Total Quality Management

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My beloved
Chandra, Prabhakar and Thangakumaran

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Section IV—TQM Tools

Preface

"A firm will, coupled with undivided attention is all that is required. Everything that you seek for shall then be found to be quite close to you, rather with you; nay, in fact you are yourself that which you seek."

—Shri Ram Chandraji Maharaj

ABOUT TQM

Success is the hallmark of practicing Total Quality Management (TQM) "with a firm will coupled with undivided attention", TQM provides lasting solutions to the organizations plagued with problems of defects, high costs on account of rework and waste, and delayed delivery of products and services and the like. The Software Capability Maturity Model (SW-CMM) of Software Engineering Institute, USA has provided an elegant strategy for practicing TQM in software organizations across the globe. The software organizations which attained Level 5 of the Model, performed better with regard to schedules, cost and quality as compared to the organizations at lower levels of maturity. Companies, such as GE and Motorola, which implemented Six Sigma programs, a special TQM initiative of the 1990s, have reported huge profits, by attaining a level of 3.4 defects per million opportunities (DPMO). The unprecedented growth of Toyota Motors is the result of practicing TQM for years. In short, all successful organizations adopt TQM in one form or the other. TQM has helped people, organizations and nations to alter their destiny and attain superiority, prosperity and international prominence. The biggest proof is the success of the Japanese after the perilous World War n.

TQM demands organizations in every sector to focus on customer satisfaction, by involving, every employee in their process improvement projects. This results in customer satisfaction and benefits to all stakeholders. The well-known Malcolm Baldrige National Quality Award (MBNQA), India's prestigious Rajiv Gandhi National Quality Award, European Quality Award and Deming Prize are all awarded to those who have demonstrated successful implementation of TQM. TQM not only begets awards, but also results in superior economic performance. The latest metrics for organizations proposed by Kaplan and Norton of Harvard University, USA, namely **Balanced Scorecard,** stipulates that for sustained growth the organizations should measure not only the economic performance, but all of the following: Customer Satisfaction, Employee Learning and Growth, Internal Business Processes and Financial success. TQM is the only strategy that will result in better performance in respect of all the above four measures. Thus, TQM undoubtedly is a concept and strategy that leads to economic performance, improved employee morale, customer satisfaction, increased market share and above all a deserving pride amongst their employees.

Lean Manufacturing, Kaizen, Total Productive Maintenance (TPM) and Six Sigma represent only some aspects of TQM. TQM is a holistic and an umbrella concept for definite success and prosperity of organizations. This book covers the Japanese techniques for success such as Kaizen, Just-In-Time (JIT), Kanban, Cellular Manufacturing, TPM, Quality Function Deployment (QFD), seven QC Tools and the new seven Tools for Management. .

ORGANIZATION OF THE BOOK

This book is a comprehensive guide to TQM, starting .from the first principle. It is divided into five sections. Section I provides the background information on TQM evolution, teachings of quality gurus and quality costs, the traditional measure of quality. Success of an organization depends entirely on a capable leader. Therefore, a complete chapter is dedicated to leadership. This section also provides a top-down methodology for TQM implementation.

Section II consists of some of the key principles and strategies for TQM implementation, such as customer satisfaction and employee involvement. TQM is a process approach and therefore, vital key concepts pertaining to process approach, Kaizen and 5S are discussed in this section. Performance measures including Balanced Scorecard are also discussed.

One of the essential requirements of TQM and Six Sigma is the usage of appropriate statistical tools for process improvement. Section HI gives comprehensive exposure to Statistical Process Control (SPC), seven QC Tools, Control Charts, Six Sigma and the seven new Management Tools.

The new approach is to shift the quality focus to the design stage itself and build quality processes, systems and products. Section IV focusses on the TQM Tools for improving quality of design, such as Benchmarking, Quality Function Deployment, Taguchi's Design of Experiments, TPM, and Failure Mode, Effects and Criticality Analysis (FMECA) and FMEA RPN techniques.

Section V is devoted to the improvement of systems in the organization covering quality awards as well as overview of ISO 9000, QS 9000 and ISO 14000 systems.

THE IDEA OF WRITING THIS BOOK

It took more than seven years for me to complete this book. I was quite fascinated with TQM in the early nineties and declared 1993 as a TQM Year for ETDC, Chennai, the organization headed by me. In 1997 after witnessing the initial success of running my organization on TQM principles, I thought of sharing my experiences with a larger group of people. At that point, I completed the first draft of the book. However, I did not get it published then.

THE BENEFICIARIES

The old manuscripts got a new life when Anna University, Chennai prescribed TQM as the core subject for their B.E. students in their final year. This meant that over 70 000 students in a single university will be learning this wonderful concept starting from December 2004. This gave me the motivation to rewrite my old manuscript. Rewriting meant deleting a few earlier chapters, and adding many new chapters. In short, the text was totally revised to suit the syllabus of Anna University, Chennai. I was excited when the reviewers of the manuscript gave an overwhelmingly positive opinion about the content.

TQM comprises many concepts and strategies, all experimented and proved to benefit the user. However, learning must be step-by-step. The material given in this book will serve a two-semester course as given below: °

(i) TQM Principles

(ii) TQM Tools

This book gives a strong foundation for successful management of organizations based on TQM to the future leaders, the students in particular. As the head of an organization, for over a decade, I have experimented with TQM concepts and have found it to be an eminently useful management technique for a winning organization. Therefore, I have no hesitation in recommending this management concept to every organization.

The readers are requested to send their valuable feedback to subburaj_spr@yahoo.com. Suggestions for improvement of the text are also welcome.

SUBBURAJ RAMASAMY

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Note: The views and opinions expressed in the book are that of the author in his personal capacity and NOT necessarily of the Ministry of Communications and Information Technology / STQC Directorate / ETDC, Chennai.

SUBBURAJ RAMASAMY

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List of Abbreviations

AND	Activity Network Diagram
AQL	Acceptable Quality Level
ARM	Availability, Reliability, Maintainability
BCSD	Business Charter for Sustainable Development
BPB	Business Process Benchmarking
BPR	Business Process Reengineering
BS	British Standard
BSC	Balanced Scorecard
BSI	British Standards Institution, UK
CA	Criticality Analysis
CEO	Chief Executive Officer
CFR	Centre For Reliability
CMM	Capabilities Maturity Model
CNX	Constant, Noise factor, Experimental factor
COQ	Cost Of Quality
COTS	Commercial Off The Shelf
CPM	Critical Path Method
CSI	Customer Satisfaction Index
CTQ	Critical To Quality
DFSS	Design For Six Sigma
DBRFT	Do It Right First Time
DMADV	Define, Measure, Analyze, Design and Verify
DMAIC	Define, Measure, Analyze, Improve and Control
DPMO	Defects Per Million Opportunities
DOE	Design Of Experiments
EF	Earliest Finish Date
EFQM	European Foundation for Quality Management
ERP	Enterprise Resources Planning
EMS	Environmental Management System
EQA	European Quality Award
ES	Earliest Start Date
ETDC	Electronics Test and Development Centre
ETX	Entry—Task—Exit
FMEA	Failure Mode Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis

GE	General Electric, USA
HB	Higher the Better
HOQ	House of Quality
IPCL	Indian Petrochemicals Corporation Limited, India
IEC	International Electro-technical Commission
ISO	International Organization for Standardization
IT	Information Technology
JHAM	Jishu Hozen (Autonomous Maintenance)
JIT	Just In Time
KK	Kobetsu Kaizen
KPA	Key Process Area
LCL	Lower Control Limit
LF	Latest Finish Date
LS	Latest Start Date
LSL	Lower Specification Limit
MBNQA	Malcolm Baldrige National Quality Award'
MBWA	Management By Walking Around
MR	Management Representative
MRB	Management Review Board
MSA	Measurement System Analysis
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
NABL	National Accreditation Board for Testing and Calibration Laboratories, India
NASA	National Aeronautic Space Agency, USA
NB	Nominal the Best
NIO	National Institute of Oceanography, India
NPCC	National Productivity Competitiveness Council, Mauritius
OA	Orthogonal Array
OEE	Overall Equipment Efficiency
PAT	Process Action Team
PDC	Probable Date of Completion
PDPC	Process Decision Program Chart
PIT	Process Improvement Team
PERT	Program Evaluation Review Technique
PE	Performance Efficiency

PDCA	Plan, Do, Check, Act
PDSA	Plan, Do, Study, Act
pdf	probability density function
ppb	parts per billion
ppm	parts per million
QA	Quality Assurance
QC	Quality Control, also Quality Council
QE	Quality Engineering
QFD	Quality Function Deployment
QLF	Quality Loss Function
QP	Quality Planning
QM	Quality Management; also Quality Maintenance
QMS	Quality Management System
QSR	Quality System Requirement
QUEST	Quality Excellence of Suppliers of Telecommunications Forum
RBL	Rane Brake Linings Limited, Chennai
RD	Relationship Diagram
RE	Rate Efficiency
RPN	Risk Priority Number
RGNQA	Rajiv Gandhi National Quality Award
SB	Smaller the Better
SCM	Supply Chain Management
SE	Standard Error of the means; also Speed Efficiency
S/N	Signal to Noise Ratio
SPC	Statistical Process Control
SQC	Statistical Quality Control
TEI	Total Employee Involvement
TPM	Total Productive Maintenance
TPS	Toyota Production System
TQC	Total Quality Control
TQM	Total Quality Management
UCL	Upper Control Limit
USL	Upper Specification Limit
WIP	Work In Progress
ZD	Zero Defect

Section I

TQM Perspective

Total Quality Management (TQM) is a modern management concept. Successful organizations worldwide have adopted TQM. It is important to have a thorough understanding of the fundamentals of quality management, so as to understand TQM in the right perspective. Section I provides the fundamental concepts pertaining to quality, TQM principles, quality costs, leadership needed, strategies and organizational framework for TQM implementation. This section contains the following four chapters:

1. TQM EVOLUTION

This chapter is an introduction to quality and TQM. Apart from providing the definition of quality and other related terms, it also gives a historical perspective of quality and the evolution of TQM. We discuss about the concepts advocated and practiced by various Quality Gurus.

2. QUALITY COSTS

The very purpose of quality is to provide more profit to the organization and benefit to all stakeholders. Therefore, the cost of quality has to be minimized. This chapter discusses the methodology for computing and analyzing quality costs.

3. LEADERSHIP

Top management is solely and wholly responsible for the success of TQM in the organization. This chapter outlines some of the strategies to be adopted for successful implementation of TQM. This includes Deming's 14 points and 10 more strategies advocated by the author.

4. TQM IMPLEMENTATION

This book adopts a top-down approach for TQM implementation. This chapter provides an overview of TQM implementation and the organizational framework for the same.

Chapter 1

TQM Evolution

Happiness is when what you think, what you say, and what you do are in harmony.

—Mahatma Gandhi

INTRODUCTION

Total Quality Management (TQM) is customer oriented management philosophy and strategy. It is centered on quality so as to result in customer delight. The word "Total" implies that all members of the organization make consistent efforts to achieve the objective of customer delight through systematic efforts for improvement of the organization.

The TQM philosophy was evolved in Japan after World War II. Edwards Deming, an American quality expert helped the Japanese to apply concepts of TQM. They concentrated on customer satisfaction and focused on understanding customer needs and expectations. However, the American industry ignored this development as it was still riding high because of lack of competition. During the 1980s they were forced to look for new ways to survive in an environment of deregulation, a growing trade deficit, low productivity, recession, downsizing and increasing consumer awakening. Ford Motor Company lost more than US $ 3 billion during 1980–82. The US market share of Xerox Corporation which had pioneered the photocopier, dropped from 93 per cent in 1971 to 40 per cent in 1981. The American industry now realized the importance of Deming's teachings and started applying them. This helped Xerox to regain market share from the Japanese, Ford to come out of the red, Florida Light and Power, USA reduced customer complaints by 60 per cent in 1983. In 1985, the American Navy coined the term TQM to represent broadly the Japanese way of quality management.

The need for quality was felt, during World War II, due to the unprecedented need for manufactured goods. From then on, methodologies for assuring quality in products and services evolved continuously, finally leading to TQM. Experts from many countries spearheaded this evolution, with Deming playing an important role. They are popularly called the Quality Gurus. Since TQM is the culmination of the teachings of the Quality Gurus, understanding the teachings of the gurus will give the right perspective for TQM.

This chapter will therefore highlight the contributions of the Quality Gurus for the evolution of quality control techniques and finally TQM.

TQM addresses the concepts of product quality, process control, quality assurance and quality improvement, all of which are aimed at customer delight. Therefore, it is important to get the right meaning, interpretation and understanding of the term quality and related terms. This will provide a strong foundation for TQM. We will discuss various dimensions of quality in the following paragraphs.

DEFINITION OF QUALITY

Juran[1], one of the quality gurus, defined quality as *fitness for use*. A very concise definition indeed, for a term that has so many dimensions! Quality of a product or service in simple terms is its suitability for use by the customer. Quality has to be perceived by the customer. Perception of the supplier is also important, but the customer experience of quality of a product or service is more important. Quality does not mean an expensive product; on the contrary, it is fitness for use of the customer.

