deployed in many countries and specified as the backbone signaling network for ISDN

GSM is a very complex standard, but that is probably the price that must be paid to achieve the level of integrated service and quality offered while subject to the rather severe restrictions imposed by the radio environment.

CHAPTER 3

COMPANY PROFILE

3.1 INTRODUCTION

Grameenphone Ltd., the largest telecommunications service provider in Bangladesh, received its operating license in November 1996 and started its service from March 26, 1997, the Independence Day of Bangladesh. Now, after 10 years of successful operations, Grameenphone is the largest mobile phone service provider in Bangladesh, with more than 14 million subscribers as of July 2007. Grameenphone provides services to rural and urban customers across Bangladesh, where mobile telephony is acknowledged as a significant driver of socio-economic development, both for individuals and the nation.[10]

3.2 TEN YEARS OF EMPOWERING PEOPLE

Once considered a fancy gadget for the elite, the mobile phone has been transformed into an essential tool for all. Mobile phones are now empowering people from all groups in all areas of Bangladesh.

Grameenphone Ltd. received its operating license in November 1996 and started its service from March 26, 1997, the Independence Day of Bangladesh. The shareholders established the company realizing the important role telecommunications can play in economic development Connectivity translates into productivity. They also made a commitment that "Good Development is Good Business".

Entrepreneur Iqbal Quadir first had the idea of providing mobile telephony to the poor of Bangladesh. His early discussions with Professor Yunus later resulted in launching the internationally acclaimed Village Phone Program, coupling micro-credit with mobile telephony to make telecommunications accessible to the rural poor.[10]

3.2.1 Making It Affordable

Now, after 10 years of successful operations, Grameenphone is the largest telecommunications service provider in Bangladesh. Grameenphone provides services to rural and urban customers across Bangladesh, where mobile telephony is acknowledged as a significant driver of socio-economic development, both for individuals and the nation.

From the beginning, the goal was to offer affordable mobile phone services to as many people as possible. However, the challenges were significant. The country had a very large population with a very limited purchasing power and poor infrastructure. Grameenphone saw an opportunity to utilize wireless technology to create a viable mobile telephony operation that could also become an engine for economic growth.

Providing telecommunications services to low-income groups is not without its difficulties. An increased focus on the operator's total cost of ownership is needed to ensure viability. Other entry-level barriers include subscriber handling costs, availability of affordable handsets, and regulatory and taxation issues. Grameenphone, in cooperation with Telenor, addressed many of these issues by focusing on developing the right technology, services and business models to make mobile telephony affordable for low-income customers.

3.2.2 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.[10]

3.2.3 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.

3.2.4 Beyond Business: Connecting Villages

Grameenphone's first community service initiative was the Village Phone Program, started on the same day the commercial service was launched in 1997. Administered by Grameen Telecom, the Village Phones provides access to telecommunication services in rural areas to people who could not otherwise afford to own a phone. It also provides the Village Phone operators with an opportunity to earn a good income. Typically, a village woman, also a borrower of Grameen Bank, finances a mobile phone through micro-credit and earns money by offering a phone service in their communities. Studies have shown that one of Village Phone's most important contributions was making market information accessible to everyone. It has also substantially empowered women from the rural households to make a living for themselves and their families.

3.3 THE 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 [10]

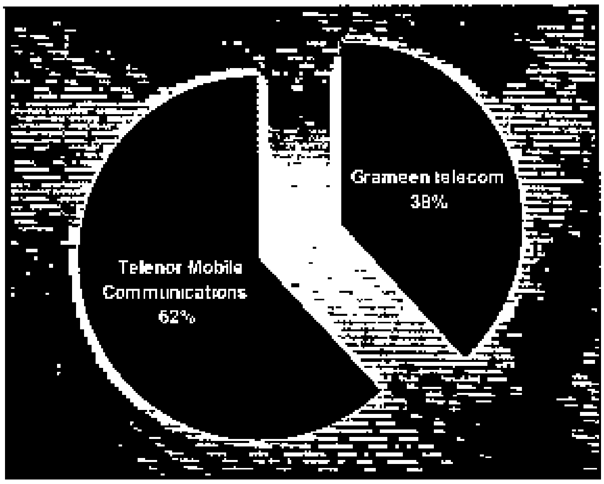


Figure 3.1 Grameenphone shareholders

3.3.1 Telenor Mobile Communications

Telenor AS is the leading Telecommunications Company of Norway listed in both the Oslo and NASDAQ Stock Exchanges. It owns 62% shares of Grameenphone Ltd.

Telenor, a 150 year-old organization, has played a pioneering role in the development of cellular communications. Manual mobile telephony services were introduced in Norway in 1966, as a forerunner to the automatic NMT system, which appeared in 1981. Its digital successor, GSM, was introduced in 1993. and third generation mobile network, UMTS, was launched for commercial use in 2004.

Telenor's strong international expansion in recent years has been based on leading-edge expertise, acquired in the Norwegian and Nordic markets, which are among the most highly developed technology markets in the world It has substantial international operations in mobile telephony, satellite operations and pay Television services. In addition to Norway and Bangladesh, Telenor owns mobile telephony companies in Sweden, Denmark, Hungary, Russia, Ukraine, Montenegro, Thailand, Malaysia, Pakistan and Serbia with more than 123 million mobile subscriptions worldwide as of June 2007.

3.3.2 Grameen Telecom

Grameen Telecom, which owns 38% of the shares of Grameenphone, is a not-for-profit company and works in close collaboration with Grameen Bank, winner of the Noble Peace Prize in 2006 along with its founder Professor Muhammad Yunus. 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 has 2399 branches, providing services in 76,848 villages, covering more than 91 percent of the total villages in Bangladesh. As of March 2007, the bank had 7.06 million borrowers, 97 percent of whom were women.

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

3.4 CONTRIBUTION TO NATIONAL EXCHEQUER

Grameenphone Ltd. has contributed more than BDT 67 billion to the National Exchequer in taxes, duties and payments to various Government bodies since its inception in March 1997 up to December 2006.

Accumulated contribution to the National Exchequer from inception up to December 2006 was BDT 67.18 billion, of which BDT 20.5 billion was made in 2006 alone. Grameenphone is now the largest corporate taxpayer in the country.

Grameenphone has also generated direct and indirect employment for a large number of people over the years. The company presently has about 5,000 employees while another 100,000 people are directly dependent on Grameenphone for their livelihood, working for the Grameenphone dealers, retailers, scratchcard retail outlets, suppliers, vendors, contractors and others.

With the payments of taxes and the investments in the network, Grameenphone is making a significant contribution to the country's development and growth.

The following chart illustrates how the National Treasury was augmented over the years

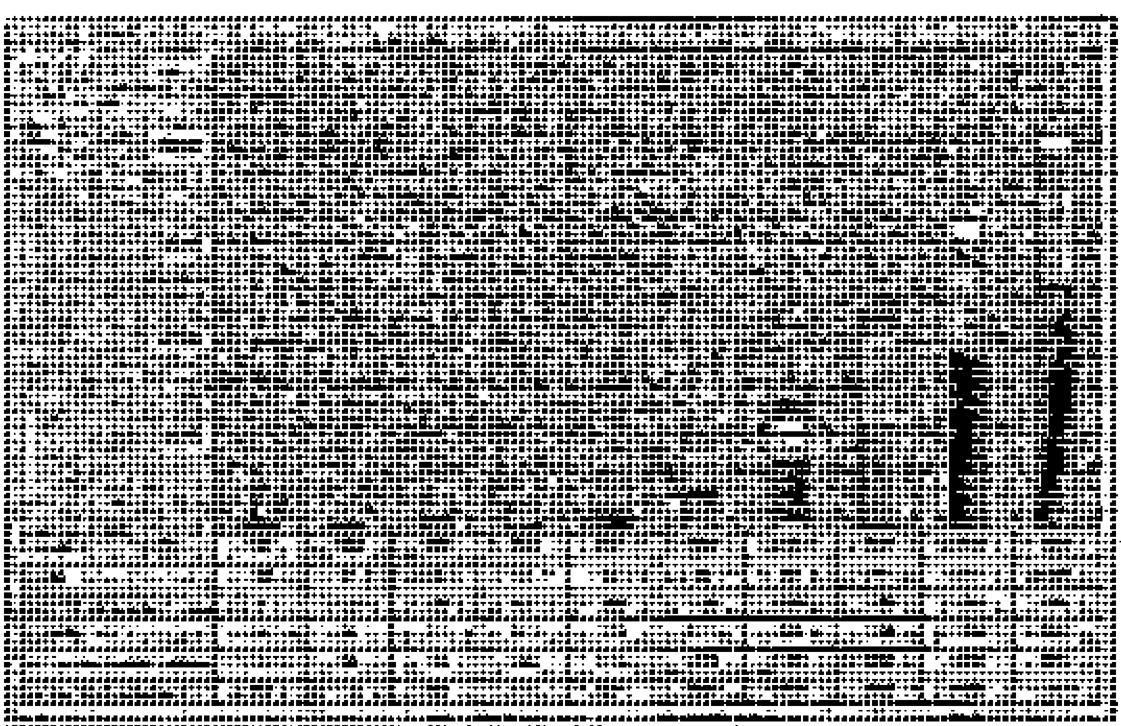


Figure 3.2 Contribution to Government as of December 31, 2006 (BDT in Million)[10]

CHAPTER 4

ANALYSIS OF PERFORMANCE FOR NEW BTS

4.1 INTRODUCTION

Ensuring a quality network along with providing coverage around the country has always been a priority focus area of Grameenphone. Extensive network expansion measures were implemented to keep up with the rapid growth of subscribers during last year. All the new sites has to pass through stability period to check the condition of the site.

4.2 STABILITY TEST PROCEDURE FOR NEW BTS

4.2.1 Introduction

Stability Test is performed to monitor the quality and performance of mainly New BTS after 3days later (72 hours) of giving the BTS on-air. In that test three major tasks (MPD, PCM quality and Cell quality) are performed one after another.

The Site Performance monitoring can be classified into 3 (three) categories.

- 900 MHz Base Station
- Co-located Site (1800 MHz Base Station)
- Swapped Base Station (RBS2102/2202 is being swapped by RBS2206)

Table 4.1 Threshold of PCM Parameters (24 Hrs Data BTS-BSC)

Threshold of PCM Parameters Monitoring the whole path BTS to BSC [Access short hauls recommendation]

Name of Parameter	Limit's 24 HRS
Unavailable Event (UAV)	<= 2 Events
Unavailable Time (UASB)	<=10s / Event [Formula=UASB/UAV]
Error Second (ES, ESR)	<=160s ESR=0.04
Severe Error Second (SES, SESR)	<=8s SESR=0 002

Recommendation ITUR-F 1493, G.827 and G.826

Table 4.2 Monitor the performance and quality of GSM 900 Band BTS

This table will be used to monitor the performance and quality of GSM 900 Band BTS only

Name of Parameter	Limit Value
Call Setup Success Rate	≥ 95%
TCH Attempt Congestion	≤ 10%
SDCCH Attempt Congestion	≤ 2%
TCH Drop	≤ 1%
MPD	≥ 30
Speech Quality Index (SQI)	≥ 50%
Interference (ICM Band)	≤ 2
Internal Incoming Handover	≥ 90%
Internal Outgoing Handover	≥ 90%
External Incoming Handover	≥ 90%
External Outgoing Handover	≥ 90%

Table 4.3 KPI to monitor the performance and quality of GSM 1800 Band

To analyze the performance of new collocated 1800 BTS the Radio KPI of the 900 BTS before collocation and Radio KPI of UL & OL Cell after collocation need to be compared. This

Reference Table will be used to monitor the performance and quality of GSM 1800 Band (Co-located) BTS only.

Name of Parameter	Limit Value
Traffic	Traffic Consistency check before and after Co-location, Change in Traffic in the Cell before and after, Traffic in the 900 Cell before co-location and total Traffic in the cell (sum of 900 & 1800) after co-location. Threshold for the change in Traffic is +/-50%. Traffic Pattern both in UL and OL need to be checked.
Call Setup Success Rate	≥ 95%
Under laid (UL) TCH Attempt Congestion	≤ 5%
Under laid (UL) SDCCH Attempt Congestion	≤ 2%
Call Drop	Call drop pattern before and after Co-location, Change in Drop in UL Cell before and after, Drop in the OL. Total TCH Drop / Hour ≤ 15 Change in Drop in UL ≤ 30%
MPD	Threshold for the change in MPD in UL can be decreased by 20% (Maximum).
Speech Quality Index (SQI)	≥ 50%
Interference (ICM Band)	≤ 2
Assignment to UL/OL	≥ 80%
Assignment to OL/UL	≥ 80%
TF Mode	Master for UL Cell (900) and Slave for OL Cell (1800)
ECSC	ECSC parameter is 'yes'.

Table 4.4 KPI to monitor the performance and quality of newly swapped (RBS)

RBS 2202 and RBS 2102 are being Swapped RBS2206. To analyze the performance Radio KPI of new RBS2206 after swapping need to be compared with that of the RBS2202/2102 before swapping This Reference will be used to monitor the performance and quality of newly swapped (RBS) site only.

Name of Parameter	Limit Value
Traffic	Traffic Consistency check before and after Swap. Threshold for the change in Traffic is -30%.
Call Setup Success Rate	≥ 95%
TCH Congestion	≤ 5%
SDCCH Congestion	≤ 2%
Call Drop	Drop pattern before and after Swapping, Threshold for the TCH Drop is Change in TCH Drop ≤ 30%.
MPD	Threshold for the change in MPD can be decreased by 20% (Maximum).
Speech Quality Index (SQI)	≥ 50%
Interference (ICM Band)	≤ 2
Internal Incoming Handover	≥ 90%
Internal Outgoing Handover	≥ 90%
External Incoming Handover	≥ 90%
External Outgoing Handover	≥ 90%

4.2.2 Process Flow

Stability Test process of New BTS is performed in three steps where performance and quality of three different factors are monitored and necessary steps are taken according to the requirement to improve the quality. The details of these steps are given below

4.2.2.1 MPD Check

NIC engineer will check MPD of all the New BTSs that have been given on-air yesterday, at 1100 am on every working day. If the MPD of the cell is good by comparing with the Reference Table 4.2 where threshold value for MPD (MPD≥30) is defined, they will not take any action. If the MPD is poor according to the Reference Table 4 2, NIC engineer will generate a Work request to solve the problem.

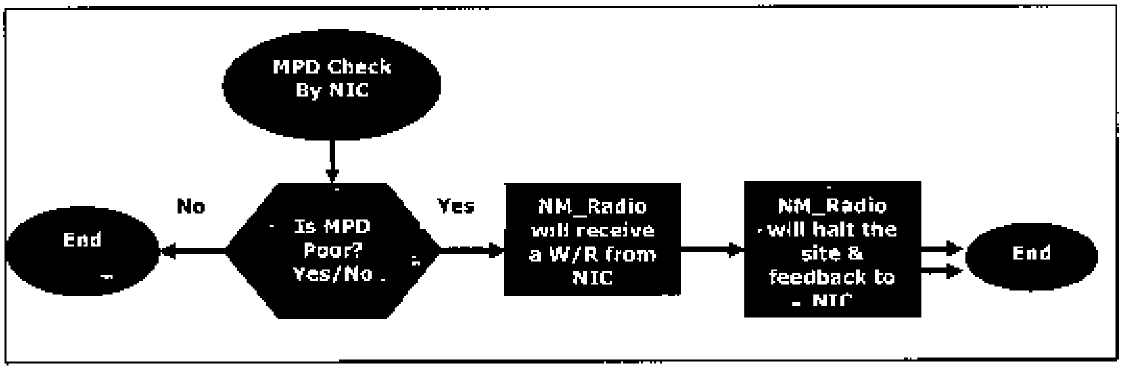


Figure 4.1 Flow chart to solve MPD

4.2.2.2 PCM Quality Monitor

NIC engineer will check the PCM quality of New BTS after One day later (24 hours) from the on-air date. If the PCM quality is acceptable with comparing the Reference Table 4.1, NIC engineer will provide that information in ROC as the PCM quality of that BTS is "OK". If the PCM quality is bad, NIC engineer will initiate a work request (W/R).