International Organization for Standardization (ISO), the world body for standards formulation was founded in the year 1946 and has its headquarters in Geneva, Switzerland. Most countries in the world are members of ISO. The national standardization bodies of various countries represent their countries in ISO. ISO is known all over the world because of its path breaking standard ISO 9000, released for the first time in the year 1987. The definition of quality as per the ISO 9000 standard is: "The totality of features and characteristics of a product or service, that bear on its ability to satisfy a given or implied need".

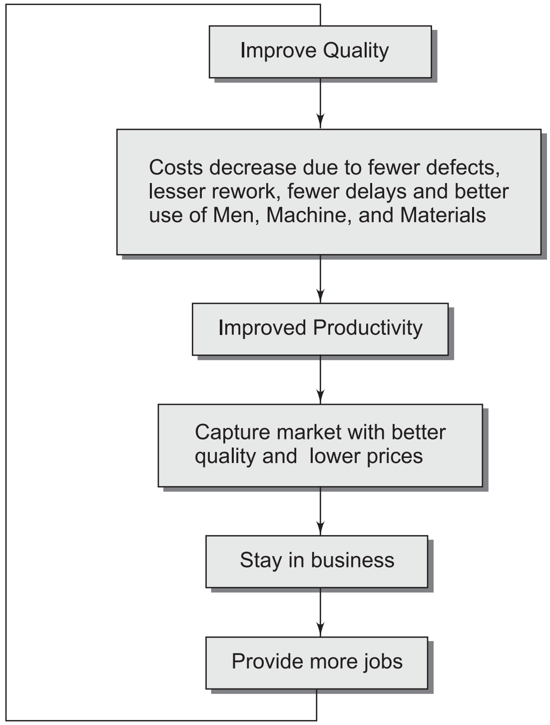
Thus, the standard definition of quality is common both to products and services. It is essentially satisfying the customer needs, both stated and unstated (implied). The latter is more dominant in a service. When there is a contract for supply of a product or service, the needs will be specified clearly. In other situations, it is the responsibility of the supplier to identify and define them.

> In the case of computer software, which is a unique service, the quality of the product can be defined as "the ability to deliver the product within the time schedule, within budget and with the least number of defects"[2].

CHAIN REACTION

The importance of quality will be clear from the chain reaction on account of quality envisaged in Japan in the 1950s[3]. The 'chain reaction' is depicted in Fig. 1.1 as follows:

Quality improvement results in improved productivity, as is clear from Fig. 1.1. By eliminating defects, non-value adding activities and rework, additional resource capacity is created. Improved quality also reduces the production cycle time and machine time. Less material is required due to reduction of scrap and rework. All this leads to improved productivity and increased capacity. If this is used to expand markets with lower prices, the company prospers and stays in business. Deming noted that this chain reaction was on the black board of every board meeting in Japan from July 1950 onwards. The Japanese success is the best case study for TQM. Understanding the chain reaction transformed them from a shattered economy to a successful nation challenging the USA after World War II.



Japanese Chain Reaction

Figure 1.1

DIMENSIONS OF QUALITY

Quality has many dimensions. The dimensions of quality are nothing, but the various features of a product or service. We will discuss some of them briefly:

Product Quality

1. ***Functionality*** Functionality refers to the core features and characteristics of a product. The definition of functionality as per ISO / IEC 9126: 1991:
   "A set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs".
   For instance, a car has to have a seating capacity for five persons; a steering wheel, an accelerator, a break, a clutch, head lights, gears, four wheels, etc. The functionality of a car represents each one of the functions mentioned above and many others not listed above. Thus, functionality refers to those functions that will satisfy a customer.

2. ***Reliability*** A car should not breakdown often. This is the reliability attribute to quality. Reliability is measured by mean (average) time between failures (MTBF). Reliability is an indicator of durability of products. For instance, the MTBF of a car can be specified as 1000 hours of running or 10000 kilometers.

3. ***Usability*** A product should be easily usable. The customer should be able to use the product easily without the help of experts. For instance, repairing a car may need the help of a mechanic, but the car can be driven by the owner himself, it he is trained accordingly. Thus, each product should be made so that a person can use it with minimum training. Usability can also be measured by the time taken for training an operator for error-free operation of a system.

4. ***Maintainability*** Maintainability refers to the ease with which a product can be maintained in the original condition. Products may become defective while in use or in transit. It should be repairable so as to retain the original quality of the product at the lowest cost at the earliest possible time. This applies to software, automobiles, household items such as refrigerator, air conditioners, personal computer, etc. For instance, when we use a Walkman we may need to change the batteries periodically. For software, maintainability is defined in the Standard ISO 9126:1991 as "A set of attributes that bear on the effort needed to make specified modifications".
   Maintainability is measured as Mean Time To Repair (MTTR). For instance, the MTTR of a street light controller is 15 minutes.

5. ***Efficiency*** This is applicable to most products. Efficiency is the ratio of output to input. If a car gives a mileage of 20 kms per litre of gasoline and another car with identical features gives 15 kms per litre, then the former is more efficient than the latter. Another example is the brightness of a lamp at a given input voltage.

6. ***Portability*** This is more important in the context of software. Portability is defined as a set of attributes that bear on the ability of software to be transferred from one environment to another. The environment may be organizational, hardware or software environment. Any program purchased, such as an accounting software, should be usable in many different machines without any problem. This is portability. This feature is applicable even to consumer goods such as bulbs, razors, etc.

Service Quality

Unlike products, every service is made to order. Therefore, the service quality has additional features. In availing a service, the customer interacts more with the service provider. The quality of service depends to an large extent on understanding the correct requirements of the customer through such interactions. Each service has to be designed specifically for the customer. Hence, quality of service design is an important feature. Service delivery is another feature of service quality. Thus, the additional features of service quality are:

- Quality of customer service
- Quality of service design
- Quality of service delivery

Each one of the above may have further dimensions. For instance, quality of service delivery includes timeliness of service and the number of defects on delivery.

1. Quality of Customer Service Customer service is important in every business. In a service industry, meeting customers and finding out their implied requirements is more challenging. Therefore, ability to satisfy customer depends on the quality of customer service. This includes but is not limited to:

- How well the customer is received?
- How well the implied requirements are elucidated?
- How well the customer is treated/handled/satisfied?

2. Quality of Service Design Since services are usually made to order, it is important that the service is designed as per the requirements of the specific customer. For instance, a software product developed for a specific bank takes into account the unique requirements of the bank. Quality of service design in turn depends on the quality of customer service.

3. Quality of Delivery Quality of delivery is important in any sector, but more crucial in case of services. Defects on delivery should be zero to satisfy the customers.

Additional attributes of quality, which are applicable to both products and services, are given below:

1. Timeliness Delivery on schedule as per requirements of the customer is a must both in the product sector as well as in service sector. No customer likes waiting. Any anticipated delay in schedule should be communicated to customer well in advance. Timeliness is critical for many products and services. Delay in arrival of aircrafts or trains are instances of poor quality of the services encountered in day-to-day life.

2. Aesthetics A product or service should not only perform well but also appear attractive. Therefore, aesthetics is an important element of quality. Aesthetics may include, but not limited to the appearance of the product, the finish, colour, etc. Customers will buy only those refrigerators or TV receivers or music systems, which look good.

3. Regulatory Requirements Regulatory requirements as stipulated by the local and federal governments should be fulfilled by the product or service. For instance, an automobile has to meet Euro II Standards in respect of emission to minimize environmental pollution. Similarly, there are regulatory requirements in respect of safety of electro-medical products.

4. Requirements of Society The products should fulfill both the stated and implied requirements imposed by society. The customer requirement should not violate society or regulatory requirements. Thus to satisfy a customer, a product cannot be built in such a way as to violate the requirements of society of a safe and healthy product. For instance, providing belts for persons sitting in the front seat in a car is a requirement of the society. Hence, the car manufacturers should provide belts for the passengers travelling in the front seat.

5. Conformance to Standards Product or service should conform to the stated and implied requirements of customers. Where applicable, they should conform to applicable standards such as national standards, international standards and industry standards. For instance, Electro-Magnetic Interference (EMI) from a PC should be within the limits prescribed by the corresponding standard.

QUALITY PAYS

Look at a news item that appeared recently.

Toyota zips past ford to be new No.2

Group Sold 6.78 m Vehicles In 2003, 60,000 More Than The Ford Family, Riding On Asian Push

Chang-Ran Kim & Justin Hyde

Tokyo/Detroit 26 January, *The Economic Times*

Ford, General Motors & Chrysler were considered to be "Big Three" in the automobile sector for decades. Toyota has unseated Ford Motors as the world's second biggest automaker. It is reported that Toyota is steadily marching towards its goal of grabbing 15% of the global car market some time in the next decade from about 11% now. This achievement will make Toyota as No.1 automaker in the world. The market capitalization of Toyota is $ 120 billion; a measure of how much investors believe a company is worth. This is more than four times that of Ford and bigger than the combined stock values of Ford, General Motors and Chrysler. By profitability too, Toyota is way ahead of pack. Its bottom line profit came to around US $ 7 billion last business year, by far the highest in the industry.

The above story is a testimony of success of Toyota's quality initiative for decades. Toyota Motors for years has been practicing TQM, Just in Time (JIT) and Zero Defect. The Kaizen, meaning continual improvement, was also initiated by Toyota three decades ago. Thus, it is no wonder that **quality pays**!

EVOLUTION OF QUALITY

Quality has been evolving for decades. The contribution of American Quality Gurus to this evolution is quite impressive. The concepts were initially experimented successfully in Japan by the American Quality Gurus. In this section, we will look at the contributions of some of them.

1. Dr Walter A Shewhart (1891–1967) worked in Western Electric Company and AT&T, USA. He advocated Statistical Quality Control (SQC) and Acceptable Quality Level (AQL). AQL is the foundation of today's Six Sigma. He is considered to be the father figure of SQC, who developed control charts for quality assessment and improvement. Dr Shewhart also developed the Plan, Do, Check, Act (PDCA) cycle for continuous improvement, which is in use even today.

He is the author of the following books:

- *Economic Control of Quality of Manufactured Products*
- *Statistical Method from the View Point of Quality Control*

2. Deming W. Edwards (1900–1993) An associate of Shewhart, worked in Western Electric Company as a statistician. He was invited to Japan to lead the quality movement. He modified PDCA cycle of Shewhart to the Plan, Do, Study and Act (PDSA) cycle. He also advocated extensive use of statistics and control charts and focused on product improvement and service conformance by reducing variations in the process. He joined the US Census Bureau in the year 1939 and proved that quality control methods could lower costs even in an exclusive service organization.

During the 1950s Deming visited Japan 18 times, held seminars and worked with Japanese Union of Scientists and Engineers (JUSE). An extract from Deming's speech on November 23, 1980 in Paris is given below:

Lectures with top management*

I don't know if I mentioned what happened in Japan with the top management in 1950 and in the 18 visits that I made since. They listened to my talks, about how management can make use of statistical methods in industry all the way from incoming materials to consumer research. I emphasized that the two ends of the line are important points; incoming materials and the consumer. Without the consumer we don't have any production. The whole world knows how they have done it. Innovation, new products, and improvement of all the products; it's fantastic.

Japanese management uses difficult methods, everywhere. On reception of incoming materials, they do not accept defective materials. They teach vendors quality control. Japanese manufacturers also learnt something that is useful in production, namely to share their manufacturing concerns with all the others; so the entire industry improves. I taught top management in all my visits, 18 in all, and their eagerness to learn how to use statistical techniques was very great.

* *From the Internet*

Deming stressed on the importance of suppliers and customers for the business development and improvement. He believed that people do their best and it is the system that must change to improve quality. His 14 points[3] formed the basis for his advise to Japanese top management. The 14 points are applicable to every industry in product and service sector.

3. Joseph M. Juran (1904) Juran also joined Western Electric Company and developed Western Electric Statistical Quality Control Handbook. JUSE invited him to Japan in 1954. He identified fitness of quality and popularized the same.

Juran's fitness of quality

1. Quality of Design—through market research, product and concept.
2. Quality of conformance—through management, manpower and technology.
3. Availability—through reliability, maintainability and logistic support.
4. Full service—through promptness, competence and integrity.

Juran's quality planning roadmap consists of the following[1]:

Juran's Quality Planning Roadmap

- Identify your customers.
- Determine their needs.
- Translate them into your language.
- Develop a product that can respond to the needs.
- Develop processes, which are able to produce those product features.
- Prove that the process can produce the product.
- Transfer the resulting plans to the operating forces.

4. Philip B. Crosby (1926) Crosby was Vice President of International Telephone & Telegraph (ITT). His 4 absolutes of Quality[4] are very relevant to TQM.