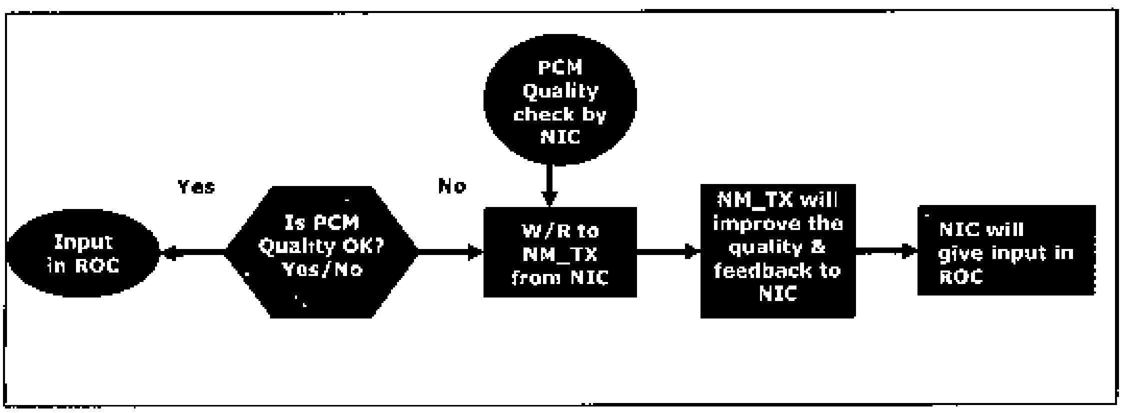


Figure 4.2 Flow chart to solve PCM Quality

4.2.2.3 Cell Performance

NIC engineer will monitor the cell performance of the new BTS that has been given on-air three days (72 hours) ago. In cell performance monitoring process, they have to check different parameters of the cell related to the quality. The following parameters will be checked by the NIC engineers to ensure the quality of that cell

Average Traffic and Congestion

NIC engineers will check average traffic and congestion of the cell. If it is found that the quality of the cell is poor due to SDCCH congestion or TCH congestion or both of them then NIC engineer will initiate a work request (W/R) in ROC and send it to the concerned planner of Radio Planning (RP) and his/her group. The concerned planner (RP) will provide the necessary steps to remove the SDCCH/TCH congestion and this feedback will be executed by NIC.

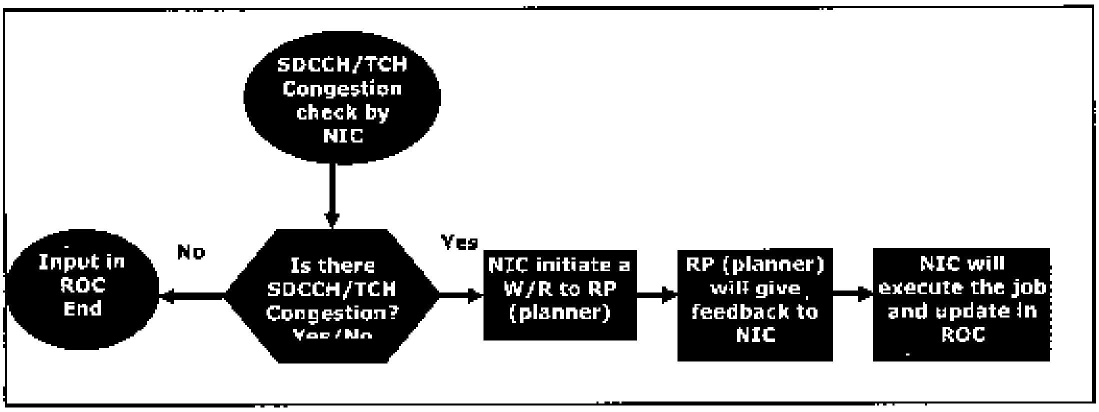


Figure 4.3 Flow chart to solve SDCCH/TCH congestion

Average MPD

NIC engineer will check the average MPD of the cell. If the MPD is poor, they will investigate and monitor eight different factors that might be the reason for poor MPD. The factors are
a. TCH drop. b. Signal strength Drop c. Quality Drop. d. Uplink Drop. e. Downlink drop f. Timing Advance drop. g. Sudden Drop. h. Other Drop.
They will escalate this information and initiate a work request (W/R) to the concerned planner (RP) and his group or NM_Radio depending upon the factor.

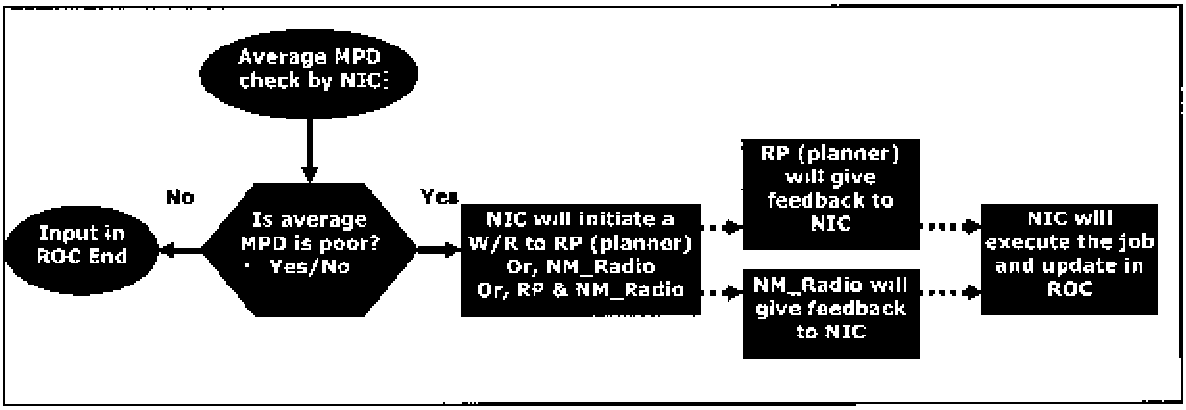


Figure 4 4 Flow chart to solve avg MPD

Average Call Setup

NIC engineer will check the average Call setup of the cell. If the average Call setup rate is poor, they will investigate and monitor the TCH attempt congestion of the cell. If TCH attempt congestion rate of the cell is high, NIC engineer will escalate this information and initiate a work request (W/R) to the concerned planner (RP) and his/her group. After receiving the W/R the concerned planner (RP) will act accordingly and he/she will provide the feedback to NIC. The SLA for that job will be one day (24 hours) after receiving the mail from NIC.

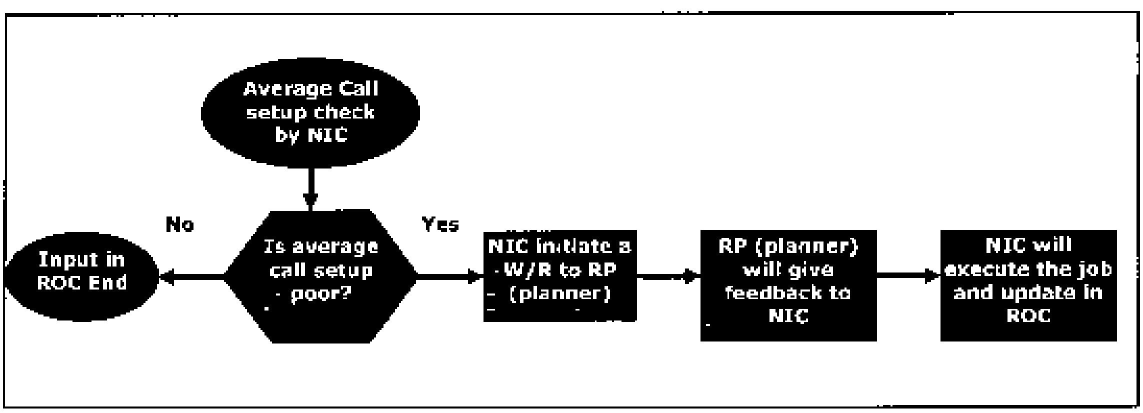


Figure 4.5 Flow chart to solve Call set up problem

Average Speech Quality Index (SQI)

NIC engineer will check the average Speech Quality Index (SQI) of the cell. If the acceptable SQI rate is poor, NIC engineer will escalate this information and initiate a work request (W/R) to the concerned planner (RP) and his/her group. After receiving the W/R the concerned planner (RP) will act accordingly and he/she will provide the feedback to NIC.

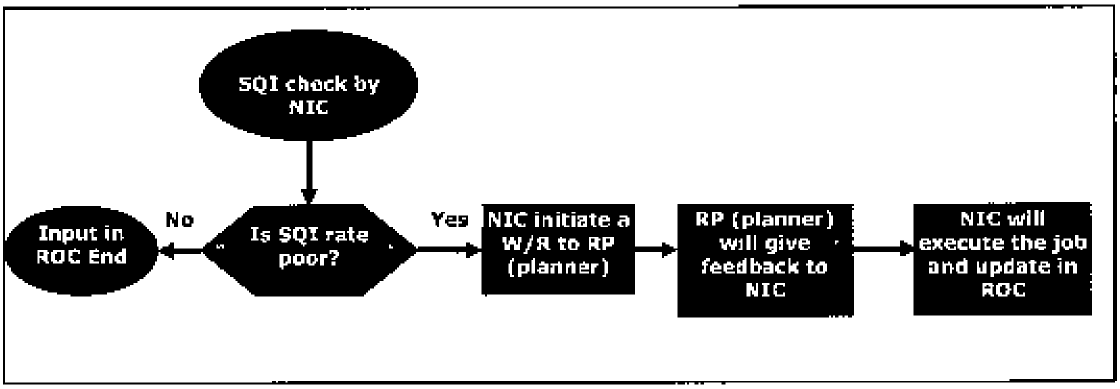


Figure 4.6 Flow chart to solve SQI

Average Incoming/ Outgoing Handover

NIC engineer will check the average Incoming/ Outgoing both external/internal Handover of the cell. If the handover success rate is poor, NIC engineer will escalate this information and initiate a work request (W/R) to the concerned planner (RP) and his group.

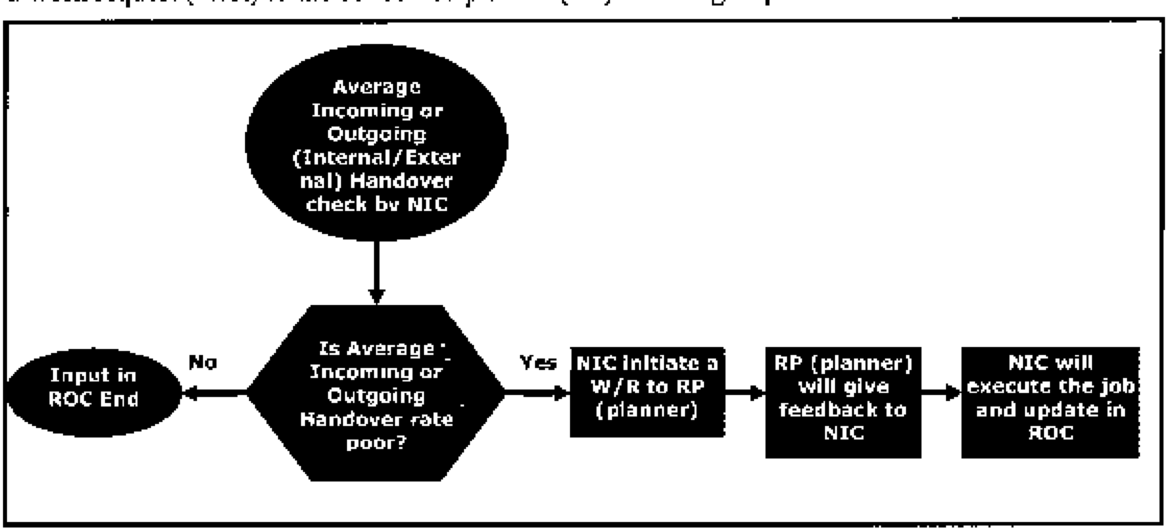


Figure 4.7 Flow chart to solve Handover

4.3 STATISTICAL PROCESS CONTROL

Statistical process control, or SPC, is a fundamental approach to quality control and improvement that is based on objective data and analysis. The origin of PC dates back to the 1920s and 1930s at the Western Electric Company and Bell Telephone Laboratories. Walter Shewhart (1891-1967) recognized that variation in a production process can be understood and controlled through the use of statistical methods. He pioneered the use of statistical methods as a tool to manage and control production. Over the next several decades, these tools were taught to engineers and production personnel throughout American industry. The need for higher-quality production to support the defense industry during World War II gave a boost to the use of SPC.

One of Shewhart's disciples, W. Edwards Deming (1900-1993), was a strong advocate of SPC and trained many engineers in the concept during the war years. However, he was never able to convince upper management in the U.S. of SPC's benefits and importance When Deming was invited to train Japanese engineers in statistical methods after the war, he realized that quality improvement efforts could never be sustained without top management support. It was not difficult for him to gain the attention of every level of worker-from maintenance to CEO, since Japan was rebuilding from complete devastation. The Japanese were eager to learn and apply new tools that would help them rebuild their economy. And the rest, as they say, is history. Statistical methods, combined with strong programs in human resources and a focus on continuous improvement to better respond to customer needs, enabled Japanese companies to emerge as powerful global competitors within only a few decades.

When Deming's contributions to Japan became recognized in America around 1980, the modern quality movement began. Many major corporations began to experiment with quality improvement techniques, such as statistical process control. Ford Motor Company and other U.S. automobile manufacturers began to require their suppliers to show statistical evidence of the quality of their products as part of their Q 101 Quality System Standard. Ford insisted that statistical process control be used as an integral part of suppliers' processes to assure quality and provide accurate information for continuous quality and productivity improvement (Chaudhry and Higbie, 1990). As these requirements spread throughout the logistics chain, the use of SPC became widespread throughout American industry.

SPC consists of three words statistical, process, and control. Understanding each of these is crucial to using SPC effectively. Let's start with process.[8]

4.3.1 A Focus On Processes

A major difference between the old-style approach to management and TQM is a focus on processes. In the past, quality control was product driven. Inspectors would measure critical dimensions carefully, and either scrap or rework the parts that did not conform Although this practice resulted in good quality of the final product, it was wasteful and did not lead to improvements in quality, cost, or productivity.

The quality of production output is determined by the process that produces the output. A process is a way of doing things. A process takes inputs (materials) from a supplier, transforms them, and delivers outputs (products) to a customer. The transformation is accomplished by the particular combination of equipment, labor, work methods, and materials used to create the product or service. By focusing on how work gets done and what process factors affect product output, quality can be improved and the number of mistakes can be reduced. SPC is a method of gathering and analyzing data about processes to better understand them and, ultimately, to improve them.

Improvement of processes leads to better quality products and services and to less waste and rework. Better quality leads to higher customer satisfaction, higher sales and higher revenues; less waste and rework reduces costs. The net result is higher corporate profitability and improved competitiveness.[8]

Variation and Statistics

We see variation all around us-in the weather, in sports, and in our own performance and behavior. When a baseball player has a .300 batting average, it does not mean that he will always get 3 hits out of every 10 at bats He may get 5 hits in a row, or he could go 10 at bats without a hit. We cannot predict what he will do at any one time that he steps up to the plate, but we can predict, with reasonable accuracy, what he will do over a long period of time provided everything remains the same-no injuries or scandals!

It is everyone's responsibility-workers and managers alike-to understand work processes and to improve them. Quantitative methods and statistical tools provide workers and managers with the tools needed to quantify variation, identify causes, and find solutions to reduce or remove unwanted variation, and monitor progress objectively. Statistical process control can help to achieve these goals when it is part of a total problem-solving effort. Simply going through the motions and providing data because the boss or customer wants it will not help to improve operations or better satisfy customers. Teamwork and participation play an important organizational role.

Control

A process is in control if it is affected only by common causes of variation. A process that is in control is stable, and its performance can be predicted, at least within limits of variation. On the other hand, if special causes occur frequently and without our knowledge, we do not know how the process will perform. We need to be able to control a process to maintain its stability. Control is the process of evaluating performance, comparing that performance to a goal or standard, and then taking corrective action when necessary.

Control is not a substitute for continuous improvement; it is a means of maintaining improvements. The data collected through systematic measurement can be used productively to identify further areas for improvement. Measures give managers the information needed to reach their goals and lead to actions for improvement.

Some quality problems are management-controllable while others are operator-controllable. Joseph Juran, who also made substantial contributions to the Japanese quality education effort after World War II, defines operator controllability in the following way To be operator-controllable, three conditions must be met

(1) the operators must have the means of knowing what is expected of them through clear instructions and specifications.
(2) They must have the means of determining their actual performance, typically through inspection and measurement, and
(3) They must have a means of making corrections if they discover a variance between what is expected of them and their actual performance.

If any one of these criteria is not met, then the quality problem must be management-controllable, not operator-controllable. W. Edwards Deming also made this important distinction.