Crosby's four absolutes of quality

1. Quality is conformance to requirements, nothing more or nothing less and certainly not goodness or elegance.
2. Quality has to be achieved by prevention and not by appraisal.
3. The performance standard must be zero defect and not something close to it.
4. The measurement of quality is the price of non-conformance, i.e. how much the defects in design, manufacture, installation and service cost the company. It is not indexes, grade one or grade two.

5. Armand V. Feigenbaum He was President of American Society of Quality Control (1961–1963). He said, "Quality is in its essence a way of managing the organization". He suggested the following methodology for cycle time reduction.

Feigenbaum's cycle time reduction methodology[5]

1. Define process.
2. List all activities.
3. Flowchart the process.
4. List the elapsed time for each activity.
5. Identify non-value adding tasks.
6. Eliminate all possible non-value adding tasks.

6. Kaoru Ishikawa (1915–1989) A Quality Guru from Japan, he strongly advocated the use of cause and effect diagrams to provide a true representation of the organizational impacts and procedures. He developed Fishbone or Ishikawa diagram for cause and effect analysis.

Other Quality Gurus include James Harrington, Taguchi and Shingo.

The reader should be familiar with some of the basic terms related to quality to understand TQM .

QUALITY CONTROL (QC)

Quality Control or QC may be defined as: The operational techniques and activities that are used to fulfill the requirements for quality. Juran[1] gives 3 steps of QC:

1. Evaluate actual operating performance
2. Compare actual performance to goals
3. Act on the difference

In simple terms, QC is inspection or appraisal of products and services to ensure that the stated requirements are fulfilled. This was the only technique practiced during World War II. Since it was found that QC was essential but not sufficient, Quality Assurance techniques were developed after the war.

QUALITY ASSURANCE (QA)

The **definition of quality assurance** is: All the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill the requirements for quality.

The purpose of QA is to fulfill the quality requirements of an entity, i.e. product or service, with adequate confidence by the supplier. This requires implementation of all the activities planned for building quality into the product. Such planned activities are to be implemented systematically within the purview of a documented quality system. Building quality into the products requires the following[2]:

- Quality of Design
- Quality of Conformance
- Quality of Performance
- Quality of Service

Quality of Design It refers to how well the product or service has been designed to meet the current and future requirements of customers and add value to all the stakeholders. The stakeholders for any organization are:

- Customers
- Employees
- Suppliers
- Owners
- Society

Quality of design involves all activities that will result in a successful design. It necessarily includes finding out the customer's requirements.

Quality of Conformance This indicates the consistency in delivering the designed product. Product quality in turn depends on the quality of all processes in the organization. Therefore, it involves all activities that will ensure the conformance of the products to its requirements consistently.

Quality of Performance Indicate the performance of the end product. This in turn depends on the quality of design (including the reliability of the product) and quality of conformance.

Quality of Service Selling a product is not the end of the business. It is the quality of associated services rendered that adds value to the product. Quality of services involves all activities that will enable the customer to procure and use the product without any hassles.

Thus Quality Assurance, is much more involved activity than mere inspection or QC. In fact QC is one of the activities of QA.

QUALITY PLANNING (QP)

In order to consistently meet customer requirements, the quality of 4 Ms namely — Man, Machine, Material and Methods need to be ensured. The requirements of the 4 Ms are to be identified in the form of quality objectives. The objectives should be established for all the functions. The functions include suppliers, purchase, product design, engineering, production, in process inspection, final inspection, after sales service, etc. Quality planning refers to the activities that establish the objectives and requirements for quality. QP involves planning for the following with regard to a product or service or project or a contract:

- Quality objectives to be met
- Specific of QA/QC practices
- Resources needed
- Sequence of QA/QC activities.

The QC activities include testing, inspection, examination and audit at various stages of product or service life cycle. Therefore, quality has to be planned for every product or service and documented in the form of a quality plan.

QUALITY IMPROVEMENT

This process aims at attaining unprecedented[1] levels of performance, which are significantly better than the past level.

STRATEGIC PLANNING

Strategic planning is important for any business. It involves making plans for the following, in particular:

- Business value
- Investment in machinery and equipment
- Manpower to be hired
- Budget
- Product diversification
- Markets to be served
- Strategies for improving profits, etc.

Strategic planning is carried out generally at annual intervals and is carried out using a formal structured approach. The strategic planning is kept confidential due to obvious reasons. Usually organizations treat strategic planning and quality planning as separate and isolated activities. However, Malcolm Baldrige National Quality Awards (MBNQA) — the prestigious quality award in USA— calls for the integration of both. It means that quality planning and improvement planning should be carried out as part of strategic planning. The quality improvement planning should focus on the needs of current and future customers and support the strategic and business goals of the organization.

QUALITY MANAGEMENT (QM)

According to ISO 9000 standards, Quality management comprises "All activities of the overall management function that determine the quality policy, objectives and responsibilities and implement them by means such as quality planning, quality control, quality assurance and quality improvement within the quality system."

The quality system consists of the organizational structure, procedures, processes and resources needed to implement quality management.

The above brings out the following:

- The company must have an objective and policy for quality of the products and services.
- The organization should plan for meeting the objective.
- The plan should include QA, QC and methodology for improvement.
- There must be a clear organizational structure for building quality into the products and services with necessary resources.
- The quality management should be implemented formally with well-defined processes and procedures and trained resources.

The strategy for quality evolved with time is given in Fig.1.2:

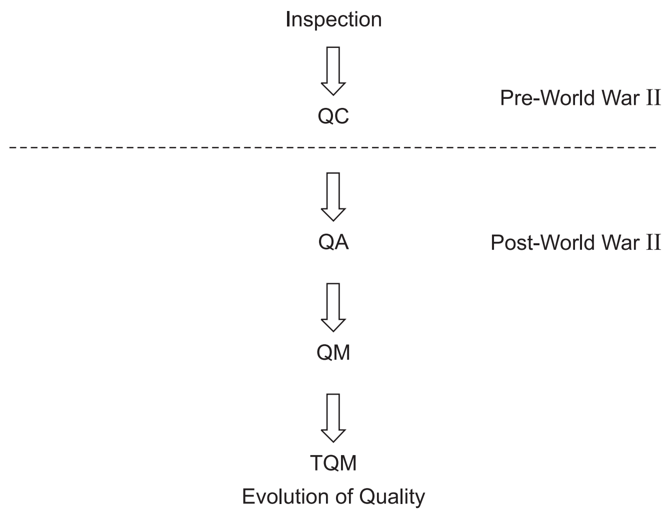


Figure 1.2

The above is the chronology of evolution of methodologies for quality assurance.

TOTAL QUALITY MANAGEMENT (TQM)

It was Feigenbaum who coined the phrase "Total Quality Control"[5]. The concept is known in Japan as Company Wide Quality Control (CWQC). In 1985, the Americans came up with the term Total Quality Management (TQM) to represent essentially the Japanese way of Quality Management[2].

Just-In-Time (JIT)

Tai-ichi Ohno of Toyota motors refined an idea for Just-In-Time. This means that at no stage of manufacturing nobody or nothing waits for anything. This is to ensure that there is no wastage of machinery, materials and manpower. JIT focuses on right scheduling so as to keep inventory as low as possible. This requires a perfect partnership between supplier and customer.

ISO 9000 Standards

ISO 9000 Standards were released for the first time in the year 1987 to bring in system for quality in every organization. The standard was revised in 1994 and later in the year 2000. The standard in the latest version advocates TQM and continuous process improvement.

Deming Award for Quality

To express their gratefulness, Japanese instituted a Quality Award in the name of Deming in the year 1951. The award is now given not only to companies in Japan, but even overseas who excel in quality.

CASE STUDY

TQM – Case study of Sundaram-Clayton

Venu Srinivasan and the Deming Prize. Kudos for India.

The Chennai-based Sundaram-Clayton has won acclaim and international recognition for setting global quality standards. From the swamp of unreliable quality that the traditional India companies were known for, Sundaram-Clayton has emerged the flag bearer of global class. Despite its disdain for TQM, Sundaram-Clayton, the manufacturer of air-brake systems and castings has emerged as Asia's first-ever winner of the Deming Prize for Overseas Companies. Every rupee of its Rs 139.37 crore turnover now carries the mark of quality that is world-class.

The Deming Prize is the last word in the world of quality. The prize was instituted 40 years ago by Japan to honour the man who gave quality to the world, W. Edwards Deming.

The Deming Prize Committee defines quality as "a system of activities to ensure the quality of products and services, in which products and services of the quality required by the customers are produced and delivered economically."

Sundaram-Clayton's integrated Deming's 10 parameters into the four streams of its quality practices, namely policies, people processes and products, respectively. Its TQM model ensures total employee involvement, policy deployment, standardization, Kaizen, and training, besides promoting employer–employee relations. In short, everyone everywhere in the company is a custodian of quality.

Sundaram-Clayton, led by its CEO Venu Srinivasan, 45, has risen above the countrywide levels for total quality, to be part of an exclusively small global elite, which have integrated all the Deming's 10 parameters into their streams of quality practices. This small elite group consists of three other companies namely the $6.51-billion Florida Power and Light, which won the Deming Prize in 1989; the $53.26-billion AT&T's Power Systems Division in 1994, and the $38.05-billion Philips Taiwan unit.

On November 14, 1998, when Srinivasan received the coveted prize, he joined the ranks of 163 CEOs and managers who had been conferred the award since it was instituted.

In quick succession, Sundaram-Clayton's managers were exposed to the quality practices of global leaders, trained in modern manufacturing techniques, and tought Total Quality Control (TQC), first by Yoshio Kondo in a workshop at the National Institute For Quality and Reliability in 1986. Srinivasan also set up a core taskforce to baptize Sundaram-Clayton in the new religion of TQC.

The results of Sundaram-Clayton's total quality movement are reflected in the company's books. Its financial indicators in the 5 years between 1992–93 and 1997–98 tell a tale of top-level performances. Thus, sales grew at an average rate of 35 per cent per annum, between 1992–93 and 1996–97, although it shrank by 25 per cent in 1997-98, on account of the recession in the automobile industry.

Likewise, the average growth in net profits in those four years was a stunning 83 per cent per annum—a glowing tribute to quality-led cost management—although it fell back by 35 per cent in 1997–98. But, internally, its performance improved consistently despite the recession, with turnover per employee rising by an average of 18 per cent a year, and gross value added climbing by an average of 12 per cent per annum.

http://www.themanagementor.com/kuniverse/kmailers_universe/hr_kmailers/perf_venu.htm

SUMMARY

As Feigenbaum said, "quality is in its essence a way of management of the organization". Quality is conformance to customer requirements. The requirements have many dimensions. Various dimensions or attributes of quality were discussed in this chapter. The concepts of quality have been evolving over many decades. A number of quality experts, also called quality gurus, contributed to the evolution of quality. Deming, an American expert helped Japan to dramatically improve the quality of their products and services and emerge as a successful nation. The prestigious Deming award for excellence in quality has been instituted. His 14 points for management are very relevant even today. The "chain reaction" proved that quality is the only way to do business. Philip Crosby's four absolutes of quality bring out the essence of quality. Juran's quality planning road map is quite practical. Feigenbaum's methodology for cycle time reduction is applicable to every business. Ishikawa was the leader of Japanese quality movement from Japan. Dr Shewart is the father figure of SQC. Quality has evolved through Inspection— QC– QA– QM––TQM. Just-In-Time (JIT) is the Japanese concept to reduce waste and ISO 9000 standards provides a basis for establishing quality system in every organization.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. Quality is
   (a) Excellence
   (b) Conformity to requirements
   (c) Meeting our own requirements
   (d) All the above
2. Quality includes
   (a) Functionality
   (b) Customer service
   (c) Delivery quality
   (d) All the above
3. Quality control includes
   (a) QA
   (b) QP
   (c) QM
   (d) All the above
   (e) None of the above

4. QM includes
   (a) QA (b) QP
   (c) QC (d) All the above
5. Quality planning roadmap was evolved by
   (a) Deming (b) Ishikawa
   (c) Juran (d) None of the above

II. True or False

1. Quality plan is the result of quality planning
2. QC means verification
3. QC is part of QA
4. Portability is applicable to software
5. Chain reaction refers to the effect of improving quality
6. Conformance to requirements is one of the four absolutes of quality
7. Quality system consists of only procedures
8. Society is not a stakeholder of an organization
9. ISO 9000 is not aimed at TQM
10. JIT is not relevant to quality
11. Customer service is important only to services
12. Quality has to be built into the products and services
13. Quality is only for highly priced items
14. Building quality requires quality of design, manufacturing and service
15. JIT was evolved in Toyota Motors in Japan
16. Deming worked with JUSE in Japan
17. Efficiency is one of the attributes of quality
18. "Economic Control of Quality of Manufactured Products" is a book authored by Shewhart.
19. Quality affects productivity

III. Write Short Notes on

1. Dimensions of quality
2. Four absolutes of quality
3. Chain reaction
4. Evolution of quality
5. Quality planning roadmap
6. Juran's fitness of quality
7. JIT
8. ISO 9000 standards
9. Feigenbeum's cycle time reduction methodology
10. Quality Assurance
11. Strategic planning and quality planning.
12. Deming Award
13. Quality concepts incorporated in TQM

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(1) Juran, et al. *Juran's Quality Control Handbook*, 3rd Edition McGraw-Hill Book Company, New York 1979.
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(3) Deming, *Out of the Crisis*, Cambridge University Press, Cambridge, 1986
(4) Crosby, Philip B. *Quality without Tears*, McGraw-Hill Book Company Singapore, 1986.
(5) Feigenbaum, Armand V. *Total Quality Control,* 3rd Edition, McGraw-Hill Book Company, Singapore, 1986.

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(1) Juran Institute: http://www.juran.com
(2) Philip Crosby Associates: http://www.philipcrosby.com
(3) The W. Edwards Deming Institute® is a nonprofit organization that was founded in 1993 by noted consultant Dr. W. Edwards Deming. www.deming.org/ –Description: To foster understanding of the Deming systems to advance commerce, prosperity, and peace.
(4) Basic principles of Total Quality Management (TQM) by Ron Kurtus (May 28, 2001): http://www.school-for-champions.com/tqm/principles.htm

Chapter **2**

Quality Costs

To exist is to change, to change is to mature,
to mature is to go on creating oneself endlessly.

—Henri Bergson

INTRODUCTION

The top management looks at every activity in the organization in terms of return on direct and indirect investment. However, this does not mean that they are looking for short-term gains only. They don't mind waiting for years, if ultimately the efforts are going to pay out. Top management will adopt ISO 9000 or TQM if it is going to help the organization. In fact, many companies have adopted ISO 9000, TQM, Six Sigma, etc. for growth coupled with profits.

TQM was evolved to satisfy customers in the most economical way. Quality means cost effectiveness. It means reducing expenditure by eliminating wastes through systematic quality management approach. Therefore it is important to compute expenditure incurred on account of poor quality, and prevent it. TQM should result in the progressive reduction of interior quality goods. Quality cost is a tool to demonstrate cost of poor quality to the top management as well as the entire organization. It will also highlight the importance of TQM activities to the top management clearly. Above all it will help the organization to know the effectiveness of the organization and the areas where the efforts are wasted.

TQM aims at gradual reduction of wasteful expenditure and eventually their total elimination. Quality costs should be accounted separately so as to know how much the organization is loosing on account of poor quality. Decreasing cost of production should indicate quality improvement. Accounting and analyzing quality costs has given innumerable benefits to the organizations. Thus quality costs is an important tool for TQM.

COST OF QUALITY

Cost Of Quality (COQ) is the sum of costs incurred by an organization in preventing poor quality. There are essentially three types of Quality Costs as given below:

1. Prevention Costs
2. Appraisal Costs
3. Failure Costs

Thus, the COQ can be classified into 3 categories as given in Fig. 2.1.

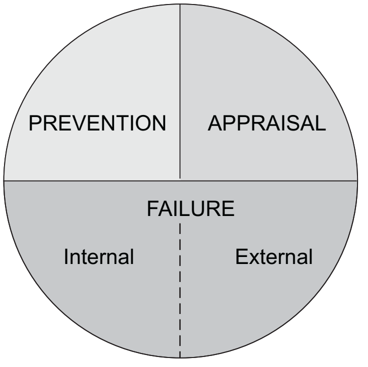


Figure 2.1 PAF Model

This is called PAF model, name abbreviated from the first letters of the three categories. Any quality cost which arises in an industry can be classified into one of the above three categories.

The prevention costs are the planned costs incurred by an organization to ensure that no defects occur in any of the stages such as design, development, production and delivery of a product or service. They are incurred to reduce the inspection as well as the failure costs. The expenditure on account of TQM implementation is a prevention cost. Prevention costs include education and training of employees, process improvement efforts, process control, market research, product qualification, field testing, preventive maintenance, calibration of instruments, audits, quality assurance staff, etc.

The appraisal costs are incurred in verifying, checking or evaluating a product or service at various stages during manufacturing or delivering. They are incurred due to lack of confidence in the quality of the product or service either due to the incoming material or due to the process. For instance, the incoming materials are inspected, because, the receiver is not sure about the quality of the incoming goods. During the process, a number of inspections take place, since the quality of the process is in doubt. Therefore, if quality improves in the organization as well as among the vendors, inspection cost can be reduced. Appraisal costs include incoming inspection, internal product audit, supplier evaluation and audit, inspection during process and final inspection, etc.

The failure costs are incurred by an organization because the product or service did not meet the expected requirements and the product had to be fixed or replaced or the service had to be repeated. The failure costs are due to the incurred failure of the organization to control defects in the product.

Defective products in the market can lead to the loss of reputation and customer loyalty. One dissatisfied customer will tell 100 others, which means the loss of both present and future customers. It will also affect the brand image, leading to loss of good will and customer loyalty. If the trend is not corrected, and the quality is not restored, the company will have to close down.

Thus, the organization should start accounting separately the costs of quality, preferably under these three heads.

CLASSIFICATION OF FAILURE COST

The failure costs can be classified into:
Internal Failure Costs Includes costs of every failure that takes place before the product is delivered to the customers. It accrues due to defective processes. The following accounts for internal failures:

- Rejected material, supplied by vendor
- Rejected pieces of sub-assemblies
- Rejected products at final inspection
- Scrap on account of poor workmanship
- Overtime due to non-conforming products.

External Failure Costs These are on cost of failure of the product after its delivery to the customers. Examples of external failure are:

- Warranty costs
- Free replacements given due to failure of items supplied
- Cost incurred to travel to customer's site for repair
- Cost of products returned.
- Cost of customer complaint administration
- Cost of customer follow up and field service department.

The aim of strategic planning and quality planning is the total elimination of wastes. This elimination leads to meeting customer requirements, at the lowest possible cost. Any defective component only adds to the cost of product. A sub-assembly that contains defective components is a waste as is the case with any product that does not work for the first time after assembly. Any defective part supplied by the vendor is a waste. Also problems encountered in the field, in the product, causes a lot of unnecessary expenditure. Such causes of waste are too many. Therefore, Juran [1] introduced the concept of Cost Of Quality (COQ) in the year 1951 in his *Quality Control Handbook*. The other Gurus such as Philip Crosby, Harrington also advocated due emphasis on COQ.

> To quote Harrington[2], the cost of poor quality accounted for about 25 per cent of the assets, 25 per cent of the people and 40 per cent of the inventory and space, in companies, which don't care about quality.

REDUCING COSTS

Reduction of Prevention Cost

Prevention cost has to be incurred. Every preventive activity should have been pre-planned to avoid wastes during the process. Periodically, the senior management should devote time to prevent problems from occurring. The establishment of a Quality System in every organization calls for the preparation of a quality manual and a set of procedures. Even the documented quality system should have been planned with a vision. If a documented set of policies and procedures already exist for an organization, the employees should strictly adhere to the same. Prevention cost means expenditure. While the organization should not hesitate to improve the processes and reduce the waste through prevention, the prevention activity itself should be carried out without wastes.

Progressive Reduction of Appraisal Costs

Inspection is essential before assessing a new vendor, a new process or a new product line. Inspection generates a lot of information. This information should be utilized skillfully by the organization to reduce future costs. For instance, for a new vendor who is already qualified, the organization may start with 100 per cent inspection; with experience this could be reduced to a sampling inspection. With the increase in confidence level, the responsibility of the inspection could be totally left to the vendor. Soon, the organization should be looking forward to reducing the cost of inspection, at the same time encouraging the vendor to maintain and improve the quality of his processes. The organization should try to make best use of the data available within the organization in the form of inspection records to improve quality and reduce the need for inspection. The inspection costs should also be reduced with the maturity of the processes.

Reduction of Failure Costs

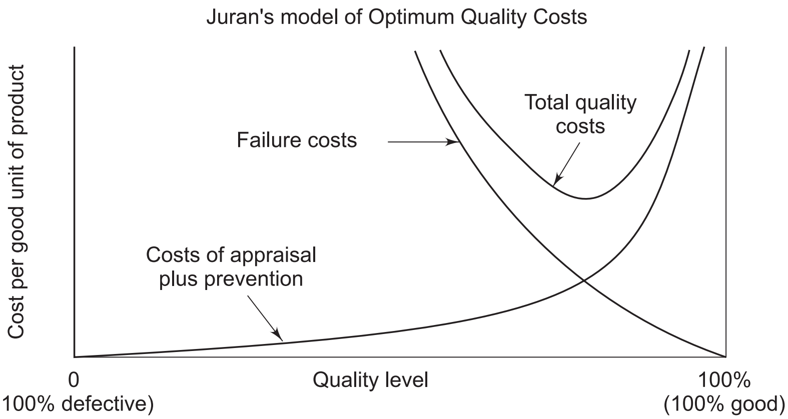
Manufacturing or delivery of a product or a service with defects is a total waste. Everything should be done right the first time and every time. There should be no occasion to reject a product or a service either at the initial stage, the intermediate stages or, at the final stages. Right the first time will happen only if the processes are streamlined and made effective and efficient. Every cause, which may lead to the immediate or gradual failure of the product, should be identified and eliminated. If a system is established to measure the process parameters and study their variations, the confidence level should go up to an extent that inspection may be forgone. Therefore, a lot of emphasis should be given to establishing a proper system to control the processes. Efforts should be made to control the process, which would lead to automatic control of the quality of the output. Scraps and reworks are the biggest wastes in any organization. Any rework reduces the value of the output. It only increases hassles and scraps, accounting and storage of which is a problem. Therefore, systematic action should be taken to reduce the rework and the scrap by following TQM principles.

Hidden Costs

There are many costs, which cannot be identified easily. They may be defined as hidden costs. These include customer-incurred costs, lost reputation costs and customer dissatisfaction costs. These costs can vary and some times affect business. Hidden costs can be eliminated only by eliminating external failures.

JURAN'S MODEL OF OPTIMUM QUALITY COSTS[1]

Juran's model for quality costs is illustrated in Fig. 2.2, the quality level increases, when the number of defects in the product or service reduces. The cost of non-conformance (failure cost) decreases as quality level improves. The quality level increases when the cost of conformance (sum of prevention and appraisal cost) increases. But the figure indicates that 100 percent quality is very expensive. The total quality cost is the sum of both. The lowest tip is the optimal cost. The figure gives a feeling that we must put up with some defects.



From J.M. Juran's *Quality Control Handbook*
Third Edition (New York McGraw Hill, 1979) p. 5–12.

Figure 2.2

Schneiderman[3] expressed the quality costs mathematically as given below:
Total cost of non-conformance = f
Total cost of conformance = P
Total cost = $T = (f + P)$
Quality level (0 to 100% good product) = q
The optimal cost occurs when T is minimum or when

$$\mathrm{d}T/\mathrm{d}q = 0$$

Since $$T = f + P$$

$$\delta f/\mathrm{d}q + \delta P/\mathrm{d}q = 0$$

or $$\delta P/\mathrm{d}q = -\,\delta f/\mathrm{d}q$$

In other words, at the minimum total cost, every dollar spent on conformance reduces non-conformance by one dollar. Below the minimum (optimum) the returns are high and above it, the return is lower.

Schneiderman argues that there is no mathematical necessity that the optimum occurs at q<100 per cent. There might be a minimum, rather than optimum, and it could very well be at q =100 per cent. This is illustrated in Fig. 2.3.

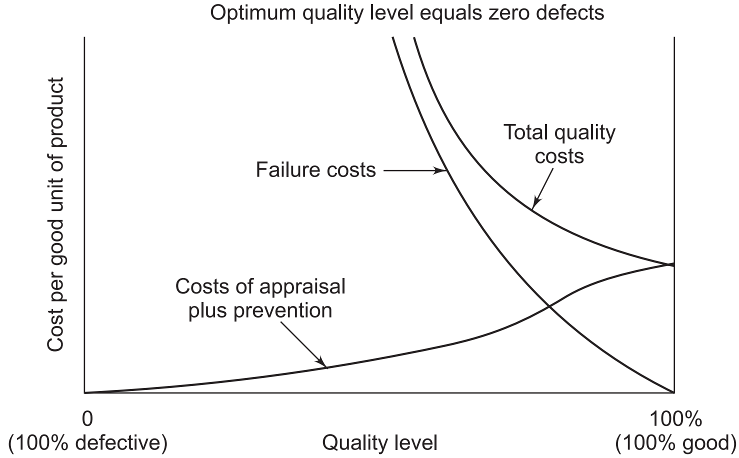


Figure 2.3

Here the minimum quality costs occur at 100 per cent quality level. This is the ideal situation. Six sigma quality level is very close to 100 per cent. Thus, Fig. 2.3 represents the current scenario. Zero defect programs should result in costs as given in Fig. 2.3.

The various costs should be accounted for and periodic analysis conducted. The top management will understand cost of quality easily. Therefore in order to get the support of top management for TQM it is important that quality costs be computed and the results analyzed.