4.3.2 Assistance 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[2]

4.3.3 Basic Statistical Process Control (SPC) Methods

Statistical process control or SPC is a family of tools used to monitor, control and improve process and systems. The tools "make the process and systems visible". As per Dr. Kaoru Ishikawa "As much as 95% of quality related problems can be solved with seven fundamental quantitative tools".

Despite a lofty title, understanding and using SPC does not require advanced knowledge of statistics. Rather, the seven basic tools of quality and formalized body of techniques involve tabulating, depicting and describing data sets.
Once the system is visible, the describing and identifying appropriate actions to improve the process and systems are generally self evident.[7]
The basic tools of quality include

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

4.3.3.1 Pareto Principle

The Pareto principle suggests that most effects come from relatively few causes. In quantitative terms 80% of the problems come from 20% of the causes (machines, raw materials, operators etc.); 80% of the wealth is owned by 20% of the people etc. Therefore effort aimed at the right 20% can solve 80% of the problems. Double (back to back) Pareto charts can be used to compare 'before and after' situations.

General use: to decide where to apply initial effort for maximum effect.

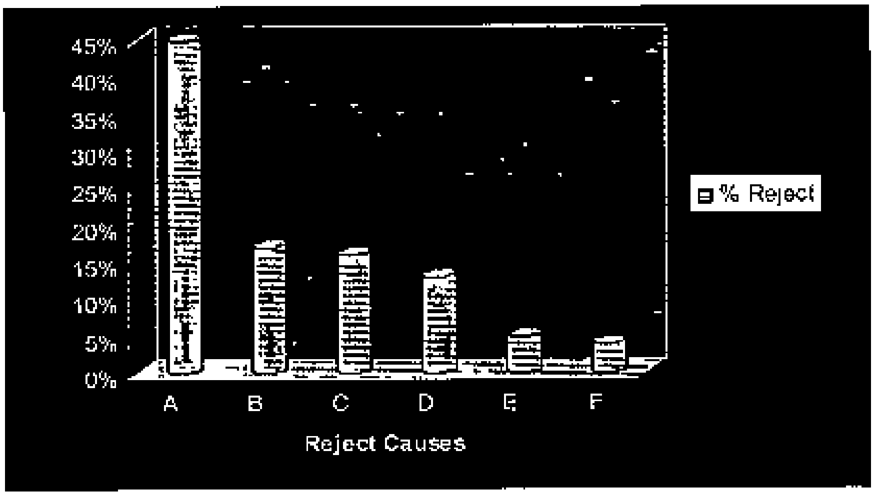


Figure 4.8 Graphical display of Pareto principle[7]

4.3.3.2 Control Charts

Control charts are a method of Statistical Process Control, SPC. (Control system for production processes). They enable the control of distribution of variation rather than attempting to control each individual variation. Upper and lower control and tolerance limits are calculated for a process and sampled measures are regularly plotted about a central line between the two sets of limits. The plotted line corresponds to the stability/trend of the process.

General Use: Action can be taken based on trend rather than on individual variation. This prevents over-correction/compensation for random variation, which would lead to many rejects.[7]

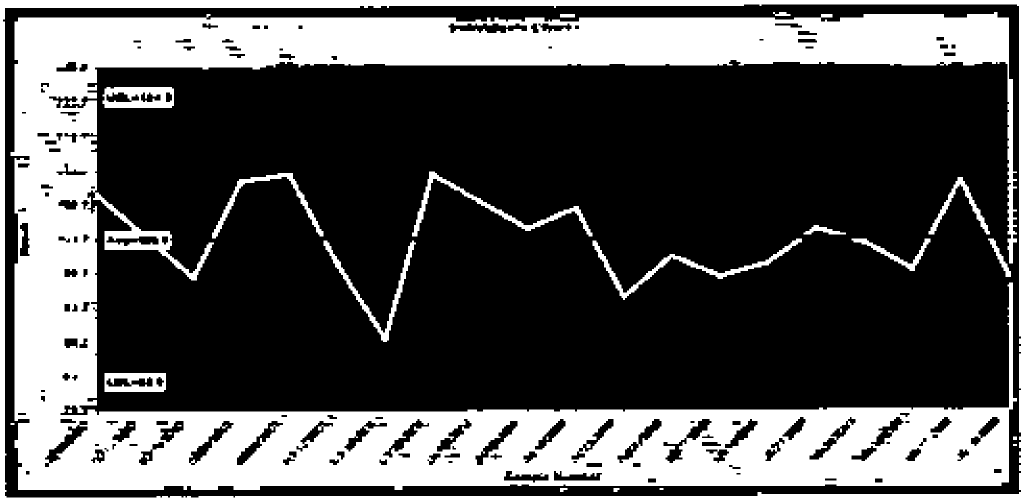


Figure 4.9 Graphical display of Control Charts

4.3.3.3 Cause Effect, Fishbone, Ishikawa Diagram

This is the tool for analyzing and illustrating a process by showing the main causes and sub causes leading to an effect (symptom). It is sometimes referred to as the "Ishikawa diagram," because Kaoru Ishikawa developed it, and the "Fishbone diagram," because the complete diagram resembles a fish skeleton. The fishbone is easy to construct and invites interactive participation.[7]

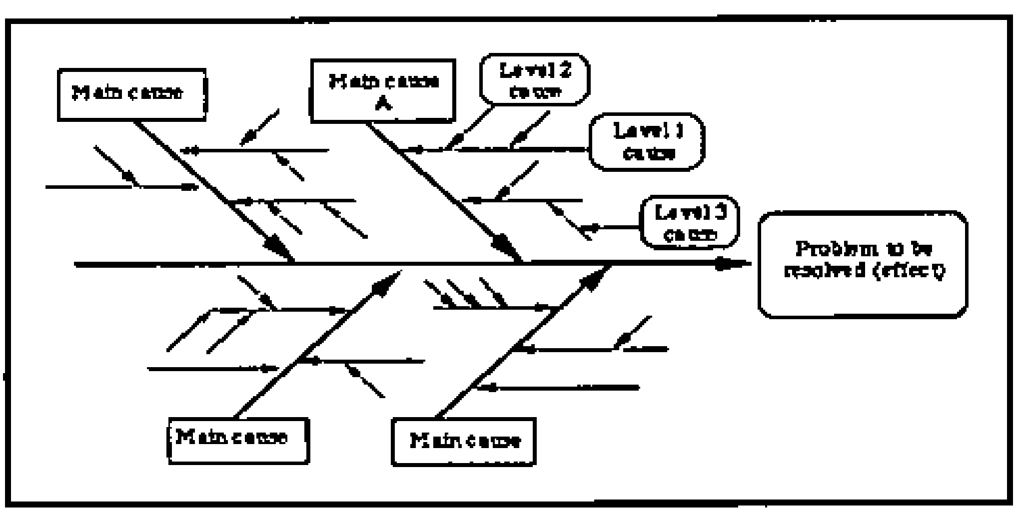


Figure 4.10 Graphical display of Cause effect diagram

4.3.3.4 Histogram Or Bar Graph

A Histogram is a graphic summary of variation in a set of data. It enables us to see patterns that are difficult to see in a simple table of numbers. It can be analyzed to draw conclusions about the data set.

A histogram is a graph in which the continuous variable is clustered into categories and the value of each cluster is plotted to give a series of bars as bellow.[1]

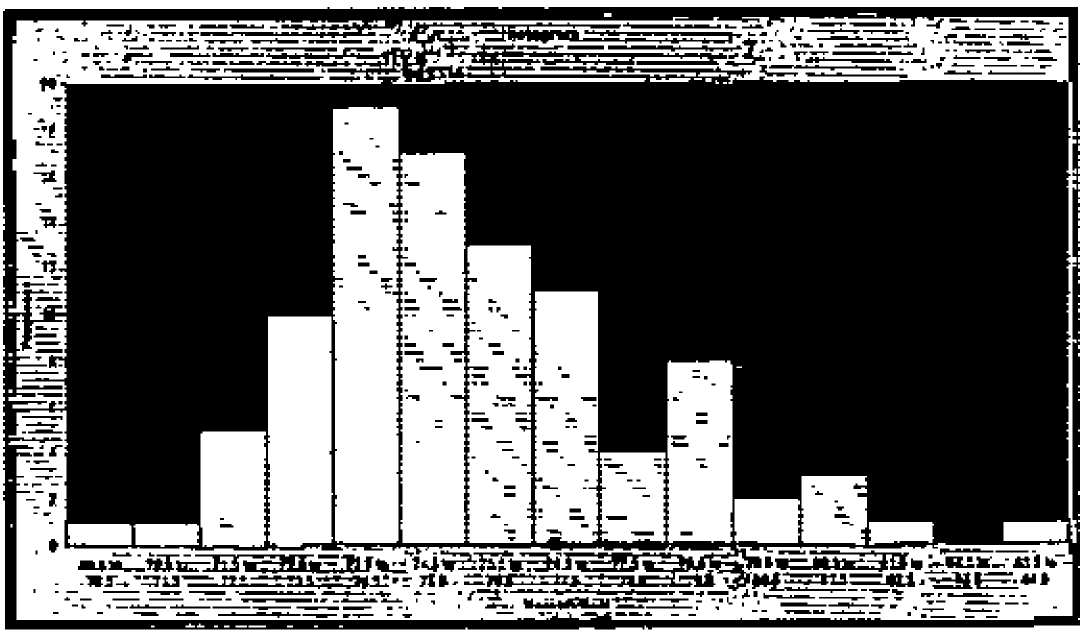


Figure 4.11 Graphical display of Histogram

4.4 ANALYSIS OF PERFORMANCE BY CONTROL CHART

4.4.1 Characteristics Of Control Charts

If a single quality characteristic has been measured or computed from a sample, the control chart shows the value of the quality characteristic versus the sample number or versus time. In general, the chart contains a center line that represents the mean value for the in-control process. Two other horizontal lines, called the upper control limit (UCL) and the lower control limit

(LCL). are also shown on the chart. These control limits are chosen so that almost all of the data points will fall within these limits as long as the process remains in-control.[1]

4.4.2 Types Of Control Charts

A Control Chart is most effective when used for repetitive processes that are important to an organization and for which data can be obtained. There are two categories of Control Charts[1]

Variables Control Charts - used when measurements are quantitative, for example, height, weight, or thickness. Types of variables control charts are

- X bar R chart (also called averages and range chart).
- X bar S chart
- Chart of individuals (also called **X** chart, **X-R** chart, **IX-MR** chart, Xm R chart, moving range chart).
- Moving average–moving range chart (also called MA–MR chart)
- Target charts (also called difference charts, deviation charts and nominal charts)
- CUSUM (also called cumulative sum chart)
- EWMA (also called exponentially weighted moving average chart)
- multivariate chart also called Hotelling T2

Attributes Control Charts - used when measurements are qualitative, for example, accept/reject. Types of Attributes Control Charts are

- p chart (also called proportion chart)
- np chart
- c chart (also called count chart)
- u chart

4.4.3 Elements Of A Control Charts

A control chart consists of

1. a central line,
2. an upper control limit,
3. a lower control limit, and
4. Process values plotted on the chart.

If all process values are plotted within the upper and lower control limits and no particular tendency is noted, the process is referred to as "In Control." If the process values are plotted outside the control limits or show a particular tendency, however, the process is referred to as "Out Of Control" (see red-circled data points in Figure 2 below).

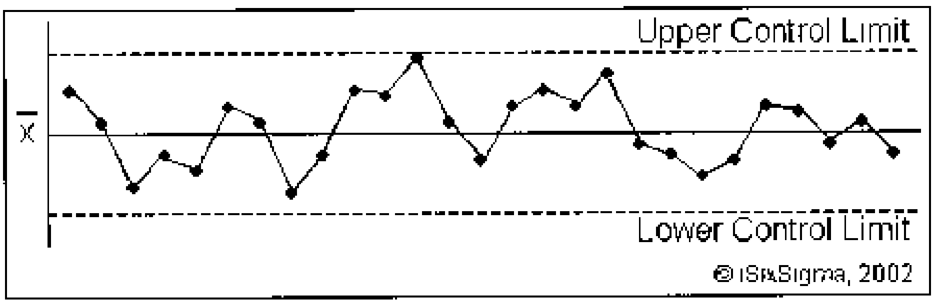


Figure 4.12 "In Control" Process Control Chart

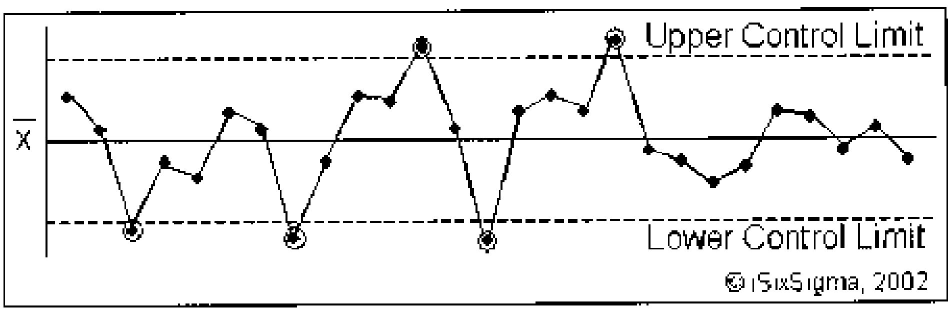


Figure 4 13 "Out Control" Process Control Chart

In a control chart, control limits are calculated by the following formula

(Average Process Value) ±(3 x (Standard Deviation))

Where, the standard deviation is due to unassigned process variation only.[1]

4.4.4 Constructing a Control Chart

Here is the general process for making or constructing a control chart for your process

1. Select the process like to chart
2. Determine process sampling plan
3. Collect data from process
4. Calculate the control chart specific statistics

5. Calculate control limits
6. Construct of control chart

4.4.5 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. [1]

4.4.6 Analysis Using 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

The control limits for this chart type can be determined by the formula[1]

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

Needed computations are

- Divide the number of Non conformities to batch size, thus result the proportion of non conformities in each batch.
- Sum separately the number of all batches and number of defectives.
- Divide the sum of non conformities to the sum of batches and the result is mean of the proportion of defectives.
- Compute the lower and upper control limits (LCL and UCL) using the formulas LCL = p -3 sqrt(p(1-p)/ni), where ni is the batch size and p is the mean computed previously. UCL = p +3 sqrt(p(1-p)/ni);
- If LCL is lower than 0 set it to 0. If UCL is greater than 1, set it to 1;
- Plot the computed data on the chart and observe if there is any observation that fall outside the control limits.

Table 4.5 Stability Test Period Data for GP Network[10]

Week No	Total Sites	Both PCM & Cell performance OK	Poor Performing sites	PCM performance is Poor	Cell performance is Poor	Both PCM & Cell performance are poor
W1	88	56	32	4	22	6
W2	60	34	26	12	12	2
W3	143	80	63	25	30	8
W4	110	89	21	9	10	2
W5	108	83	25	10	11	4
W6	15	9	6	2	3	1
W7	85	54	31	15	13	3
W8	154	106	48	16	26	6
W9	60	32	28	10	18	0
W10	114	69	45	21	22	2
W11	41	29	12	6	6	0
W12	99	58	41	18	20	3
W13	111	74	37	21	11	5
W14	104	75	29	23	11	5
W15	14	9	5	1	3	1
W16	13	10	3	2	1	0
Sum	1319	867	452	195	219	48

Calculation for Poor Performing sites

Table 4.6 Data for Poor Performing Site Using P Chart

Week No	Total Sites	Poor Performing sites	Sample fraction Poor performing
W1	88	32	0.3636
W2	60	26	0.4333
W3	143	63	0.4406
W4	110	21	0.1909
W5	108	25	0.2315
W6	15	6	0.4000
W7	85	31	0.3647
W8	154	48	0.3117
W9	60	28	0.4667
W10	114	45	0.3947
W11	41	12	0.2927
W12	99	41	0.4141
W13	111	37	0.3333
W14	104	29	0.2788
W15	14	5	0.3571
W16	13	3	0.2308
	1319	452	

Here P bar= 452/1319= 0.3427

n bar (For variable sample)= 1319/16= 82.4375

$UCL=0.3427+3\sqrt{0.3427\,(1-0.3427)/82.4375} = 0.4995$

CL=0.3427

$LCL=0.3427-3\sqrt{0.3427\,(1-0.3427)/82.4375} = 0.1859$

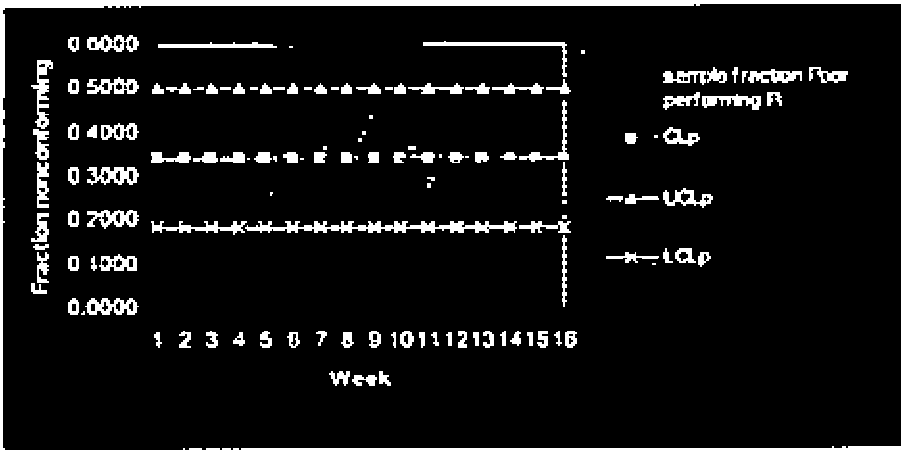


Figure 4.14 Chart for Poor Performing sites

Comments

a. All results fall within control limits.

b. The pattern of plots of points is more or less random (with random ups and downs around the mean .03427). That means there is no shift in the process mean or no indication of process incapability.

c. The overall chart indicates the existence of a control in the process.

Calculation for Poor PCM Performance

Table 4.7 Data for Poor PCM Performing Site Using P Chart

Week No	Total Sites	PCM performance is Poor	Sample fraction Poor performing
W1	88	4	0.0455
W2	60	12	0.2000
W3	143	25	0.1748
W4	110	9	0.0818
W5	108	10	0.0926
W6	15	2	0.1333
W7	85	15	0.1765
W8	154	16	0.1039
W9	60	10	0.1667
W10	114	21	0.1842
W11	41	6	0.1463
W12	99	18	0.1818
W13	111	21	0.1892
W14	104	23	0.2212
W15	14	1	0.0714
W16	13	2	0.1538
	1319	195	

Here P bar= 195/1319= 0.1478

n bar (For variable sample)= 1319/16= 82.4375

$UCL=0.1478+3\sqrt{0.1478\,(1-0.1478)/82.4375} = 0.2651$

CL=0.1478

$LCL=0.1478-3\sqrt{0.1478\,(1-0.1478)/82.4375} = 0.0306$

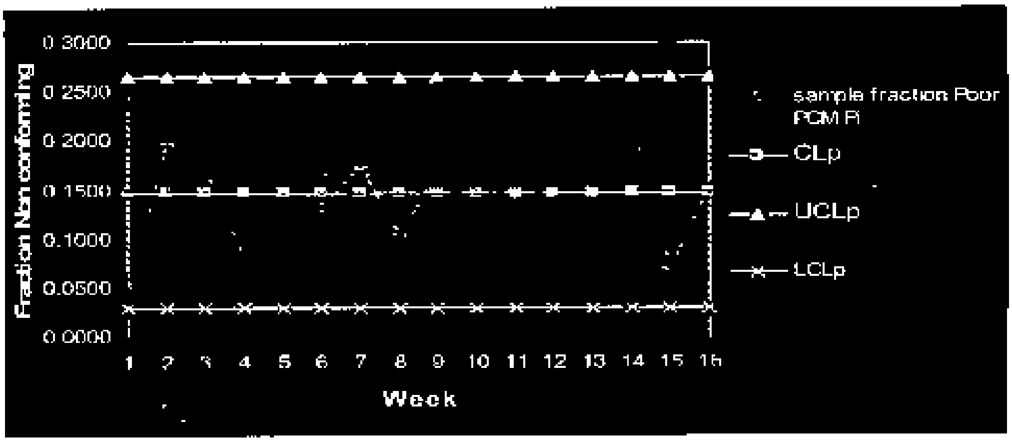


Figure 4.15 Chart for Poor PCM Performing sites

Comments

a. All results fall within control limits.

b. With an exception of a single plot (WK01), all others remain nearer to mean.

c. The pattern of plots of points is more or less random (with random ups and downs around the mean 0.1478). That means there is no shift in the process mean or no indication of process incapability.

d. The overall chart indicates the existence of a good control in the process.

Calculation for Poor Cell Performance

Trial 01

Table 4.8 Data for Poor Cell Performing Site Using P Chart

Week No	Total Sites	Cell performance is Poor	sample fraction Poor performing
W1	88	22	0.2500
W2	60	12	0.2000
W3	143	30	0.2098
W4	110	10	0.0909
W5	108	11	0.1019
W6	15	3	0.2000
W7	85	13	0.1529
W8	154	26	0.1688
W9	60	18	0.3000
W10	114	22	0.1930
W11	41	6	0.1463
W12	99	20	0.2020
W13	111	11	0.0991
W14	104	11	0.1058
W15	14	3	0.2143
W16	13	1	0.0769
	1319	219	

Here P bar= 219/1319= 0.1660

n bar (For variable sample)= 1319/16= 82.4375

$UCL=0.1660+3\sqrt{0.1660\,(1-0.1660)/82.4375} = 0.2890$

CL=0.1660

$LCL=0.1660-3\sqrt{0.1660\,(1-0.1660)/82.4375} = 0.0431$

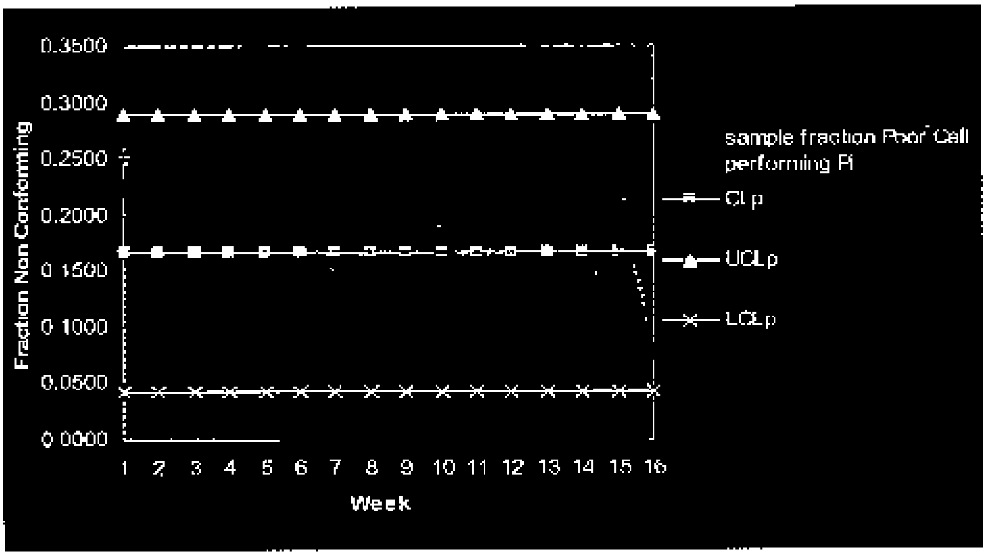


Figure 4.16 Chart for Poor Cell performing sites Trial 01

Comments

a. The pattern of plots of points is more or less random against the central line.
b. But, it is observed that at Week no 9, the proportion of Poor cell Performing (0.3000) go beyond the upper control limit (0.2890). Which is certainly unwanted. This may indicate a lack of control, and is a strong suggestion that a 100% inspection of week no. 9 should be undertaken.

Thus for getting smoother control limit, the data from week no 09 is dropped and new Trial limits can be computed.

Trial 02

After dropping Week No 09 from the data sheet, the revised center line, Upper & Lower control limits will be following

Here P bar= 201/1259= 0.160

n bar (For variable sample)= 1259/15= 83.933

$UCL=0.160+3\sqrt{0.160(1-0.160)/83.933} = 0.280$

CL=0.160

$LCL=0.160-3\sqrt{0.160(1-0.160)/83.933} = 0.040$

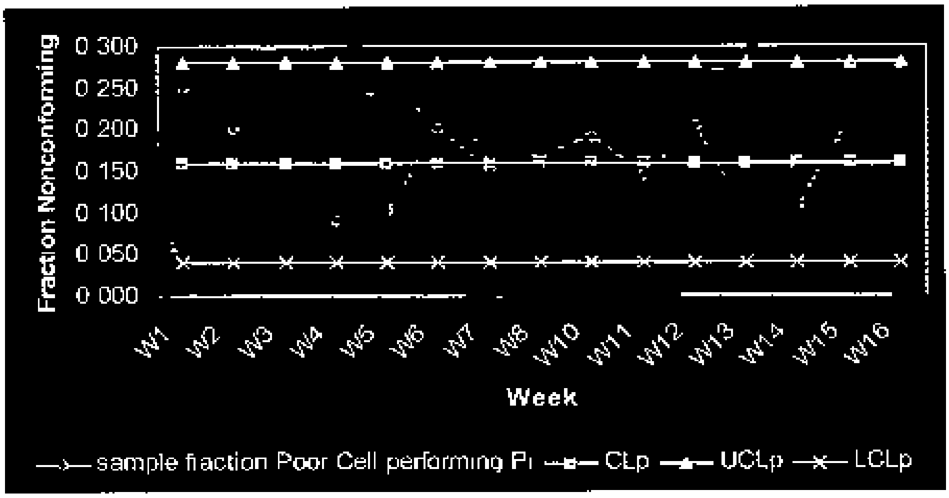


Figure 4.16.1 Chart for Poor Cell performing sites Trial 02

Comments

a. After this trail, it is seen that all the plots fall within the control level.
b. The pattern of plots of points is more or less random (with random ups and downs around the mean .160). That means there is no shift in the process mean or no indication of process incapability.
c. New plots are more random against the new center line than the earlier one, which indicates more stability in the system and acceptability as well As such the new Trial limits can be accepted as the final control limits.

Calculation for both Poor PCM & Cell Performance

Table 4.9 Data for Poor PCM & Cell Performing Site Using P Chart

Week No	Total Sites	Both PCM & Cell performance are poor	sample fraction Poor performing
W1	88	6	0.0682
W2	60	2	0.0333
W3	143	8	0.0559
W4	110	2	0.0182
W5	108	4	0.0370
W6	15	1	0.0667
W7	85	3	0.0353
W8	154	6	0.0390
W9	60	0	0.0000
W10	114	2	0.0175
W11	41	0	0.0000
W12	99	3	0.0303
W13	111	5	0.0450
W14	104	5	0.0481
W15	14	1	0.0714
W16	13	0	0.0000
	1319	48	

Here P bar= 48/1319= 0.0364

n bar (For variable sample)= 1319/16= 82.4375

UCL=0.0364+3$\sqrt{0.0364\ (1-0.0364)/82.4375}$ = 0.0983

CL=0.0364

LCL=0.0364-3$\sqrt{0.0364\ (1-0.0364)/82.4375}$ = -0.0255 » 0.0000

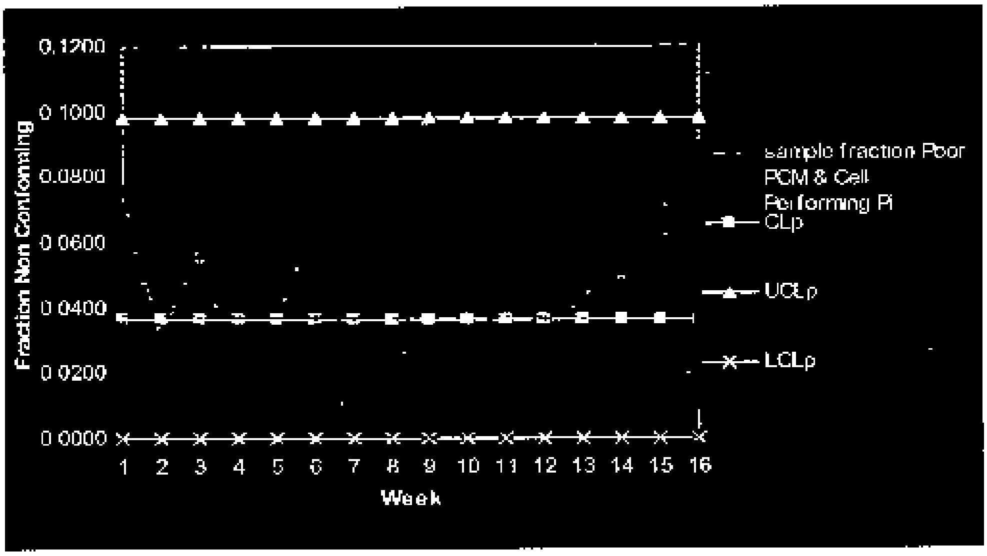


Figure 4.17 Chart for both Poor PCM & Cell performing sites

Comments

a. All plots fall within control limits.

b. The fluctuations are really random against the center line with no significant trend (exception 5 sample shows increasing trend but 2 of them are bellow the mean and 3 plots above the mean).

c. It can be concluded that the process is in statistical control, although scopes for continuous improvements are always there. Continuous improvement may bring in less degree of variations in the plots, which is always desirable.

4.4.7 Analysis Using U Chart

Another approach is to bast the control chart on the average number of nonconformities per inspection unit. Then

$$\bar{u} = \frac{\sum_{i=1} c_i}{\sum_{i=1} n_i}$$

Where ci is the number of nonconformities in the ith sample and ni is the sample size of the sample. (This approach is particularly useful when the entire production is inspected and the production quantity varies with each lot.). Note that u bar is the Poisson random variables Thus, the parameters of the control chart are given by

$$UCL_u = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$$
$$CL_u = \bar{u}$$
$$LCL_u = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$$

On the control chart, each data point is based on a different sample size. The control limit will vary from sample to sample. There are three procedures to handle the variable sample size solution.

a. Use variable control limits.
b. Use $\bar{n} = \sum n_i / m$
c. Use n bar to compute the control limits, but use n i to examine values for points near these limits.[1]

Calculation for Poor Performing sites

Table 4.10 Data for Poor Performing Site Using U Chart

Week No	Total site ni	Poor Performing sites ci	ci/ni
W1	88	32	0.36
W2	60	26	0.43
W3	143	63	0.44
W4	110	21	0.19
W5	108	25	0.23
W6	15	6	0.40
W7	85	31	0.36
W8	154	48	0.31
W9	60	28	0.47
W10	114	45	0.39
W11	41	12	0.29
W12	99	41	0.41
W13	111	37	0.33
W14	104	29	0.28
W15	14	5	0.36
W16	13	3	0.23
	1319	452	

Here U bar= 452/1319= 0.34

For u control chart for average control limit

n bar = 1319/16= 82.44

UCL=0.34+3√(0.34/82.44) = 0.53

CL=0.34

LCL=0.34-3√(0.34/82.44) = 0.15

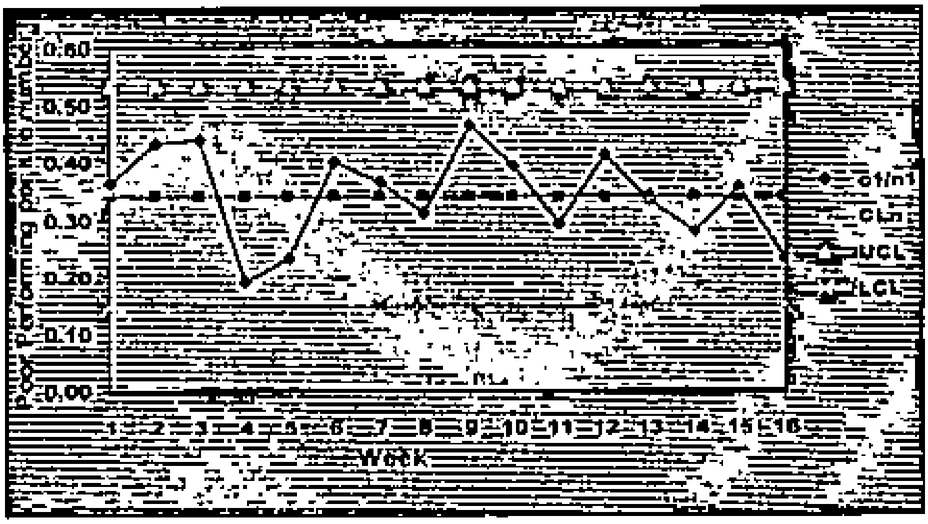


Figure 4.18 Chart for Poor performing sites

Comments

- It can be seen from the above figure that all the points are within control limits, which means the process is in statistical control.
- Besides this, the plots are also fairly random against the mean or center line.
- Thus, it can be concluded that the process is in good condition.