ANALYSIS OF COQ FOR IMPROVEMENT

Management should use the COQ data to identify and prioritize improvement opportunities. The first priority is to eliminate external failures and then internal failures. Thereafter inspection can be reduced gradually. By spending more money on prevention all these can be achieved. A typical case study is given in Table 2.1.

Table 2.1 Cost of Quality as a Percentage of Total Manufacturing Cost

Year	*External*	*Internal*	*Appraisal*	*Prevention*	*Total COQ*
1995	3	1.5	1	0.5	6
1997	1.5	2.5	1.5	0.5	6
1999	0.5	1	1.5	1	4
2001	0.1	0.2	0.5	1.2	2

During 1997, increasing appraisal without increasing prevention increased internal failures but reduced external failures. However, the total COQ did not change. This is certainly an improvement because external failures affect business very badly. During 1997, the organization decided to get into ISO 9000 and focus on prevention. During 1999 when prevention was stepped up, keeping the same level of inspection, the failures and overall COQ came down. In 1999, the CEO decided to adopt TQM. Vigorous efforts were made to improve quality further and do things right, the first time and every time. Hence in the year 2001, appraisal could be brought down drastically. However, the result is much better as the table indicates. Now both the internal failures and external failures are quite low. Efforts should be made in the same direction so that overall COQ reduces further. Thus, TQM is aimed at enabling the lowest cost of quality.

ANALYSIS OF EXTERNAL FAILURE COST

Similarly an analysis of external failures was made by the organization. The pie chart below indicates the distribution of causes of external failure.

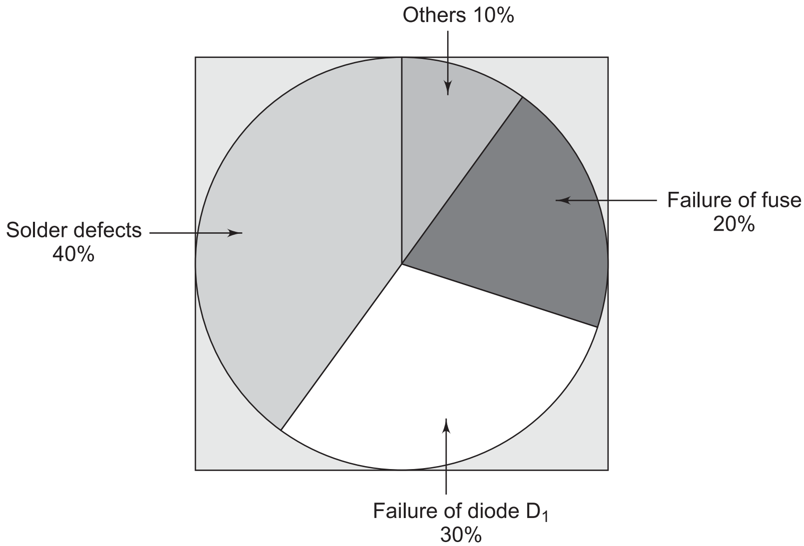


Figure 2.4

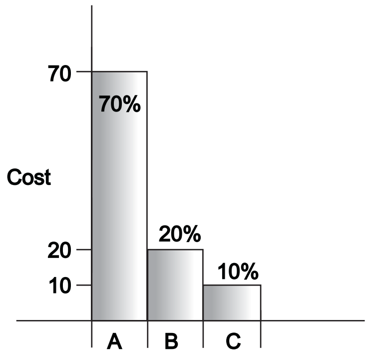
The above pie chart gives the priorities for action to be taken as given below:

1. Improve quality of soldering
2. Eliminate the cause of failure of diode D_1
3. Estimate the correct rating of fuse and analyze the causes of failure of fuse.

If all the above failures can be eliminated then the failure cost will reduce to about 10 per cent.

ANALYSIS OF INTERNAL FAILURE COSTS

From the data available, the causes for the internal failure costs were analyzed and plotted as a Pareto Diagram.



A. Wrong component placed
B. Soldering failure
C. Other causes.

A major cause of internal failure was insertion of wrong components in the PCB. The process was studied and found that the lighting in assembly line needed improvement and the operators needed training. This analysis and the external failure analysis pointed to problems in the soldering process. A thorough study was required to reduce the defects caused by poor soldering.

Thus, it is very important to analyze the data more closely to derive benefits to the organization.

The COQ analysis gives the following benefits to the organization.

- Brings out the magnitude of the quality problem in the organization. It further leads to establishing goals for the organization to improve quality.
- Enables cost reduction owing to steps taken for improvement based on analysis.
- Enables taking steps to improve customer satisfaction.
- Displaying the results motivates employees to improve further.

SUMMARY

TQM will lead to the gradual reduction of wastes and eventually their total elimination. Quality costs should be accounted separately so as to know how much the organization is loosing on account of poor quality. The organization should not hesitate to take preventive actions as only through preventive action, it can eliminate failures. Inspection may be required for initial assessment of processes, vendor supplied products, etc. Through appropriate preventive actions, inspection should be reduced to the minimum and failure to nil. Therefore, an organization with matured processes should incur expenditure on prevention costs and reduce and finally totally eliminate the failure costs. Computation of quality costs helps in reduction of costs on account of failure of control by raising an alarm not only to the management, but also, to the employees. Therefore one of the important tasks in TQM is computing, accounting, and analyzing quality costs and taking corrective action based on the results.

The cost of quality can be divided into two categories as given below:

- Cost of conformance
- Cost of non-conformance

The failure costs are cost of non-conformance since it arises due to non-conformance of materials and products. Both the appraisal cost and prevention costs can be counted as cost of conformance. This expenditure is made to ensure that the product conforms to the requirements. The inspection related expenditures are the cost of appraisal. The costs on account of improving quality such as on TQM, ISO 9000 preparation are all prevention costs.

REVIEW QUESTIONS

I. Choose the most appropriate answers.

1. Total quality costs include
   (a) Prevention cost (b) Appraisal cost
   (c) Failure cost (d) All the above
2. ISO 9000 certification cost is
   (a) Appraisal cost (b) Internal failure cost
   (c) External failure cost (d) All the above
   (e) None of the above
3. Cost on account of incoming inspection is
   (a) Internal failure cost (b) External failure cost
   (c) Appraisal cost (d) None of the above

II. True or False

1. Quality costs means cost of poor quality
2. Top management will understand quality costs better
3. Inspection of vendor-supplied products is prevention cost
4. One should operate at the maximum total quality cost
5. Minimum total quality cost can occur at 100 per cent quality level
6. Failure costs increases with prevention
7. Cost on account of prevention should not only reduce failure cost but also appraisal cost.
8. Juran is the author of quality costs
9. Product qualification is prevention cost

III. Explain briefly or write short notes on

1. Cost of conformance
2. Cost of non-conformance
3. Optimum quality level and Zero defect (with illustration)
4. TQM and Quality costs
5. Prove that at optimum quality level a dollar of cost of conformance reduces the failure costs by the same amount.
6. The following table gives quality costs in an organization. Express it in the form of PAF model and Pareto diagram.

Item	**Expenditure in dollar($)**
External Audit	20,000
Field failure	40,000
In-process inspection	10,000
Product qualification	240,000
Scrap	45,000
Quality System	24,000
Warranty costs	50,000

7. Describe how will you proceed systematically to bring down quality costs in an organization that has an external failure cost of 4 per cent of sales. What kind of results you expect at yearly intervals?

References

(1) Juran, et.al, *Juran's Quality Control Hand Book*, Third Edition, McGraw-Hill Book Company New York, 1979, pp 5–12.

(2) Harrington James, *The Improvement Process*, McGraw-Hill, Singapore, 1987.

(3) M. Schneiderman, *Optimum Quality Costs and Zero Defects: Are they Contradictory Concepts*?, Quality Progress, 1986.

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(1) Arthur M Schneiderman ,"Optimum Quality costs and zero defects: Are they contradictory concepts?" *Quality Progress*, November 1986, American Society of Quality Control – also available on the following website: www.schneiderman.com

(2) Cost of Quality, Quality Planning and The Bottom Line, by G. Dennis Beecroft http://www.iiqp.uwaterloo.ca/Reports/RR-01-08.pdf

Chapter **3**

Leadership

To accomplish great things, we must not only act,
but also dream; not only plan, but also believe.

—Anatole France

INTRODUCTION

Total Quality Management is a way of managing an organization with the objective of carrying out right jobs right—the first time and every time. In quality management, there is a thumb rule called 85/15 Rule. It means that the root causes of 85 per cent of the problems in the organization are due to faulty systems and 15 per cent are a result of the behaviour of employee. The top management is responsible for the faulty systems. Therefore, the most important agent for correcting a faulty system and enabling TQM is the top management. The leaders, who broke away from the traditional style and adopted TQM-based style of management, have been well rewarded. The TQM based leadership put companies far ahead of their competitors in terms of sales, profits and employee morale. Effective leadership for TQM involves everyone in the organization in value adding activities.

The most important prerequisite to practice TQM is that the senior management should firmly believe that TQM is the only way to do business and manage the organization and that TQM would lead the organization to prosperity in the long run. Unless the top management believes in TQM, there is no way to implement TQM in an organization. In addition, the top management should also have faith in the following to build quality values in the organization:

- Customers are the only reason for being in business and hence they should be delighted
- Zero defect is possible to achieve
- Teamwork results in a win-win situation
- CEO has to lead the quality movement
- Proper communication is essential
- Continuous improvement is needed in processes.

TQM is the right model to manage organizations since it assures the highest return on investment. At the same time, organizations should venture into TQM after a thorough analysis of the pros and cons. TQM calls for hard work on the part of management. Above all, the management should be prepared to invest time and money in training their employees. If TQM is to be practiced they should be prepared to run a transparent organization. Therefore, before presenting this idea to the employees, the top management should be understanding, discussing, consulting, analyzing and exploring all the actions needed before deciding whether to practice TQM or not. If the top management has the slightest inclination not to get into TQM, then it is not the right time to get into TQM. Only those organizations where the top management is ready for organizational change and personal change will be successful. TQM is the modern management concept and is the only road to consistent growth of organization as well as survival in a competitive environment, since all other options have failed.

In this chapter, we will discuss about the principles and strategies to be adopted by the top management to provide effective leadership for TQM.

DEFINITION OF TQM

The International Standard, ISO 9000[1], defines Total Quality Management (TQM) as "a management approach of an organization, centered on quality, based on the participation of all its members and aiming at long term success through customer satisfaction and benefits to the members of the organization and to the society".

A detailed analysis of the definition of TQM is essential to avoid misunderstanding. TQM is a management approach for the entire organization led by the Chief Executive Officer (CEO) of the organization. Involvement of all the employees in the continuous process improvement is one of its goals. Every member of the organization should understand and practice TQM. TQM, unlike other concepts, which are centered on profit making, is centered on quality. TQM means long-term success, which is achieved through customer satisfaction and benefits the employees and society. The benefits of TQM include not only the profits but also the success of the organization in term of satisfaction of the customers and hence more business, and goodwill of the society at large towards the organization. The standard also stipulates that a strong and persistent leadership of top management and training of all the members of the organization is essential for the success of this approach. TQM should be the basis of all the activities in the organization as it aids in achieving the organization's objectives and goals. TQM aims at continuous improvement of the current practices so that the customer satisfaction and employee satisfaction improve day by day. TQM is also called Total Quality Control (TQC) or CWQC.

There is a standard on TQM [2] issued by British Standards Institution (BSI), UK, entitled TQM part I, Guide to Management principles BS 7850:part I: 1992.

It provides another definition for TQM, which is reproduced below:

"Management philosophy and organization practices that aim to harness the human and material resources of an organization in the most effective way to achieve the objectives of the organization".

Thus, TQM represents management philosophy and organization practices. The philosophy and practices should aim at purposeful and effective utilization of human and material resources of the organization. It means that every machinery, material and men should be effectively utilized to fulfill the objectives of the organization. The note following the definition adds that the objectives may include customer satisfaction, business objectives such as growth, profit or market position or the provision of services to the community. Therefore, TQM is applicable to all the organizations both government and non-government, either engaged in commercial activities or service oriented activities which are non-commercial. The standard also says that there are so many other names, which are used essentially to represent TQM as given below:

- Continuous quality improvement
- Total quality
- Total business management
- Organization wide quality management
- Cost effective quality management

TQM is an umbrella concept and it encompasses all these and represents the new management philosophy, which will enable the growth of the organization based on total quality. Total quality means, quality in every activity of the organization. To put it in simple terms, it helps to improve the productivity on account of quality in everything an organization does. In the foreword of the standard it is said, "the application of TQM primarily involves investment in time for people to move forward into new and different organization cultures". The crux of the problem in implementing TQM is the inability of the senior personnel in investing time on people. The time invested is going to bring in many benefits to the organization later. It also hints that it takes time to change people from the traditional work culture to modern work culture. It also says that the important investments for TQM to happen are time and employees.