Calculation for Poor PCM Quality sites

Table 4.11 Data for Poor PCM Performing Site Using U Chart

Week No	Problem	PCM Performance Quality	C1/n1
W1	88	4	0.05
W2	60	12	0.20
W3	143	25	0.17
W4	110	9	0.08
W5	108	10	0.09
W6	15	2	0.13
W7	85	15	0.18
W8	154	16	0.10
W9	60	10	0.17
W10	114	21	0 18
W11	41	6	0.15
W12	99	18	0.18
W13	111	21	0.19
W14	104	23	0.22
W15	14	1	0.07
W16	13	2	0.15
	1319	195	

Here U bar= 195/1319= 0.15

For u control chart for average control limit

n bar = 1319/16= 82.44

UCL= $0.15+3\sqrt{(0.15/82.44)}$ = 0.28

CL= 0.15

LCL= $0.15-3\sqrt{(0.15/82.44)}$ = 0.02

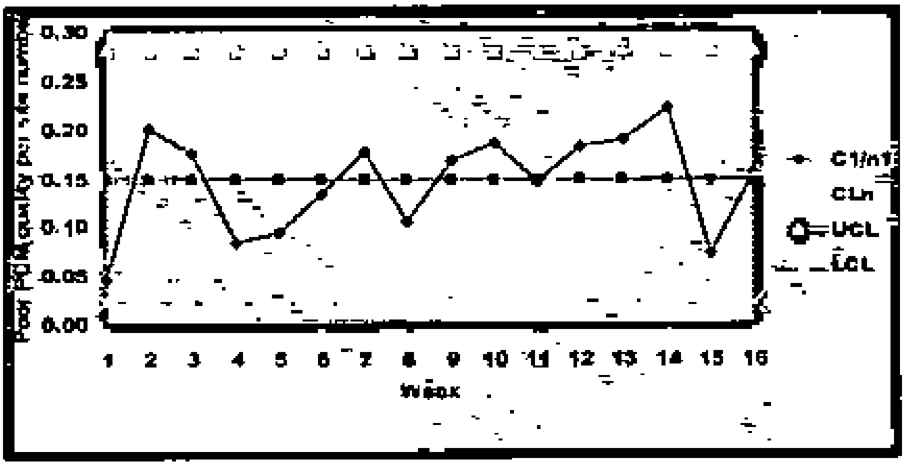


Figure 4.19 Chart for Poor PCM performing sites

Comments

a. All results fall within control limits.
b. The fluctuations are random against the center line up to WK 09. From WK 09 to Wk 14, samples fall on or above the center line. But there are no specific trend (increasing or decreasing).
c. No points are very close to upper or lower control limit.
d. The overall chart indicates that the process is in good condition and there is a fair control in the process though there is improvement scope in the process.

Calculation for Poor Cell Quality sites

Table 4.12 Data for Poor Cell Performing Site Using U Chart

Week No	Total site	Cell Performance quality	c1/n1
W1	88	22	0.25
W2	60	12	0.20
W3	143	30	0.21
W4	110	10	0.09
W5	108	11	0.10
W6	15	3	0.20
W7	85	13	0.15
W8	154	26	0.17
W9	60	18	0.30
W10	114	22	0.19

W11	41	6	0.15
W12	99	20	0.20
W13	111	11	0.10
W14	104	11	0.11
W15	14	3	0.21
W16	13	1	0.08
	1319	219	

Here U bar= 219/1319= 0.17

For u control chart for average control limit

n bar = 1319/16= 82.44

UCL= 0.17+3$\sqrt{}$(0.17/82.44) = 0.31

CL= 0.17

LCL= 0.17-3$\sqrt{}$(0.17/82.44) = 0.03

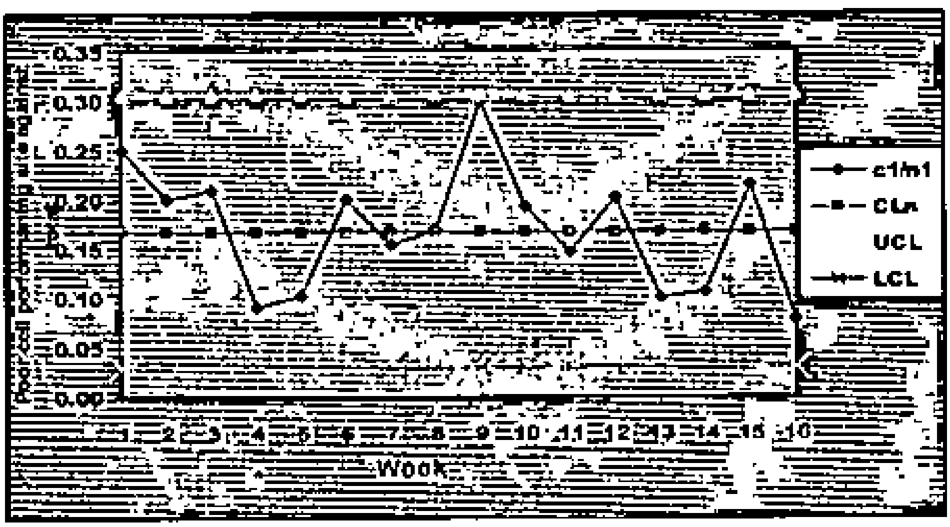


Figure 4.20 Chart for Poor Cell performing sites

Comments

a. It can be seen from the above figure that all the points are within control limits, which means the process is in statistical control. Though one plot at WK 09 it is close to Upper control Limit.

b. Besides this, the plots are also fairly random against the mean or center line.

c. Thus, it can be concluded that the process is in good condition.

Calculation for both Poor PCM & Cell Quality sites

Table 4.13 Data for Poor PCM & Cell Performing Site Using U Chart

Week No .	Total site	Both PCM &Cell performance is poor	C1/n1
W1	88	6	0.07
W2	60	2	0.03
W3	143	8	0.06
W4	110	2	0.02
W5	108	4	0.04
W6	15	1	0.07
W7	85	3	0 04
W8	154	6	0 04
W9	60	0	0.00
W10	114	2	0.02
W11	41	0	0.00
W12	99	3	0.03
W13	111	5	0.05
W14	104	5	0.05
W15	14	1	0.07
W16	13	0	0.00
	1319	48	

Here U bar= 48/1319= 0.04

For u control chart for average control limit

n bar = 1319/16= 82.44

UCL= 0.04+3√ (0.04/82.44) = 0.11

CL= 0.04

LCL= 0.04-3√ (0.04/82.44) = -0.03>>>> 0

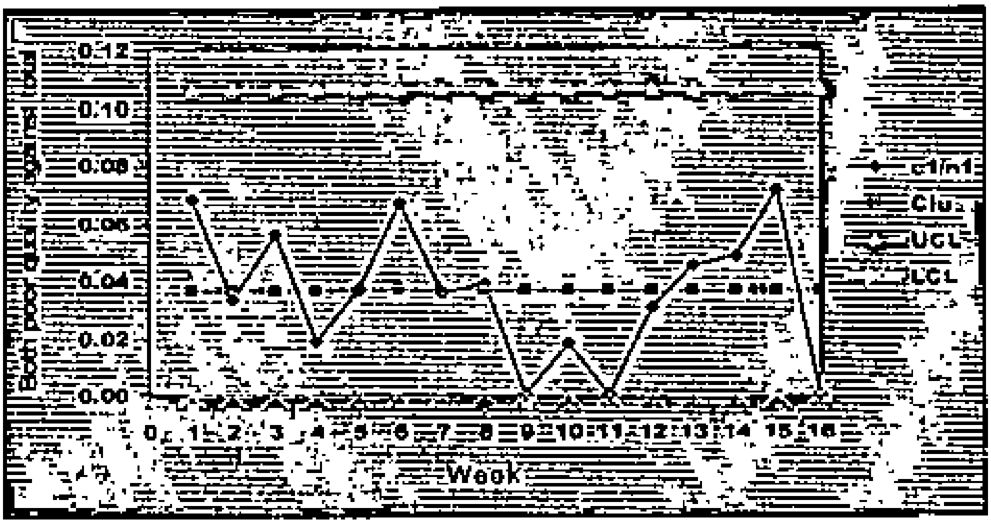


Figure 4.21 Chart for both Poor PCM & Cell performing sites

Comments

a. All results fall within control limits.
b. The pattern of plots of points is more or less random (with random ups and downs around the mean .04). That means there is no shift in the process mean or no indication of process incapability.
c. The overall chart indicates the existence of a control in the process.

4.4.8 Analysis Using C Chart

The C Chart is an attribute control chart for number of Nonconformities, under Poisson's assumption. In case of C chart, the 3 Sigma can be found from the basic equations as follows[1]

UCL C + 3 Sqrt C

CL Mean=C

LCL C - 3 Sqrt C

If lower control limit is less than zero, it must be set at Zero, because number of nonconformities can not be negative.

Similar to Fraction non conformities chart (P- Chart, u chart), when population C value is unknown, it can be approximated by an estimated C bar value, which is to be obtained from sample distribution of sample means. Then the equation becomes

UCL C + 3 $\sqrt{C}$

CL Mean= $\overline{C}$

LCL $\overline{C} - 3\sqrt{\overline{C}}$

Calculation for Poor Performing sites

Table 4.14 Data for Poor Performing Site Using C Chart Trial 01

Week No	Poor Performing sites
W1	32
W2	26
W3	63
W4	21
W5	25
W6	6
W7	31
W8	48

Week No	Poor Performing sites
W9	28
W10	45
W11	12
W12	41
W13	37
W14	29
W15	5
W16	3

Here C bar= 452/16= 28

UCL= $28+3\sqrt{28}$ = 44

CL= 28

LCL=0

These first Trial limits, along with individual sample non conformities, are plotted in a graph bellow

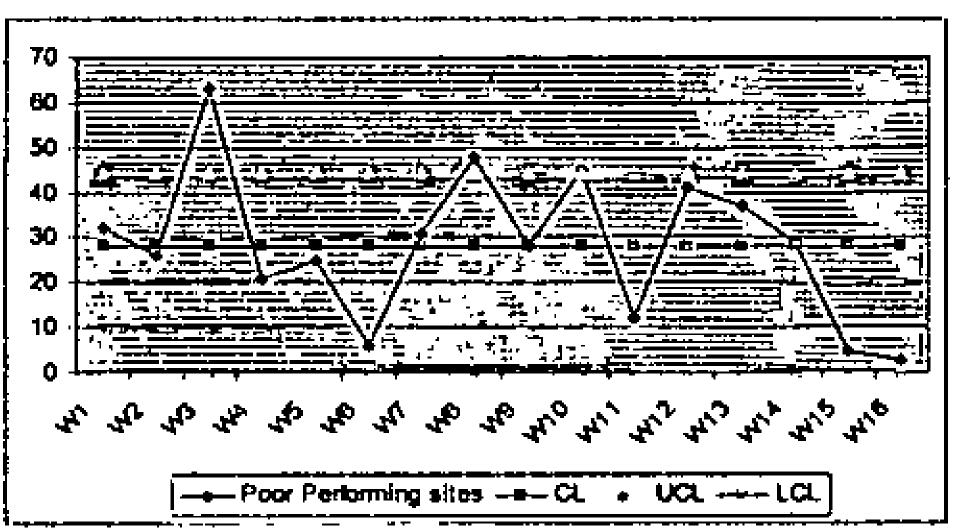


Figure 4.22 Chart for both Poor performing sites

Comments

a. The C control chart in the above figure demonstrate that 13 out of 16 samples indicates fair degree of randomness around the mean CL.

b. Three samples (Wk 03, WK 08, WK 10) falling outside the upper control limit. Among them WK3 fall far above the Upper Control Limit. Further investigation required on that 3 weeks It shows Type I error.

c. The overall chart indicates that the process is not in good condition.

So, to achieve better control in the process new control limit need to be calculated omitting that 3 weeks from the process.

2nd Trail

The 2nd Trial limits are calculated as follows

Table 4.14.1 Data for Poor Performing Site Using C Chart Trial 02

Week No	Poor Performing sites
W1	32
W2	26
W4	21
W5	25
W6	6
W7	31

Week No	Poor Performing sites
W11	12
W12	41
W13	37
W14	29
W15	5
W16	3

Here C bar= 296/13= 23

UCL= $23+3\sqrt{23} = 37$

CL= 23

LCL=0

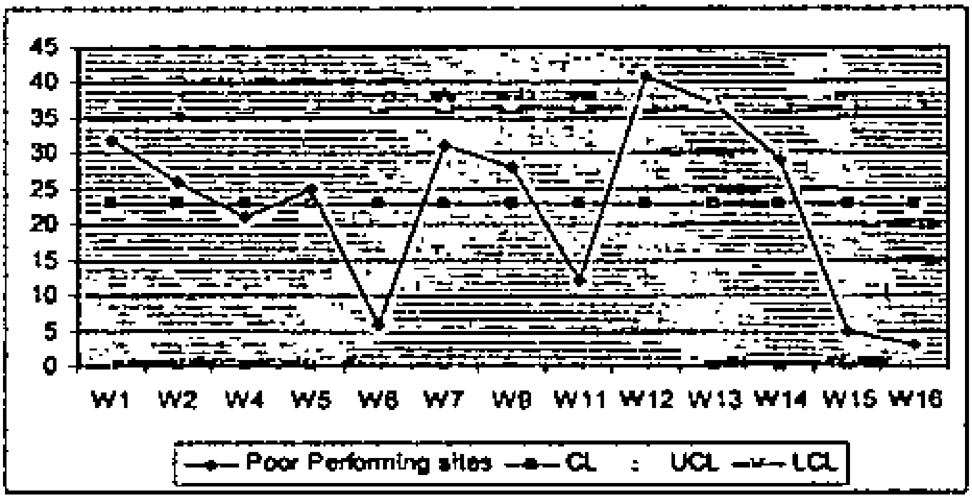


Figure 4.22.1 Chart for both Poor performing sites Trial 02

Comments

a. The revised Trial limits are plotted on the graph above.

b. This demonstrate that 2 samples falls beyond the control limit.

c. New plots are more random against the new center line than the earlier one, which indicates more stability in the system and acceptability as well. But still the process seems to be out of control.

d. So, to achieve better control in the process new control limit need to be calculated omitting that 2 weeks from the process.

Trial 03

The 3rd Trial limits are calculated as follows

Table 4.14.2 Data for Poor Performing Site Using C Chart Trial 03

Week No	Poor Performing sites
W1	32
W2	26
W4	21
W5	25
W6	6
W7	31

Week No	Poor Performing sites
W9	28
W11	12
W14	29
W15	5
W16	3

Here C bar= 218/11= 20

UCL= 20+3√20 = 33

CL= 20

LCL=0

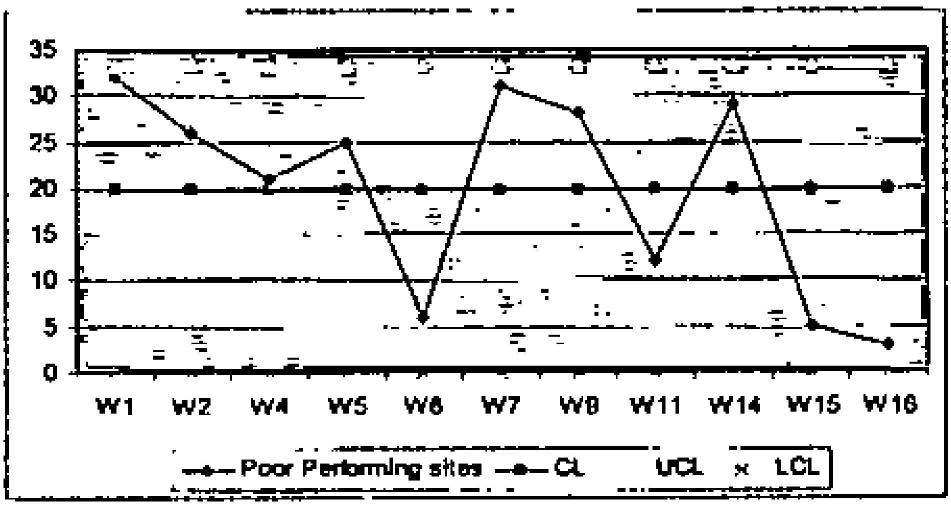


Figure 4.22.2 Chart for both Poor performing sites Trial 03

Comments

a. All samples are within the control limits with fair randomness around the mean or central limit.

b. Thus this limit can be considered as the final control limit.