ELEMENTS OF TQM

TQM is application of a number of activities with perfect synergy. The various important elements of TQM are illustrated in Fig. 3.1 as follows.

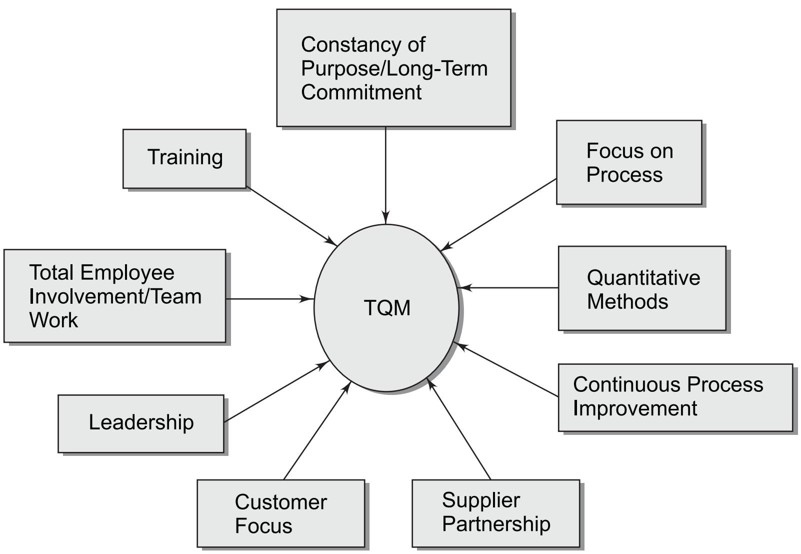

Figure 3.1 TQM Elements

In this chapter, we will look at only one of the elements of TQM namely, leadership for TQM. The other elements for implementing TQM will be discussed in the remaining chapters.

LEADERSHIP FOR TQM

When we peruse the teachings of the quality gurus, we gather that the higher echelons of management has an important role to play for TQM to be implemented. In fact, the management is solely responsible for the success of TQM as it is responsible for selecting people, forming teams, providing resources and establishing the system in the organization. As Crosby says senior management is 100 per cent responsible for the problem of quality and its continuance [3]. According to Harrington [4], between 70 and 85 per cent of all errors can only be corrected by management. Thus, it is important that top management understands TQM and leads the organization through the TQM journey.

DEMING'S 14 POINTS FOR TOP MANAGEMENT

Deming is the father figure of Japanese quality movement. Deming addressed the Japanese top managers several times in the 1950s. He gave the 14 points for top management. These initiatives of Deming transformed the nation. The results are there for every one to see. Let us identify the role of top management for TQM to happen from the 14 points given by Deming [5.]

1. Create Constancy of Purpose for Improvement of Products and Services

The top management must believe that their business will continue for 100 years. Such a confidence will motivate them to aim long-term success. It will infuse a constant quest for innovation, improvement of processes, products and services. They will invest in research to innovate new products and will train their employees without the fear of loosing them. If the employees understand that the company is interested in long-term success, then the employees will follow suit. Therefore, it is the role of the top management to create constancy of purpose for improvement of products and services, which is essential for TQM. They have to constantly reiterate their intention to practice TQM and improve products and services.

2. Adapt the New Philosophy

The new philosophy is to practice the Japanese CWQC, which was renamed as TQM much later. The new philosophy means elimination of wastes, delays and radically changing the work culture. The new philosophy means, Just-In-Time (JIT) manufacturing is possible with zero defects. All the 14 points of Deming should to be adopted by the top management to result in long-term success through the implementation of TQM in the organization.

3. Cease Dependence on Mass Inspection

Doing things right and doing it right the first time would reduce the dependence on inspection, in fact it would be eliminated. TQM is aimed at eliminating inspection in the long run through prevention.

4. End the Practice of Awarding Business on the Basis of Price Tag Alone

This point addresses supplier partnership. The supplier should be selected on the basis of the following 4 parameters:

- Quality
- Price
- Delivery
- Service

Therefore price alone should not be the criterion for selection of supplier. Supplier partnership is discussed in Section II.

5. Constantly Improve the System of Production and Services

The processes in the organization need continuous improvement, Kaizen in Japanese. TQM is aimed at continuous improvement of processes so that the quality of products and services improve continuously. The very purpose of TQM is the constant improvement of the system for production and services.

6. Institute Training

The abilities of employees should be improved and harnessed only through training. Deming advocates, "Management needs training to learn about the organization, all the way from incoming material to the customer." Today every Japanese employee receives six weeks of training every year. This is the proof of Deming's teachings and the adoption of his concepts by the Japanese.

7. Adopt and Institute Leadership

Deming urges that the senior employees must conduct themselves as leaders rather than managers. The difference between the characteristics of managers and leaders are given in Table 3.1 as follows:

Table 3.1 Leader and Manager

Leader	*Manager*
Proactive	Reactive
Coaches	Finds fault
Understands process	Doesn't care to understand
Moves around	Sits in his chair
Improves process	Maintains process
Communicates frequently	Communicates rarely
Seeks suggestions	Questions

Thus the senior employees should be trained on leadership qualities.

8. Drive Out Fear

Employees should be encouraged to suggest improvements and new ideas, ask questions about the existing process, etc. If freedom to express new ideas is curtailed, then the employees will continue to do what they are doing. This will stunt improvement. Fear is detrimental to improvement of processes.

9. Break Down Barriers Between Staff Areas

Quite often, the various teams in the organization stop communicating with each other. The teams, over the years become watertight compartments. Every team may prove that it is the best. But organization as a whole may be doing poorly due to lack of communications between the teams! TQM dictates removal of barriers between the departments.

10. Eliminate Slogans, Exhortations and Targets for the Work Force

Here Deming talks about slogans and targets for increasing productivity. He says that barriers to quality and productivity exist within the organization itself. Hence, to achieve higher productivity, the system has to be improved for which, management is responsible. The posters are directed at the wrong people, namely the workers. They only generate "frustration and resentment" among workers. The best strategy for improvement is to correct defects in the system, not slogans or posters.

11. ***(a) Eliminate Numerical Quota for the Work Force*** Setting a target for production, say producing 1000 bolts per shift, etc. may affect the quality of workmanship. This forces the worker to ignore quality and concentrate on quantity. This is detrimental to the organization. On the contrary, standards for quality workmanship, etc. could be prescribed. Numeric quota is given assuming that the worker may be idling. That is not the right approach.

(b) Eliminate Numerical Goals for People in Management Setting goals without the necessary wherewithal does not work. Goals such as growth of business by 15 per cent or reduction of quality cost by 5 per cent given in a New Year day will end like New Year promises! Such improvements should arise out of improving processes and not by passage of time.

12. Remove Barriers that Rob People of Pride of Workmanship

The organization should establish the right processes and a proper system for quality management. This will lead to carrying out jobs correctly. If the work is carried out correctly, it gives pride to those who did. Any barrier that robs the managers or workers their pride of workmanship should be removed. Every employee should be encouraged to work as much as he can. Removing the obstacles to this pursuit is the responsibility of the top management.

13. Encourage Education and Self-improvement for Every One

Employees should be encouraged to pursue higher education and training while in service, for improving the skills or updating knowledge. If an employee undergoes education or training, it will improve his ability, which will be beneficial to the organization. Hence, employees should be motivated and encouraged to improve their knowledge and skills through various channels.

14. Take Action to Accomplish the Transformation

The top management should understand the above 13 points and then enable their employees to understand them. They should interpret the 13 points properly and educate their employees appropriately. They should have the courage to break the status quo and improve their employees, processes, system and thereby their products continually. They should identify all the processes in the organization and improve each one of them using PDSA cycle. Therefore the final point is about implementation of the 13 points, which in essence are the TQM principles and strategies.

Thus the 14 points formulated for Japanese management by Deming are relevant even today. He emphasized the same points to the American industry during the 1980s when they looked for his guidance.

TEN STRATEGIES FOR TOP MANAGEMENT

We will now look at some of the strategies advocated by experts to be adopted by the CEO and the top management to lead the organization on TQM principles. The author in guiding the organization, of which he is the head, adopted these strategies for the success of the organization in its TQM journey. Thus, they are very practical. Some of the strategies are:

1. Proactive management
2. Adventurous and bold change management
3. Do It Right First Time (DIRFT)
4. Continuous preventive action
5. Care for little things and accumulate gains
6. Ensure economic performance
7. Practice manage by walking around
8. Measure success
9. Never rest on laurels, continue to improve
10. Build a virtual organization

1. Proactive Management

The leaders have to be proactive. They have to foresee what will happen in the future and take advance action to prevent the occurrence of the problems as prevention is always better than cure. If the management is actively engaged in managing the organization, then they will be able to foresee the problems. They should be able to nip the problem in the bud, so that the problem will not recur. This is proactive management.

Proactive Management Needs Proper System Proactive management needs a proper system in the organization. The problem can be identified before occurring, only if there is a proper system in the organization. Unless a system is in order, the roles and responsibilities are clear, the organizational structure in place the procedures set and the system of recording everything laid out, it will be extremely difficult to think of prevention. If these measures are not taken then, it will only be fire fighting, which is reactive management. Fire fighting does not add value. Unless timely action is taken to prevent problems, it may lead to losses in terms of revenue, reputation and employee morale. Thus, proactive management calls for establishment of proper system for quality as well as the operations.

TQM Calls for Proactive Management Inspite of all the best efforts if an error has occurred, then corrective action has to be taken after an analysis so that such errors are not repeated. TQM envisages taking preventive actions so that mistakes do not recur. Quality can be improved only through preventive actions. The corrective action resulting out of failure is only a post-mortem. The failure is going to affect someone, it could be an external or an internal customer or an employee. But, preventive action enables achieving the organization’s goals without hurting anybody. Therefore, one should take preventive action and save the organization from disaster. Such concepts should be inculcated even among the vendors, so that they supply only quality materials. According to Deming, the dependence on inspections is a bad sign. A level should be attained when the inspection of materials is not required. By controlling the processes and by improving the skills of the employees, the organization should be able to manufacture an item or deliver a defect free service. This is the role of proactive management.

2. Adventurous and Bold Change Management

Nobody likes Change Human beings by their very nature resist change. Even, if a change is going to make them much more comfortable, they may not agree to it straightaway. They cannot visualize that the changes are in fact for their good. They resist change as they feel they may have to work more or learn new techniques. Each employee develops unique attitudes and values and they are strongly wedded to them. Anything different is unacceptable. Therefore, changing anything in an organization is a difficult task and requires tactful handling. Even, if the people concerned are consulted before change and explained in detail how the proposed change is going to be beneficial, they may not see the merit. However, the resistance to change will reduce. Quite often, the processes have to be changed proactively by the top management in an adventurous manner. The initial results of change might not be positive. But if persisted, the subsequent results would convince the employees that the change was for good.

Change is Essential An organization cannot progress without change. It has to continuously change for better. There should be an on-going rethinking and restructuring of the organization, so that the organization is receptive to the needs of the customers. The management should look at every process without any bias. Each employee looks at his or her activity from their own angle. Sometimes they do not understand the problems faced by the organization. In their own small shells they feel uncomfortable about change. But, the management should not give in because of the reluctance on the part of the employees.

Changes are required in a number of activities such as in the process, machinery, materials, inventory control, methods of carrying out an activity, inspection, and so on. The executives should check at periodic intervals whether the process is carried out efficiently. If not, they should try to change it. Change management is an important activity in TQM environment and is crucial for continuous improvement of processes and the organization. The essential requirements of change and change management are:

Be Adventurous Successful people are those who have taken the challenges and grown beyond expectations. This calls for adventurous decision-making and high self-esteem among the senior management persons. They should visualize the improvements needed and make every effort to achieve it. Any term of improvement is not going to be easy. If the organization wants to maintain status quo, it will not improve. In fact, most successful executives should be dreamers with the necessary drive. They should aim high and make every effort to achieve it. Those who have aimed high have reached high. They should feel that the impossible is within reach. It is important that if an executive wants to grow, he should be ambitious as far as the organization's improvement is concerned. Only ambition can lead to success. Therefore, one should develop an adventurous attitude for the larger good of the organization. Business Process Reengineering (BPR) concept calls for adventurous decisions.

Be Bold The other prequisite for change management are boldness, self-confidence or self-esteem. Boldness is very essential for making bold decisions for improvement, based upon the study and analysis of the current practices and system in the organization. Such boldness may be required for many purposess from fighting lethargy among employees to guarding against vested interests. Therefore, boldness is the basic requirement for making an efficient organization.

Role of CEO for Adventurous and Bold Change Management Like many other aspects, the adventurous and the bold change management depends on the personal qualities of the CEO. The CEO, in addition to his own bold initiatives, should support innovative change management initiated by his employees. He should motivate and encourage his colleagues to change the unproductive ways of the organization. Therefore, the primary responsibility for adventurous and bold change management lies with the CEO. He should give them the confidence and support till the successful completion of the initiative. Such a confidence bestowed by the CEO will help them in achieving adventurous and bold changes. As Tom Peters says, knowing when to retreat is as important as knowing when to advance[6] . The CEO should be monitoring what is happening and ensure that it is in the right direction.

3. DIRFT—Do it Right First Time

Take Right Decisions In every organization a number of decisions have to be taken by the CEOs, managers and supervisors. They are the leaders in the organizations. Before making every business decision, the leaders should carry out the following sequence of activities:

- Plan the decision—weigh the pros and cons
- Foresee the impact of the decision on the organization
- Take opinion of the right people
- Involve the concerned (employees who will be affected by the decision)
- Implement the decision
- Persist

Why People don't Do it Right the First Time? Do It Right First Time (DIRFT) concept was advocated by Philip Crosby[3]. This is a time-tested concept and employees and organizations should adopt DIRFT. The question is why people do things wrong and do it and over again? It could be due to some of the reasons as given below:

Why Things are Done Wrong?

1. The employee does not know what to do clearly, leave alone how to do!
2. If he knows how to do, he is not motivated enough to do it right the first time
3. He may not have the right tools to do a good job
4. He does not have the necessary education or training to know how to DIRFT
5. Probably his seniors have trained him to do the wrong way
6. He is not proud of the job he is doing
7. He does not get appreciated when he does it right

Not doing it right first time is going to cause hassles to every stakeholder. Therefore, it is important to know how to make DIRFT happen.

Problems of not Doing it Right

1. In some cases, not doing it right the first time may result in not doing it right ever, thereafter
2. Leads to unnecessary expenditure
3. Increases the failure costs
4. Demotivates employees
5. Causes hassles to employees and customers
6. Brings down the reputation of the organization
7. Leads to schedule slippages.

8. Increases scraps leading to more cost on account of storage, accounting, disposal, etc.
9. Forces the organizations to buy additional components to take care of defects in the process.
10. The productivity gets affected due to holding up of the process to correct the defective product shunting from place to place for fault diagnosis, altercation between employees as to who or which machine caused the defect, wastage of supervisor's time and the top management's time in resolving disputes.

Therefore, one should do things right the first time, rather than doing it wrong and trying to correct it later which causes wasteful expenditure.

Basic Requirements for DIRFT

Philip Crosby has suggested three simple[3] requirements for DIRFT to happen which are given below:

> The top management should carry out the following for DIRFT to become a reality in the organization. The top management should
> I. Define the requirement for each employees
> ii. Provide the wherewithal to achieve the requirement and
> iii. Keep on motivating and encouraging the employees.

Right the First Time and Every Time The "It" refers to every activity in the organization. It is not only the making of the final product or service, but also many things done by the employees in their organization on a daily basis. They should do only the right things—right first time and every time. Therefore, the management cannot just define the requirements once and forget about it in the fond hope that things will always be done perfectly. They have to consistently look for improvements, find out the aspects overlooked earlier and correct them. They should always be preventing errors, defects, hassles, demotivation of employees and the like. Such a determination is not only applicable to the management, but also to the employees in the organization. They should always strive to rise to the occasion.

Set Right Goals It is essential for every organization to set the right objectives towards which the organization should be moving. As part of the TQM journey, an organization has to arrive at a vision, mission, and the goals. The statement containing the goals should be concise but from that, the goals for each employees or each team should be deducible. Formulating goals is an important activity and it is also a difficult task. The goals of each employee/team/section in the organization should be set to match with the goals of the organization. Every employee should be clearly informed of the goals of the organization, their team goals and the goals of their internal customers and suppliers. The goals should be appropriate so that the whole company prospers. If the goals are logically incorrect, it will send wrong signals to the employees. The general human tendency is to question the wisdom of the management. Therefore, if the goals are not very clear, then the response of employees to achieve the goals will not be encouraging. Hence, it is important that right goals are set and communicated to the employees in the most appropriate manner.

Select Right Personnel The whole process of recruitment starting from advertisement, conducting interviews, etc. should aim at selecting the right personnel for the right job. If a person is not suitable for the Job-in-hand, then definitely it is going to be counter-productive. One bad employee will spoil the rest. Therefore, it is important that the right personnel is selected first time and every time. The situation with regard to employees is similar to cultivating a good crop. No doubt, each crop needs watering and care, but, if the seed itself is defective, no one can expect to get a right tree whatever may be the further investments. Therefore selecting the right employees is essential.

Establish Right Processes Organizations should establish a right process, which is very essential. If the right process is not selected, how can we expect the right products? Therefore, the company has to necessarily invest time, energy, money and right team of employees for identifying, establishing and commissioning the right process.

Within the organizations, the supervisors should train the new employees in the process. It is essential that the management establish the proper guidelines and train the employees to perform accordingly. Simple and appropriate methods should be developed in an organization for getting the desired results. Therefore, the right methods should be identified and deployed for each one of the work operations. Documentation has many advantages such as building memory into the organization, helping the organization to update the methods based on experience and serving as a basis for further improvements, and quality auditing. Therefore, the right methodology should be identified and documented.

Choose Durable Raw Materials Materials can be converted into products only through the right process. Therefore, without the proper raw materials, expecting quality would be farce. Therefore, right materials should be selected from the right vendors. It should be ensured that the vendors supply good quality raw materials which doesn't call for an inspection.

Choose Right Machinery The process consists of people, machinery, material and methods, out of which machinery generally is very expensive. Therefore, machinery should be selected properly so that the production can start from day one. There are many important considerations for selecting the right machinery including formulating specifications, calling for competitive bids, arriving at a criteria for objective assessment of bids, getting a demo organized and thereafter placement of orders. A right method should be adopted and implemented so that there are no glitches later on. Along with the machinery, the required accessories and spare parts are also to be procured so that the equipment can be used effectively.

4. Continuous Preventive Action

Read the news item given below to understand the importance of Preventive Action.

Chrysler to recall three million cars

Detroit

14th January

DAIMLER CHRYSLER'S Chrysler division said on Tuesday it was recalling nearly three million cars to fix a gear shift problem that could allow the vehicles to roll out of parking positions inadvertently.

Vehicles affected by the recall include the 1955–1999 Chrysler Cirrus, ... and 1993–1999 Chrysler 300 m, the automaker said. Federal safety regulations had upgraded an investigation into the gearshift problem last July – Reuters.

The Economic Times, Thursday 15 January 2004, Chennai.

Corrective Action is a Post-mortem What is corrective action? When a product or service is delivered, if the customer finds defects or faces problems. Then the deficiencies are registered and corrected by the organization. It would only be a post-mortem of the process. It does not satisfy the customer, in fact the customer is frustrated. However, a corrective action is better than no action at all when a defect is found.

Corrective actions were identified and acted upon in a systematic manner only after ISO 9001 standards were set. When there is absolutely no concern for quality in an organization, corrective actions should be the first logical step to improve quality. Rightly, the revised ISO 9001 standard released in the year 1994 (and subsequently in the year 2000), has revised the clause as "corrective and preventive action". Therefore, one has to foresee the problems and prevent its occurrence. If they have not been successful in prevention then they should take corrective action in the machinery, material, methods and the men (employees), so that the problem never recurs.

Prevention is Better than Cure There are two ways of handling a problem, one is to cure it and the other to prevent it. All of us give full justification as to why a problem could not be prevented early enough. Not preventing a problem is a reactive approach. However a manager cannot be reactive, if he wants to practice TQM. He has, to be proactive, i.e. should carry out all his tasks as per standards and foresee if any problem is going to arise and prevent it. Being proactive may be considered to be an in-born quality, But it can be developed by anybody who is willing to put in that extra effort.

One Shot Prevention is not Good Enough Like other TQM principles and practices, preventive actions have to be continuous and should cut across all sections in the organization. No organization can afford to stop after taking one or two preventive actions. If they do so, the quality of the product would decline and no amount of corrective action will help. The organization will earn a bad reputation. Therefore, preventive actions should be taken at periodic intervals.

5. Care for Little Things and Accumulate Gains

TQM is a continuous process improvement program and aims at one step at a time. Therefore, the management should aim at scaling greater heights through small and continuous improvement in every process. For instance, when materials are received, if a label indicating the details such as date of receipt, quantity, inspection details are written and attached either to the item or to its container, will help in saving a lot of time later.

Caring for Small Things While efforts will be made to maintain sophisticated and expensive machinery and equipment, the same care may not be taken of small things such as accessories, jigs and tools. Every tool used, should be maintained properly, calibrated at periodic intervals and handled properly. If that is not done, the weakest link is going to break the chain. Therefore, every employee should take care to maintain every tool whatever may be its cost or importance.

Communicate with Junior Employees No doubt, overall economic performance, strategies, quality council meetings, visit of customers are all-important, but at the same time, the junior most employees are also equally important in an organization. Hence, the senior management should establish a channel of communication with the junior employees in the organization. For instance, there will be field sales employees, who know the customer reactions directly and immediately. It is, therefore essential to hold meetings with the sales persons at periodic intervals and get their views on how the customers react to the company's services. This information will be much more useful than surveys conducted by the organizations either in formal or informal manner. The field employees will be able to give a true feedback if they are motivated and encouraged to do so. Adopting techniques of Tom Peter's MBWA will help the management to know the real customer reaction with regard to quality and other matters. Hence, the management should allocate time to communicate with the junior employees.

Keep on Accumulating Small gains accrued due to conscious initiatives by the management should be accumulated. These small rewards will be more permanent than the bigger gains attained all of a sudden. Once a major initiative is taken, many small improvements will take place side by side. They should not be ignored and such side effects should be given the official seal of approval and made part of the regular system.

The management should consider little things and improve everything in the organization. The CEO should take care to improve even simple process aids. Since the TQM journey is continuous such small gains accrued will give substantial benefit to the organization. Many times, simple problems may be the cause for major failure of processes. The CEO should also communicate with junior employees as part of his MBWA. Accumulation of small gains needs unending enthusiasm of every employee in the organization.

6. Ensure Economic Performance

Importance of Economic Performance While marching on the TQM path, the CEO should not lose track of economic performance of the organization. All TQM activities should lead to better economic performance in the long run. If an organization is implementing TQM correctly, then the bottom line will improve automatically. Inspite of other goals like satisfying one's aspirations, serving society, providing employment, etc., the primary purpose of a business is to earn profits. Similarly, the primary goal of an employee is to earn higher salaries. The goal of an organization should be higher Return on Investment (ROI), as economic performance is one of the key measures of success of every organization on their journey towards TQM.

A service organization engaged in testing and calibration adopted TQM. It was able to consistently maintain about 40 per cent growth rate every year. This was achieved with the same manpower. Thus, the organization could grow only due to application of TQM.

Quality should Increase Productivity Also The objective of continuous quality improvements is to satisfy the customers. Improving quality for customer satisfaction should definitely lead to increase in overall productivity. This not only satisfies external customers, but also the internal customers. Satisfied internal customers all over the organization will deliver more, thus improving productivity. Improved quality leads to improved productivity due to reduction in scrap, rework and associated hassles. When the executives aim at improved quality, it should also result in improved productivity. The establishment of quality system leading to ISO 9000 certification, following TQM principles, establishing strategies for TQM implementation, all should lead to reduced defects, reduced rework, reduced hassles, improved clarity in operations, thereby improving and increasing productivity and profitability. This point should be clearly understood, not only by the CEO, but also by every employee in an organization.

Talk about Success in Economic Performance There is no harm in managers taking about their achievements and feeling proud of it. Therefore, the CEO should talk about economic performance. It will help him to motivate the employees and customers alike. There is no end for improvement in economic performance. By its very nature, the business will block the improvement of economic performance continuously. Year after year, the organization will face different problems not only from the customers, but also, from the employees, shareholders, society and the suppliers. If the management is not careful, the expenditure will increase without any corresponding increase in the organization's economic output.

Therefore, TQM should be implemented, with a view to reduce the blocks and overcome the barriers to success. TQM should help the organization to climb the ladder of economic performance. It is therefore important that a sound foundation for quality is laid through proper education, training and determination of the employees. The aim should be to improve quality and productivity, thereby keeping the flag of the organization flying high.

Stakeholders will Understand Economics Better The motivation of employees depends upon many factors like their personal development, happiness, sense of fulfillment, security, achievement, etc. Motivation goes up, when they find that the organization is performing well. The employees will be proud to work with an organization, which continues to make profits and sustains improvement over growth rates and growth of profits and whose share price is on the rise. Even certifying bodies will be enthusiastic to certify winning organizations.

Economic performance is a clear indicator of the health of the organization. Thus, it motivates the customers to do business with the organization, which is doing well. The suppliers too would like to supply only to those firms, which are economically sound, irrespective of the quality of the product or service. The shareholders or the proprietors would like to see the profits. They are also interested in the long-term benefits to the organization. Similarly, every country should look forward to better performance of its organizations, so that it is able to achieve social goals. Thus, all the stakeholders will equally gain on the best economic performance of the organizations. Therefore, every organization should make efforts to see that the organization is performing well, with regard to quality, employee motivation, satisfaction of the customers as well as in the economic front.