Calculation for Poor PCM Quality sites

Table 4.15 Data for Poor PCM Performing Site Using C Chart Trial 01

Week No	Poor PCM performing
W1	4
W2	12
W3	25
W4	9
W5	10
W6	2
W7	15
W8	16

Week No	Poor PCM performing
W9	10
W10	21
W11	6
W12	18
W13	21
W14	23
W15	1
W16	2

Here C bar= 195/16= 12.19

UCL= 12.19+3√12.19 = 23

CL= 12.19

LCL=0

These first Trial limits, along with individual sample non conformities, are plotted in a graph bellow

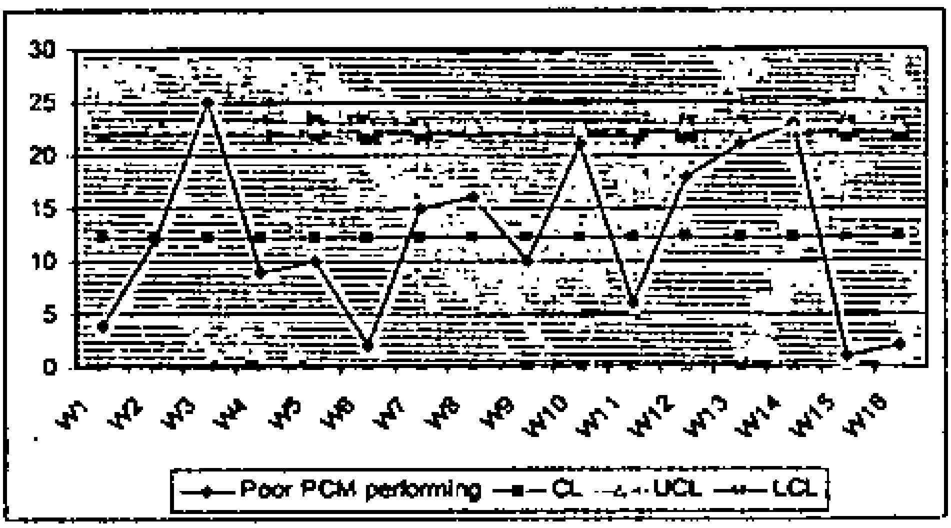


Figure 4.23 Chart for both Poor performing sites Trial 01

Comments

a. From the graph above it can be seen that 2 plots out of 16 fall beyond the Upper Control Limit which may be a sign of process out of control.
b. But, all the plots are random around the control Limit or mean.
c. No increasing or decreasing trend found at the plot. It shows Type I error.
d. To get more control over the process we have to go for new Trial limit omitting W03, WK 14.

Trial 02

The 2nd Trial limits are calculated as follows

Table 4.15.1 Data for Poor PCM Performing Site Using C Chart Trial 02

Week No	PCM performance is Poor
W1	4
W2	12
W4	9
W5	10
W6	2
W7	15
W8	16

Week No	PCM performance is Poor
W9	10
W10	21
W11	6
W12	18
W13	21
W15	1
W16	2

Here C bar= 147/14= 10.50

UCL= $10.50+3\sqrt{10.50} = 20.22$

CL= 10.50

LCL=0

These 2[nd] Trial limits, along with individual sample non conformities, are plotted in a graph bellow

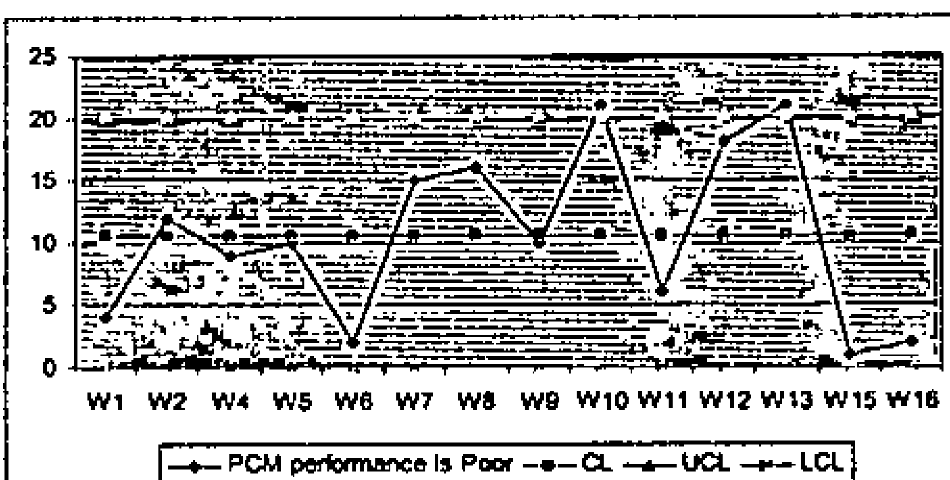


Figure 4.23.1 Chart for both Poor performing sites Trial 02

Comments

a. This graph demonstrates that 2 samples falls just beyond the control limit.
b. New plots are more random against the new center line than the earlier one, which indicates more stability in the system and acceptability as well. But still the process seems to be out of control.
c. So, to achieve better control in the process new control limit need to be calculated omitting that 2 weeks from the process.

Trial 03

The 3rd Trial limits are calculated as follows

Table 4 15.2 Data for Poor PCM Performing Site Using C Chart Trial 03

Week No	PCM performance is Poor
W1	4
W2	12
W4	9
W5	10
W6	2
W7	15

Week No	PCM performance is Poor
W8	16
W9	10
W11	6
W12	18
W15	1
W16	2

Here C bar= 105/12= 8.75

UCL= $8.75+3\sqrt{8.75} = 18$

CL= 8.75

LCL=0

These 3rd Trial limits, along with individual sample non conformities, are plotted in a graph bellow

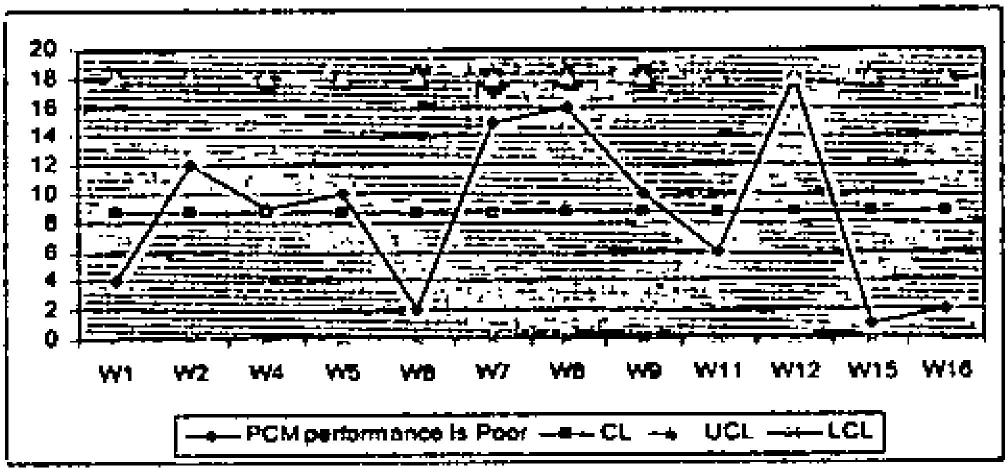


Figure 4.23.2 Chart for both Poor performing sites Trial 03

Comments

a. All Plots fall within the control Limits.
b. The pattern of plots of points is more or less random (with random ups and downs around the mean 8.75). That means there is no shift in the process mean or no indication of process incapability.
c. The overall chart indicates the existence of a control in the process.
d. Thus this limit can be considered as the final control limit.

Calculation for Poor Cell Quality sites

Table 4.16 Data for Poor Cell Performing Site Using C Chart Trial 01

Week No	Cell Performing poor
W1	22
W2	12
W3	30
W4	10
W5	11
W6	3
W7	13
W8	26

Week No	Cell Performing poor
W9	18
W10	22
W11	6
W12	20
W13	11
W14	11
W15	3
W16	1

Here C bar= 219/16= 13.69

UCL= 13.69+3√13.69 = 24.79

CL= 13.69

LCL=0

These first Trial limits, along with individual sample non conformities, are plotted in a graph bellow

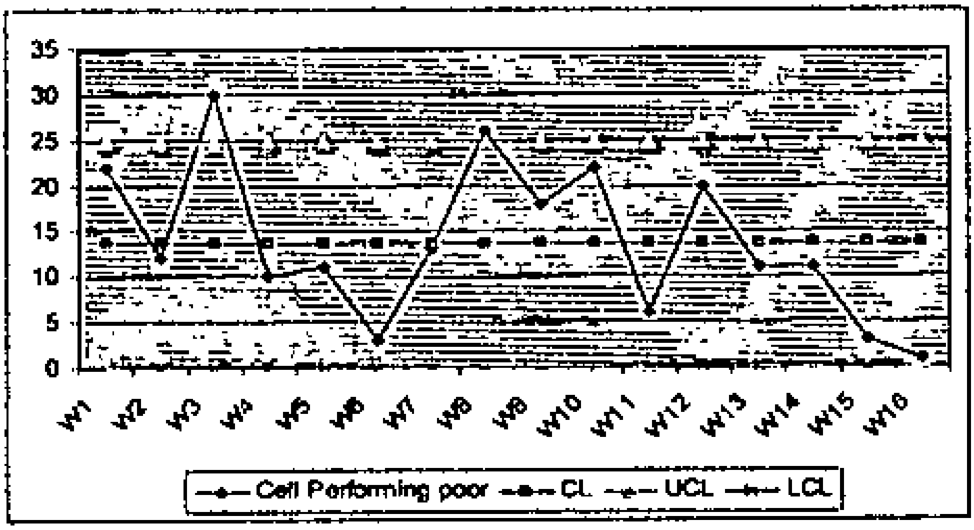


Figure 4.24 Chart for Poor Cell performing sites Trial 01

Comments

a. From the above C chart we can see that 02 plots out of 16 fall beyond the upper control limits. It indicates the process may be out of control. There may be Type I error.
b. The pattern of plots of points is more or less random (with random ups and downs around the mean 13.69) upto WK13.
c. From WK12 to WK16 the plots shows continuous decreasing trends though all plots fall within the control limits
d. From the above discussion it can be concluded that the process is not in good shape.
e. So, to achieve better control in the process new control limit need to be calculated omitting WK03 & 08 from the process.

Trial 02

The 2nd Trial limits are calculated as follows

Table 4.16.1 Data for Poor Cell Performing Site Using C Chart Trial 02

Week No	Cell Performing poor
W1	22
W2	12
W4	10
W5	11
W6	3
W7	13
W9	18

Week No	Cell Performing poor
W10	22
W11	6
W12	20
W13	11
W14	11
W15	3
W16	1

Here C bar= $163/14= 11.64$

UCL= $11.64+3\sqrt{11.64} = 22$

CL= 11.64

LCL=0

These first Trial limits, along with individual sample non conformities, are plotted in a graph bellow

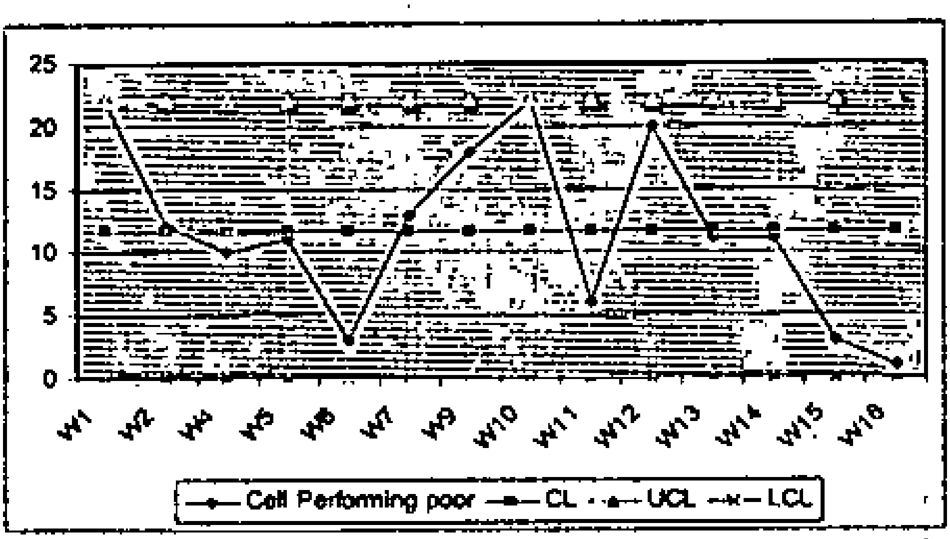


Figure 4.24.1 Chart for Poor Cell performing sites Trial 02

Comments

a. From the above C Chart it can be seen that all the Plots are within control Limits. Though 2 plots touches the upper Control Limit.

b. The Plots are relatively more random around the mean than the previous trail.

c. There is one increasing trend from WK6 to WK 10 and decreasing trend from WK14 to WK16.

d. The overall chart indicates that the process is in good condition and there is a fair control in the process though there is improvement scope in the process. So, we can consider this control limits as the final.

Calculation for both Poor PCM & Cell Quality sites

Table 4.17 Data for both Poor PCM & Cell Performing Site Using C Chart

Week No	Both PCM & Cell performance are poor	Week No	Both PCM & Cell performance are poor
W1	6	W9	0
W2	2	W10	2
W3	8	W11	0
W4	2	W12	3
W5	4	W13	5
W6	1	W14	5
W7	3	W15	1
W8	6	W16	0

Here C bar= 48/16= 3

UCL= $3+3\sqrt{3}$ = 8.20

CL= 3

LCL=0

These first Trial limits, along with individual sample non conformities, are plotted in a graph bellow

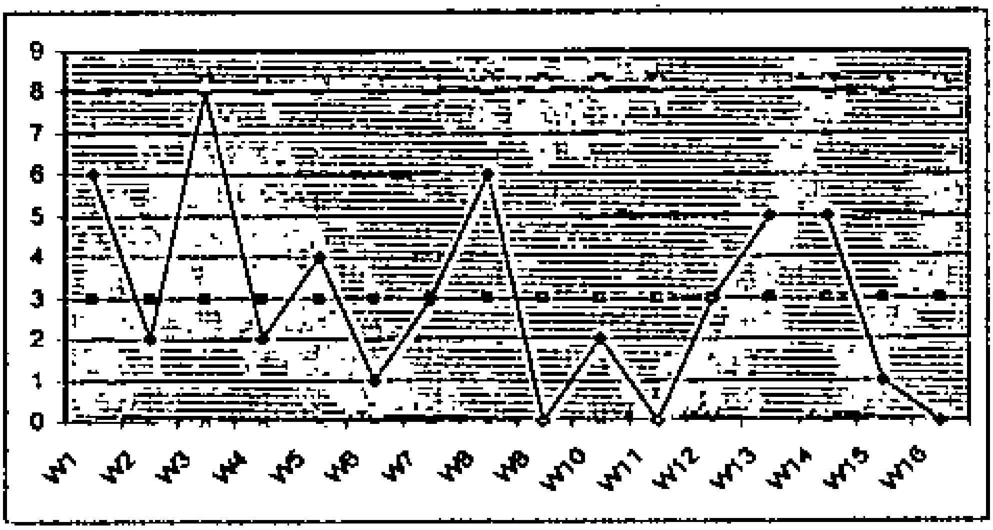


Figure 4.25 Chart for both Poor PCM & Cell Performing Site Using C Chart

Comments

a. All results fall within control limits.
b. The pattern of plots of points is more or less random (with random ups and downs around the mean 3). That means there is no shift in the process mean or no indication of process incapability.
c. The overall chart indicates the existence of a control in the process.

4.4.9 Analysis Using Pareto Principle

The misnamed Pareto principle (also known as the 20-80 rule, the law of the vital few and the principle of factor sparsity) states that for many phenomena 80% of consequences stem from 20% of the causes. The idea has rule-of-thumb application in many places, but it's also commonly and unthinkingly misused [8]

The principle was suggested by management thinker Joseph M. Juran. It was named after the Italian economist Vilfredo Pareto, who observed that 80% of property in Italy was owned by 20% of the Italian population. Since J. M. Juran adopted the idea, it might better be called "Juran's assumption". That assumption is that most of the results in any situation are determined by a small number of causes. That idea is often applied to data such as sales figures

"20% of clients are responsible for 80% of sales volume." This is testable, it's likely to be roughly right, and it is helpful in your future decision making.

It is important to note that many people misconstrue the principle (because of the coincidence that 20+80=100) it could just as well read that 80% of the consequences stem from 10% of the causes. Many people would reject such an "80-10" rule, but it is mathematically meaningful nevertheless.

From our STP data we found the type of Poor quality are

a. Poor Cell Performance Quality at 219 nos sites.
b. Poor PCM performance quality at 195 nos sites.
c. Both poor Cell & PCM performance at 48 sites.

So, it can be seen at the following perato diagram

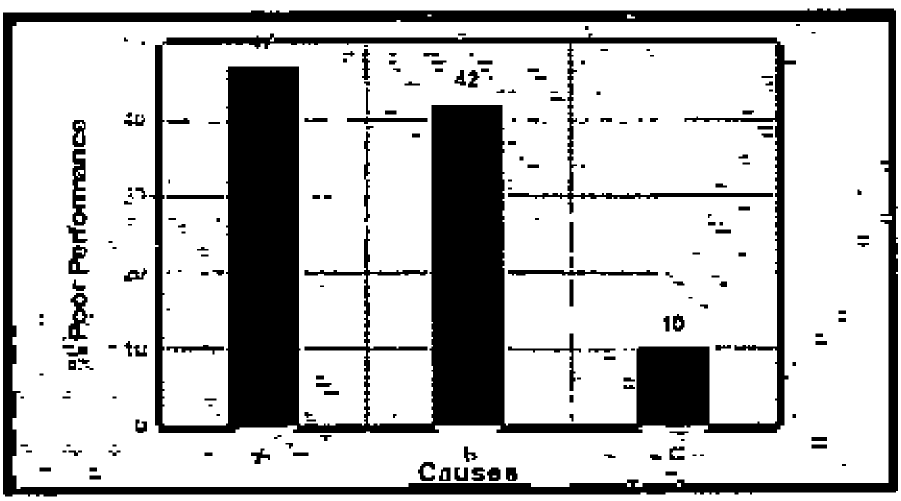


Figure 4.26 Pareto chart for Poor Performing sites

Comments From the graph it can be seen that cause A & B are the main contributor of poor performance.

4.4.9.1 DIFFERENT CONTRIBUTORS FOR POOR PERFORMANCE QUALITY

The main and sub categories that contribute to the poor performance of new on air sites are provided bellow[11]

Main Category	Sub category
Transmission Problem	Bad Tx Quality/Bad PCM Quality
	DIP ABL
	Fiber Cut
	Microwave link problem
Planning Problem	Interferance
	TCH/SDCCH congestion
	Handover Problem
	Call set up problem
	MPD
Hardware Problem	BS Fault
	GSM Cable Missmatch
	Feeder cable connetion Problem
Configuration Problem	Parameter Problem
Environmental	Ducting Effect
	Geographical Reason

4.4.9.2 PARETO ANALYSIS FOR MAIN CATEGORY

Table 4.18 Pareto Table for main Category

SL No	Main Category	Nos of Problems	% Problems
01	Transmission Problem	206	42
02	Planning Problem	201	41
03	Environmental	51	10
04	Hardware Problem	27	6
05	Configuration	03	8

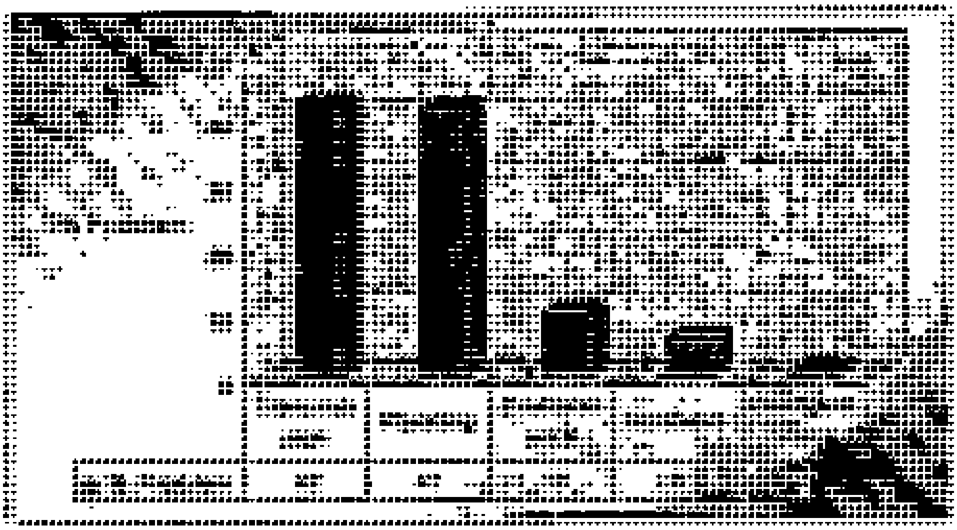


Figure 4.27 Pareto chart for Main Category for Poor Performing

Comments From the Graph it can be concluded that Transmission & planning problem contributes to the poor performance.

4.4.9.3 PARETO ANALYSIS FOR SUB CATEGORY

Table 4.19 Pareto Table for Category I Transmission Problem

SL No	Sub Category	Nos of Problems	% Problems
01	Bad Tx Quality/Bad PCM Quality	176	85
02	DIP ABL	16	08
03	Fiber Cut	09	04
04	Microwave link problem	05	02

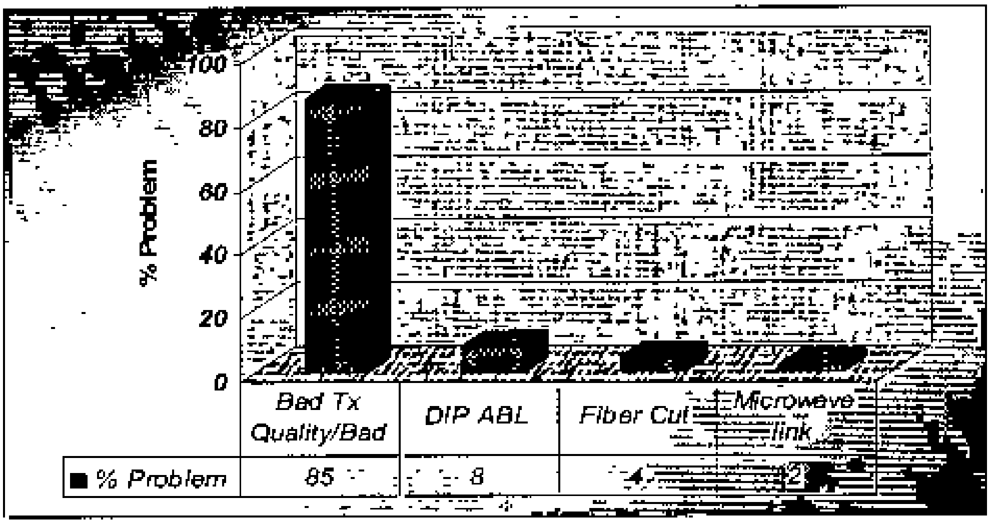


Figure 4.28 Pareto chart for Transmission Related Problem

Comments From the Graph it can be concluded that Bad Tx quality/ Bad PCM quality alone mostly contributes to the Transmission Problem.

Table 4.20 Pareto Table for Category 2 Planning Problem

SL No	Sub Category	Nos of Problems	% Problems
01	TCH/ SDCCH congestion	61	30
02	MPD	61	30
03	Handover Problem	47	23
04	Call set up problem	19	9
05	Interference	13	6

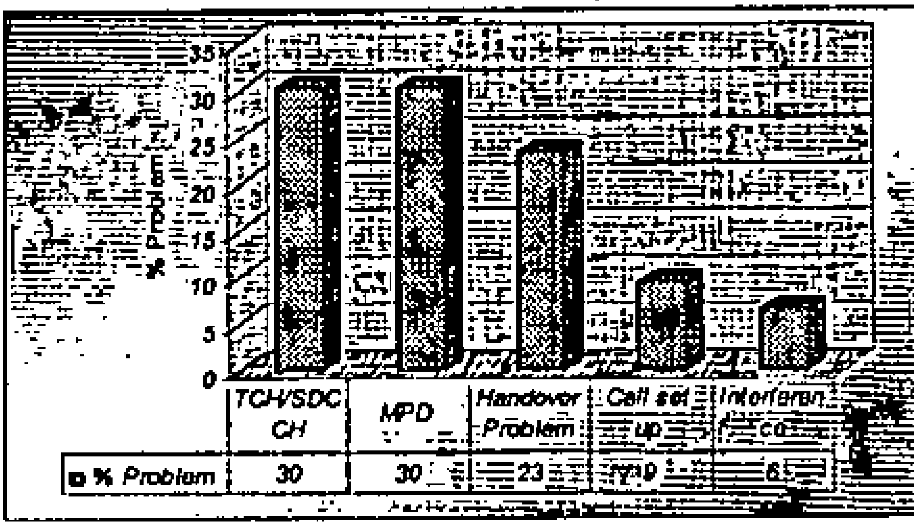


Figure 4.29 Pareto chart for Planning Related Problem

Comments From the Graph it can be concluded that TCH/SDCCH congestion, MPD, handover problems contributes to the Planning Problem.

Table 4.21 Pareto Table for Category 3 Hardware Problem

SL No	Sub Category	Nos of Problems	% Problems
01	Feeder cable connection Problem	15	56
02	GSM Cable Mismatch	09	33
03	BS Fault	03	11

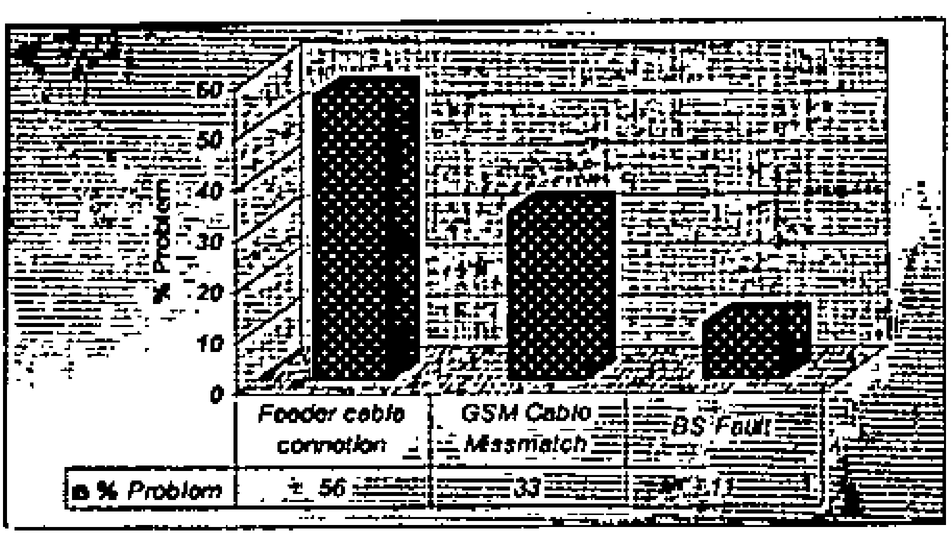
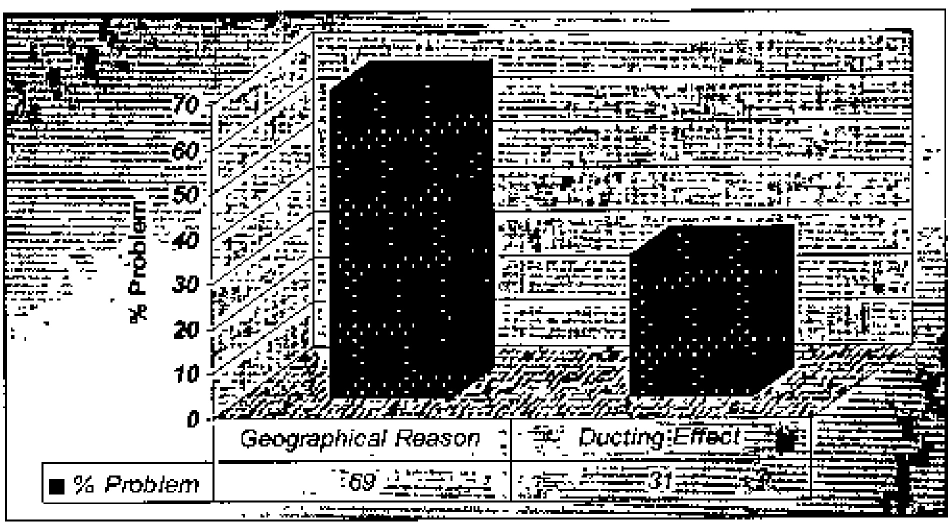


Figure 4.30 Pareto chart for Hardware Related Problem

Comments From the Graph it can be concluded that Feeder Cable Connection & GSM cable mismatch are the 89% contributor of Hardware Problem that contributes to poor performances

Table 4.22 Pareto Table for Category 4 Environmental problem

SL No	Sub Category	Nos of Problems	% Problems
01	Geographical Reason	35	69
02	Ducting Effect	16	31



Fig

Figure 4.31 Pareto chart for Environmental Related Problem

Comments From the Graph it can be concluded that Graphical & Ducting effects contributes to the Environmental Problem.

4.4.9.4 Pareto Analysis For All Types Of Problems

Table 4.23 Pareto Table for All types of problem

Sub category	Nos of Problems	% Problem	% Problem (Cumulative)
Bad Tx Quality/Bad PCM Quality	176	36	36
TCH/SDCCH congestion	61	13	49
MPD	61	13	61
Handover Problem	47	10	71
Geographical Reason	35	7	78
Call set up problem	19	4	82
Feeder cable connection Problem	15	3	85
Ducting Effect	16	3	88
DIP ABL	16	3	91
Interference	13	3	94
GSM Cable Mismatch	9	2	96
Fiber Cut	9	2	98
BS Fault	3	1	98
Microwave link problem	5	1	99
Parameter Problem	3	1	100

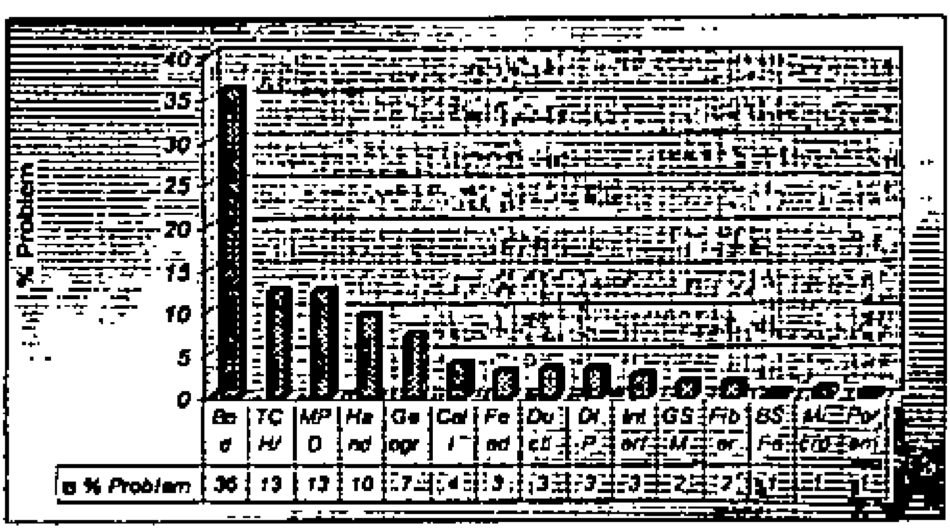


Figure 4.32 Pareto chart for Overall Poor quality Problem

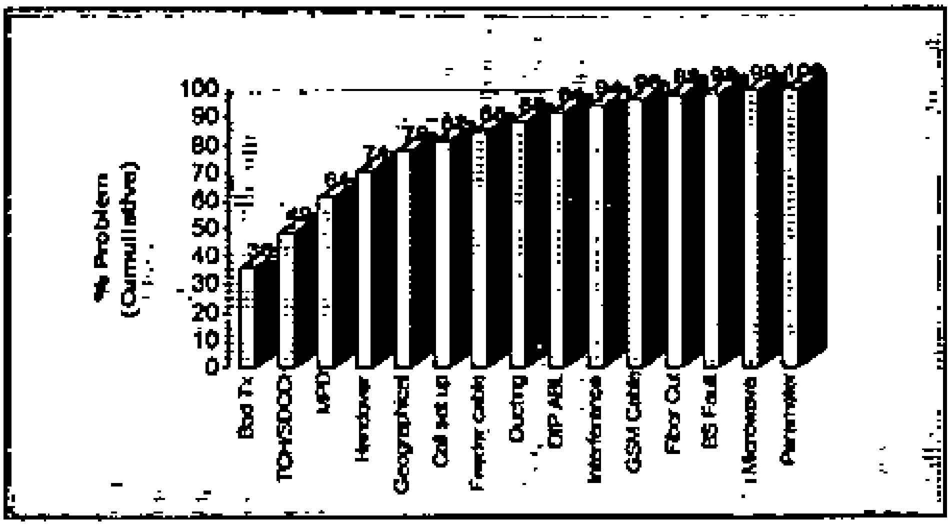


Figure 4.33 Pareto chart for Overall Poor quality Problem (Cumulative)

Comments The above two figures illustrate individual as well as cumulative percentage of problems that contributes to the poor performing of Newly on air BTS. As per the Peratto diagram it is clear that 82% Contributors for poor performing are 6 types of problems. They are

1. Bad Tx Quality/ Bad PCM Quality.
2. TCH/SDCCH Congestion.
3. MPD
4. Handover problem.
5. Geographical.
6. Call Set up Problem.

Primarily, we should focused on the above six types problem and try to minimize this problems that will eventually reduce the problems and consequently improve the quality of new BTS.

4.4.10 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.[1]

- 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.

4.4.10.1 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.[1]

4.4.10.2 CREATING CAUSE EFFECT DIAGRAM FOR OVERALL QUALITY PROBLEM

- Here the Effect is "Quality Problem of New 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 Planning, Transmission, Hardware, Environmental & Configuration problem.
- 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.

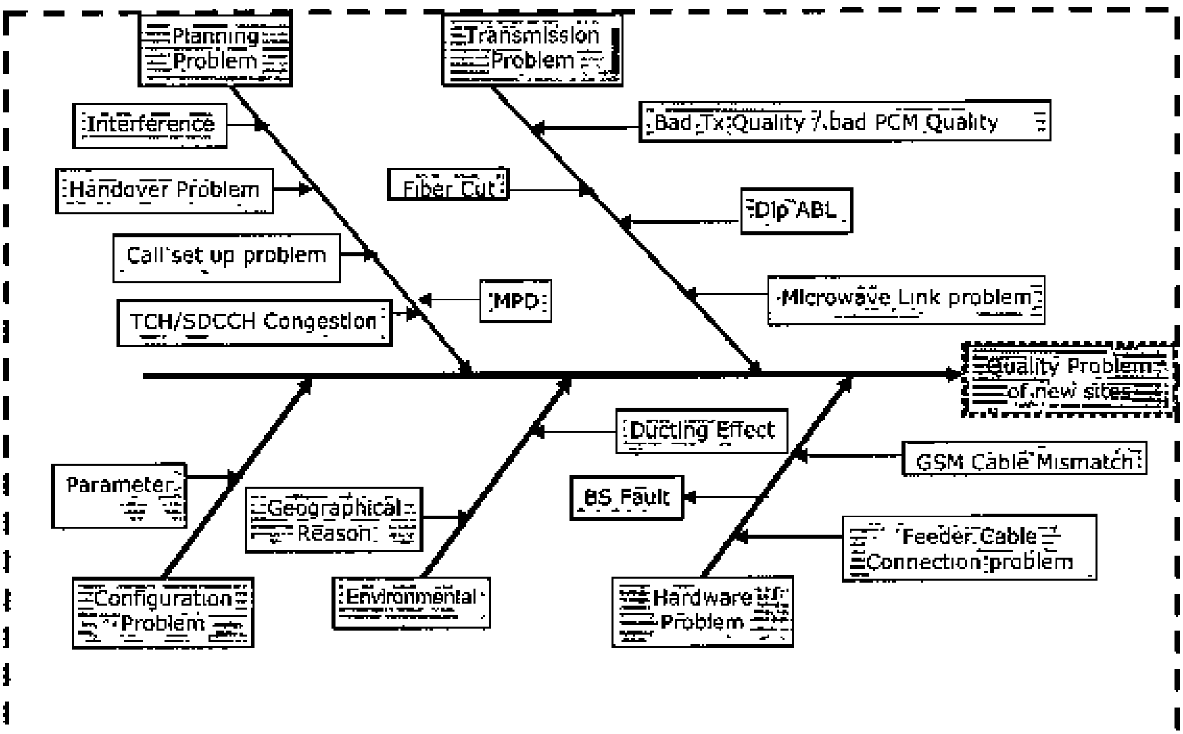


Figure 4.34 Cause Effect Diagram for Overall quality Problem

4.4.10.3 CREATING CAUSE EFFECT DIAGRAM FOR PARETO FINDINGS

From Pareto analysis we came to this conclusion that 82% Contributors for poor performing are 6 types of problems. They are

1. Bad Tx Quality/ Bad PCM Quality

2. TCH/SDCCH Congestion.
3. MPD
4. Handover problem.
5. Geographical.
6. Call Set up Problem.

So, we came to the following decision that to reduce 82% fault we have to give focus on the 6 Major problems that contributes to it. If we decrease the causes for this Major Problems we will definitely improve the quality of our sites and thus reduce the CAPEX & OPEX. Above all quality of the existing network will further improve. It will increase the customer satisfaction that link to grameenphone's business.

Here, I perform extensive study on STP report & brainstorming about the root causes that contributes to the faults. These causes are described in the Cause effect diagram bellow and detail description has been provided in the next article. Also the action need to be taken also described in that article.

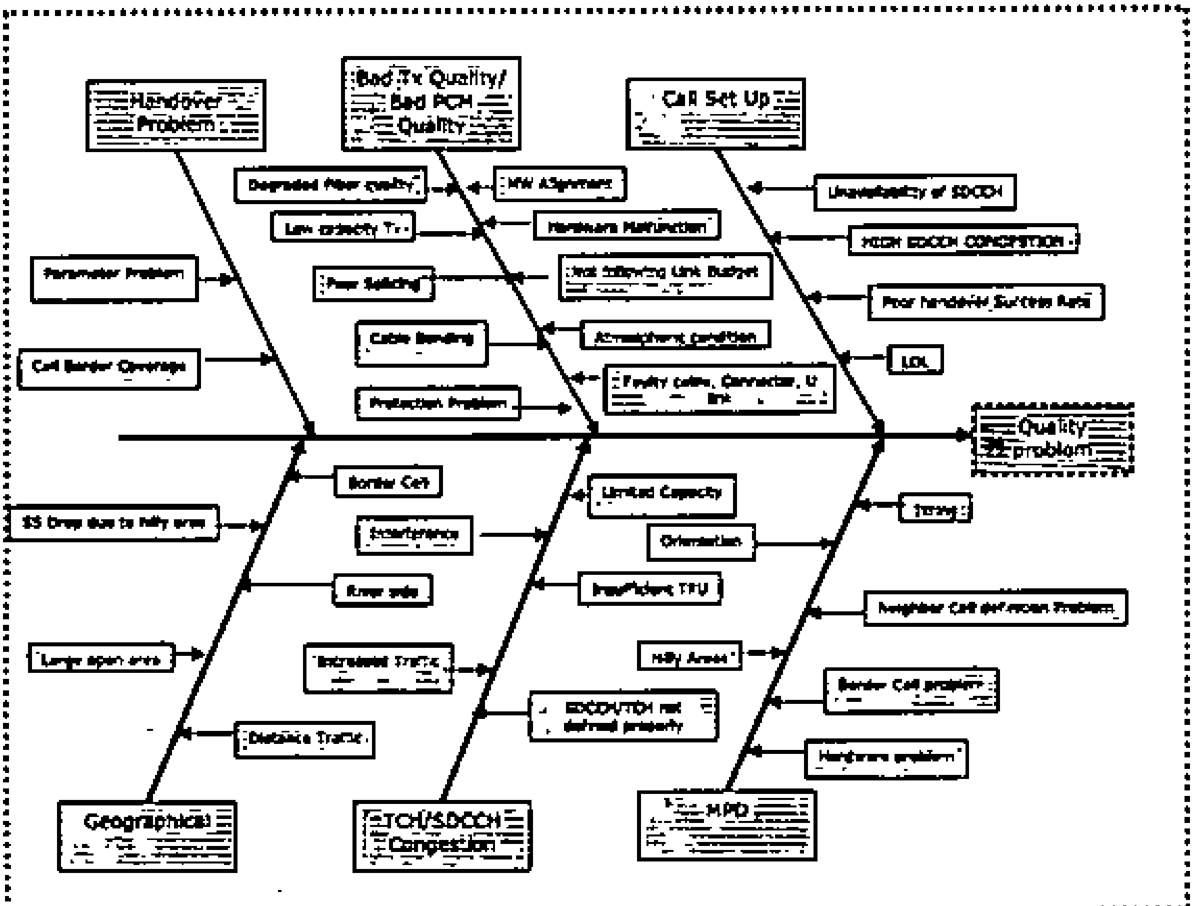


Figure 4.35 Cause Effect Diagram on the basis of Pareto findings

4.4.10.4 MAJOR CAUSES AS PER PARETO FINDINGS

Bad Tx Quality or Bad PCM Quality

Transmission of any signal could pass through wireless (microwave) or physical (twisted pair, coaxial, SHDSL, Fiber etc) medium. When the signal is attenuated through its propagation path due to any signal distortion then it is called as Bad TX quality which often occurs due to below reasons

Causes

- MW alignment problem due to poor support causing break in LOS.
- Hardware malfunctioning.
- Excess distance than link budget.
- Atmospheric condition (rainwater, snow, dust, sand etc).
- Faulty PCM Cables & connectors.
- Faulty U link.
- Degraded Fiber Quality.
- Low capacity transmission.
- Poor splicing at Fiber joint
- Excessive cable bending along transmission path.
- Protection problem at logical level.

TCH/SDCCH congestion

Stand alone Dedicated Control Channel (SDCCH) is one of the most important logical channels required for signaling of call set up. This is a bi-directional channel supporting both uplink and downlink direction.

The BTS switches to the assigned SDCCH used for call set up signaling. TCH is assigned on SDCCH. The MS switches to the assigned SDCCH. Call setup is performed. The MS receives TCH assignment information (carrier and time slot).

SDCCH is also used for SMS messages to MS.

Once call setup procedures have been completed on the control physical channel, the MS tunes to a traffic physical channel known as TCH. There are two types of TCH

- Full Rate (TCH) Transmits full rate speech (13 Kbits/s). A full rate TCH occupies one physical channel.
- Half Rate (TCH/2) transmits half rate speech (6.5 Kbits/s) Two half rate TCH can share one physical channel, thus doubling the capacity of a cell.

Causes

- Limited capacity
- Interference occurs due to same frequency use in neighbor cell.
- Insufficient TRU.
- Due to increase traffic there might be unavailability of TCH/SDCCH for setup of mobile calls
- SDCCH and TCH has not been defined properly.

MPD

MPD refers to Minutes Per Drop call. It is a performance measuring parameter of a particular cell. If the MPD is high the cell performance is considered to be good and vice-versa. Threshold value for MPD in Gramenphone is ≥30. If it crosses this limit action needs to be taken

Causes

- Electrical or Mechanical Tilting of GSM antenna.
- Orientation of GSM antenna.
- Neighbor Cell definition problem.
- Hilly Areas.
- At border cell Timing Advance (TA) is controlled and as a result MPD (Minute per Drop) is relatively low and excessive drops encounter.
- Hardware problem.
- TCH Drop
- Signaling Strength Drop

- Uplink and or Downlink Drop
- Timing Advance drop
- Sudden Drop

Handover Problem

Handover is the process, where a call is switched from one physical channel to another. while the MS moves around. This is the active mode when the MS is on and a call is in progress.

BSC performs the following functions that lead to Handover

Dynamic power control in MS and RBS

The BSC calculates adequate MS and BTS output power based on the received measurements of the uplink and downlink This is sent to the BTS and the MS every 480ms to maintain good connecting quality.

Locating

This function continuously evaluates the radio connection to the MS, and. if necessary, suggest a handover to another cell. This suggestion includes a list of handover candidate cells. The decision is based on measurement results from the MS and BTS. The locating process is being executed in the BSC.

Handover

If the locating function proposes that a handover take place, the BSC then decides which cell to handover to and begins the handover process.

If the cell belongs to another BSC, the MSC/VLR must be involved in the handover. However, in a handover, the MSC/VLR is controlled by the BSC. No decision making is performed in the MSC because it has no real time information about the connection.

Causes

- Occurs due to cell border coverage Problem.
- Parameter Problem.

Geographical Reason

Causes

- At border cell Timing Advance (TA) is controlled and as a result MPD (Minute per Drop) is relatively low and excessive drops encounter.
- Due to Hilly area SS drop occurs.
- If cell is placed in an open area and placed at river side for which SS and other drop occurs
- The performance of few site are suffered because of distance traffic. Most of the traffics are at the edge of the cell and as a result UL to OL HO success rate is very poor.

Call set up problem

Call set up involves the following processes

Paging

The BSC sends paging messages to the RBSs defined within the desired LA. The load situation in the BSC is checked before the paging command is sent to the RBS

Signaling set-up

During call set-up, the MS connection is transferred to an SDCCH allocated by the BSC. If the MS initiated the connection, the BSC checks its processor load before the request is further processed.

Assignment of traffic channel

After SDCCH assignment, the call set up procedure continues with the assignment of a TCH by the BSC. As this takes place, the radio channel supervision functions in the BSC are informed that the MS has been ordered to change channels. If all TCHs in the cell are occupied an attempt can be made to utilize a TCH in a neighboring cell.

Cause

- Unavailability of SDCCH.
- HIGH SDCCH CONGESTION.
- Poor Handover success rate.
- LOL (Path Loss threshold).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

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 To ensure the status of market leader she has to maintain good quality new on On air BTS.

Quality of New sites is a important concern of grameenphone for quality network for the valued customers as well as for reducing CAPEX & OPEX of grameenphone. From the above analysis and discussion the following recommendations can be drawn for improvement of quality to a further level.

5.2 RECOMMANDATIONS

- The P chart, U chart & C chart are developed here can be used for monitoring the new on Aired BTS quality with the prescribed control limit. This chart will be drawn for every 3 months interval to measure the improvement. Every time new & conservative control limit will be set and this target will be forwarded to all the concern departments to achieve the target within that period. This will continue further quarter and on. This will be the part of their SLA (Service Level Agreement).
- As we have developed The Pareto chart and from that we can draw that only 6 types of Causes actually contributes to the 82% of the Total Problems that is of Poor STP quality. I analyzed all the 6 Major contributory causes and draw the action points to minimize these causes. They are described bellow

Bad Tx Quality or Bad PCM Quality

- High quality weather proof PCM transmission cable.
- Use of quality connectors.
- Making of U link should be properly done.
- Microwave alignment with exact LOS.
- Proper splicing of Fiber.
- Use of good IDU & ODU.
- Capacity up gradation.

TCH/SDCCH congestion

- TRU addition.
- Parameter tuning.
- After SDCCH re-dimension CONGESTION decreased.
- Proper SDCCH and TCH has to be defined at planning end.
- Capacity up gradation is the simple and straight forward method of reducing TCH/SDCCH congestion.

MPD

- Change in LOL (Path loss threshold)
- Parameter tuning.

Handover Problem

- Handover addition/deletion.
- Parameter tuning (LOL,LOLHYST,BSPWR,BCCH,BCCHNO,DCHNO)
- New band introduction

Geographical Reason

- Parameter tuning.
- Selection of location (Example For Hilly areas the highest point should be taken if wide range of coverage need to be provided.)

Call set up problem

- TRU addition
- Handover addition/deletion
- Parameter tuning
- New band introduction
- LOL change.

Finally I have ended up with drawing a Cause Effect diagram/ Fish Bone diagram that will give a clear idea where more focus needed for Quality Improvement of New BTS Sites. This will also help in operation as what action needs to be taken against specific problems is described in more clear way.

REFRENCES

1. Hasin, M. A. A., Quality Control and Management, Bangladesh Business Solution, Dhaka, Bangladesh, 2007.
2. GSM System Survey, Student Text, Edition EN/LZT 123 3321, R5A Ericsson, Stockholm, Sweden, 2003
3. CME 20 System Survey, Training document. Edition EN/LZT 120 226 R9. Stockholm, Ericsson Radio Systems AB. Stockholm, Sweden, 2002
4. CME 20/CMS 40 Mobile Intelligent Network Overview R9.1, Training document. Edition EN/LZT 123 3974 R2C, Ericsson Radio Systems AB. Stockholm, Sweden. 2004.
5. Freeman, R.L., Fundamentals of Telecommunications; Wiley IEEE press, USA. 2005.
6. Wadsworth, H. M., Stephens, K. S. and Godfrey, A. B., Modern Methods for Quality Control & Improvement, 2nd Edition, John Wiley & Sons, USA, 2001.
7. George, S. and Weinerskirch, A., Total Quality Management, John Wiley & Sons, USA, 2004.
8. Montgomery, C., Introduction to Statistical Quality Control, John Wiley & Sons, USA, 2004
9. Chase, R. B., Aquilana, N. J., and Jakobs, R., Production and Operations Management Manufacturing and Services, McGraw-Hill, USA, 2000.
10. Annual Report 2007 of Grameenphone Ltd.
11. Weekly STP report for week 37- week 52 published by NIC(Network Integration & Configuration Center)