7. Management By Walking Around (MBWA)

What is MBWA? The Concept of Management By Wandering Around[6] was postulated by Tom Peters. In the author's opinion Management By Walking Around (also abbreviated as MBWA) is one of the most effective tools of management and leadership for the growth of the organization. But, the supervisors have to be convinced that MBWA will not affect their authority. They will be convinced only when their authority has not eroded in reality. Their apprehension has to be removed to make MBWA successful.

MBWA can be defined as the unannounced visit of the CEO to the various work spots for getting direct and first hand information, from the employees, the customers and the suppliers. MBWA is not a "State" visit. To quote Tom Peters, "State visit is an announced visit by the CEO accompanied by all the deputies in line and is a formal visit" .[6] In State visits, the employees or customers or suppliers may not reveal the absolute truth and will try to play safe. Therefore, this unannounced visit to the factory floor has to be carried out at random. The CEO goes to various work spots and talks to the employees about what they are doing, how they are doing, what are their problems, what help they require and so on. The CEO has to make the employees comfortable to make them speak freely and frankly. In fact, Tom Peter advocates that the CEOs should spend more than 25 per cent of their time in MBWA.

What is to be Done during MBWA? The three major activities done together simultaneously during MBWA are '*listening, teaching and facilitating*'.

While on MBWA, the CEO should listen to the problems, then guide the employees in overcoming the problem. During an MBWA, suppose it may be found that the employees do not have a simple tool or funds for the procurement of some accessory, etc. During MBWA, the top management should instantly agree to fulfill such requirements. As soon as he gets back, he must arrange for providing them after convincing their supervisors. This will also keep the middle managers happy. MBWA means "necessarily also questioning why the activity is being done in a particular manner". It is not to just for questioning but also to make them think about the alternate design and development, engineering or manufacturing methodology. Such questions are very helpful both for the employees and the organization. Successful people who have practiced MBWA are knowledgeable and are able to frame the right questions during the process. At the same time, the CEO should not give an impression that he is taking over the project from the employees or their supervisors. He must give all possible suggestions and guide the employees towards the right course of action. This way, the project will not get transferred from the employee to the CEO. He should be a stimulator, motivator and a logical thinker and should help the employees to overcome their bottlenecks instantly. The CEO should show concern about personal welfare of the employees, however most part of MBWA should be dedicated to the official work. The CEO should use the session for coaching the employees to shed their inhibitions, to overcome their inertia and break barriers of the bureaucracy in getting things done. The CEO should realize that his innocent questions can be presumed to be a command from the CEO. Hence, he should be very careful during an MBWA. The CEO should convey that he trusts the ability of the employees and their supervisors and that his expectations from them are the highest. This will automatically motivate the employees and their supervisors to do better.

Barriers to Practicing MBWA The problem occurs mainly because MBWA appears to violate the chain of command. The first line supervisors feel agitated about the idea that information directly reaches the CEO. They feel that they are loosing their authority. The first line managers should accept this concept and cooperate with the CEO, in his MBWA in the larger interest of the organization. The CEO, while he can obtain information and promise action within the stipulated time, should ensure that the action is taken through the chain of command. This way, the problem could be solved fast, without making the first line supervisors feel too unhappy. However, in an appropriate manner the CEO should also make attempts to convince the first line supervisors that he is not going to destroy the chain of command.

Advantages of MBWA MBWA helps the organizations to consolidate the talents, wisdom of all the employees, customers and suppliers. The process helps the CEOs to remain in touch with the people, customers and suppliers. It also gives the message to the customers, employees and suppliers that they are important to the organization. It helps in attracting more business, improving the quality of suppliers, workmanship in the organization and customer relationship.

8. Measure for Success

Measuring for success primarily involves, looking for, measuring and analyzing the feedback from customers, either internal or external. An organization marching towards Total Quality Management (TQM) has to make efforts to measure how well the organization is performing in terms of fulfilling the customers needs and expectations. The management should help employees to know how well they are doing. Employees should be helped to measure and report performance. Each employee should be helped to measure his own performance. Thus, measurement should be part of routine work.

Measure 3 Ps In a TQM environment, the measurements have to encompass the total system, starting from the submission of bids till collecting the charges after delivery. The entire quality system should be measured. Successful implementation of any process means higher profits, improved productivity, efficiency and above all improved morale of the employees and satisfaction of all other stakeholders. Therefore, the measuring of success has to encompass all the phases and all characteristics of the business. The measures should be formulated for measuring the performance of each one of the parameters, which has an impact on the stakeholders. The measurement should cut across 3 Ps, i.e. Process, Personnel and Product as shown in Fig. 3.2 given below:

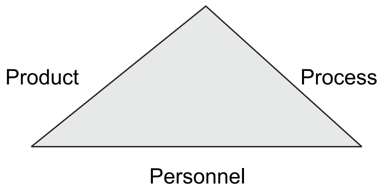

Figure 3.2 Measure for success

The measure should be such that it brings out the quality of the 3 Ps

PDSA for Measurement PDSA's Cycle popularized by Deming, is an important tool for any activity. It is more so for measuring success, since it is a tricky affair and if not carried out systematically can lead to wrong conclusions and costly mistakes.

Plan for Measuring Success In the planning stage, the organization should identify the various measures for success. It is very difficult to identify the measures in a service organization. If it is a manufacturing organization, it may be concluded, for instance, that quality of the final product is the most important measure. But in a service organization, it is difficult to measure the quality of the end product objectively. For instance, how is the quality of any food item in a hotel measured clearly and unambiguously. Even if efforts were made to measure the quality of the food item, it would turn out to be subjective. Therefore, formulations of measures for service industry are quite a difficult task, at the same time, an interesting job. It calls for innovation by organization's employees for identifying the right measures.

The service organization has to first identify what measures could be adopted to determine the quality of service delivered. All such measures need not be totally objective, some of them could also be subjective in a service organization. Experienced personnel in the field would be able to suggest appropriate measures. The employees themselves could identify measures so that it would find easy acceptance by the employees later at the time of measurements as well as analyzing and concluding. Employees may also be awarded for suggesting good measures. The organization may also solicit ideas for measures from its customers, suppliers and even consultants. This is due to the difficulty in finding appropriate measures in a service industry. Such measures identified should be placed before the quality council for a thorough discussion. The quality council could also nominate, if necessary, a set of employees to carry out brainstorming of the ideas and prioritize the same. Thereafter the quality council can finalize the measures for success in the organization. Some of the common measures for service industries are:

1. Planned delivery time and actual delivery time.
2. Repeat customers
3. Perception of the customers about quality
4. Perception amongst customers about competitors
5. Productivity
6. Revenue generated per employee
7. Revenue vs. expenditure ratio
8. Return on investment
9. Customer complaints
10. Rejects in process
11. Rejects at customers site

12. Rework
13. Reminders given by customers
14. Errors in invoices
15. Under payment/over payment
16. Result of field survey, etc.

Too many measures will complicate the measurement process and may lead to unnecessary expenditure. Therefore, the management should identify a few vital measures which when measured will indicate the successful conduct of business in the entire organization. A Pareto analysis may also be helpful in identifying a few vital measures. Once such measures have been identified, each measure has to be described in clear terms and approved by the quality council. The quality council should therefore finalize the measures to be made and how to carry out the measurement at the planning stage itself.

The Do Phase of Measuring The next step is the do phase. At this stage, the identified measurements should be carried out on trial basis with direction from the quality council. The senior executives should educate the junior employees about the intent of the measures. Generally, no employee would the accept assessment of his work by a third party. Such inhibitions and insecurity should be eradicated from the minds of the employees in the interest of the organization and employees themselves. This is also essential for the success of the measurement program as well as the TQM program. If the employees are not convinced about the need to measure, then there is no way that the measurements could be carried out in the organization for determining success. Hence, educating employees is important. Senior management should make efforts to see that the employees accept the steps to measure. The involvement of employees in the identification and describing the measures is thus helpful to overcome resistance from employees.

Study Phase of Measurement The organization should experiment with the proposed measures for about two to three months. At the end of three months, the quality council should meet again to take stock of the situation, they should discuss and see whether they need to carry out any changes in the measures, e.g. add new measures, drop originally identified measures or modify them. In this phase, the quality council could check the effectiveness of the measure, the methods of measurement and the relationships of the measures with actual customer satisfaction achieved. The result of measurement may be indicating that the organization is doing extremely well, but the organization may be going through financial cash flow crunch to the extent that they are unable to pay salaries. If this is the situation, then there is something wrong either with the method of measurement or the measures themselves. The management will know approximately 80 per cent of the status with regard to the business and hence by intuition can decide whether the results of measurement match the real situation. Therefore, the correctness of measure identified and the measurement process should be analyzed independently and objectively, in the study phase.

Quite often, people in the field of measurement may look for perfection. Some non-starters or dis-interested parties may seek perfection. They use perfection as a lame excuse for not carrying out the task. Perfection is definitely right. But, the drive for perfection cannot stall innovative idea. Therefore, there is nothing wrong in making a start in the measurement process and do corrections as experience is gained. The organization should start the measurement process in the do phase and once the results of measurements are available, they should be analyzed by the quality council in the study phase to find out if some more measures are required or some are to be dropped or modified and so on. This way an organization would be able to come out with clear, objective oriented and perfect measures.

The Act Phase of Measurement In this phase the measures and methods of measurements are confirmed. The organization starts making measurements. Measure for success is a continuing activity. However, results of the measurements of various parameters could be studied at regular intervals, analyzed and communicated to the employees. It is essential that the results of measurements be communicated to the employees at regular intervals, as it will motivate the employees to do better than before. If the results are extremely good, the employees will be motivated to do better, if such results are coupled with awards for the worthy teams. Even when there is no change in the performance between two consecutive measurements, the status quo will make the employees feel shy and motivate them to do better next time. Depending on the results, the management should also initiate improvement actions to keep up the tempo in the organization and further improve. They should strive continuously to be better than before. Therefore, displaying results will not demoralize the employees when the going is not good and will not make the employees complacent when the going is good, if the management is active.

9. Never Rest on Past Laurels, Continue to Improve

The Tale of Tortoise and Rabbit The tale of tortoise and rabbit teaches us the lesson that one should never rest on past laurels, but continue to improve. Slow and steady wins the race' and over-confidence can lead to failure. It is important to learn from the story that since rabbit was resting on its laurels and past glory, it relaxed and lost the race. No organization can afford to lose by resting on its past laurels.

The Need to Improve Continuously An organization should aim at doubling the turnover every two years, without additional manpower or machinery. Many organizations have achieved such growth rates. Such a growth rate is achievable primarily due to two factors

1. Cutting down the costs by doing right things, right the first time
2. A higher output of the motivated employees through extensive training.

Both factors are further expandable. The quality level can reach zero defect level. Even at that stage, the productivity of the employees can further grow due to improvement in the following:

(i) Improved system in the organization due to management based on TQM
(ii) Gaining more confidence due to achieving success
(iii) Accumulation of the right experience and hence cutting down lead time for jobs
(iv) Enhanced productivity due to improvement in teamwork
(v) Empowered employees expanding output due to enthusiasm and motivation

Thus, an individual or organization should never be resting on past success or laurel. They should strive towards continuous success.

Success Stories

There are many success stories to illustrate that one should not rest on past laurels, but, continue to improve, whether it is quality improvement, or productivity improvement, or profit improvement, or diversification leading to new products. For instance, Bill Gates of **Microsoft,** one of the richest person in the world is a living example of the philosophy. He started with operating system MS-DOS and kept on updating it. He was continuously trying to innovate, found strategic partners. His success is mainly due to the fact that he was not trying to make a product for the existing market; rather he tried to create markets as per his vision. He ventured in operating systems, which give Graphical User Interface. This way, he made Windows, a popular software. His success in Windows based operating system is another milestone, not only in the history of Microsoft, but also, also in the IT industry. He thought ahead and started making efforts for an information highway, years ago, before others could think of it. He could have comfortably stopped his innovation with MS-DOS, but he continued his innovation, leading to the success of not only his organization, but also the entire mankind.

There are similar success stories created by two men even when they were young, i.e. Hewlett and Packard, the founders of the giant multinational organization **Hewlett Packard**. **Apple Computer** is another success story. In India, there are so many success stories. For instance, when people thought, that training in computer will not catch up, few organizations created history, notable among them is **NIIT**. In the computer hardware sector, the success of **HCL** and **WIPRO** are similar in nature. In the software sector, the success of **Infosys, TCS, WIPRO** and the like are well known. All these organizations and their CEOs were always worrying what should they do next. They never relaxed even for a little while. Improvement is thus never ending.

10. Build a Virtual Organization

Gone are the days when vertical integration was a preferred strategy. But the situation has changed now. A smarter way of doing business is to create a near virtual corporation. Here, the core part is manufactured and the rest bought from qualified vendors. This has been found to be highly effective and profitable.

Vertical Integration There are two extremes of manufacturing. In the first extreme, everything, from the raw materials to the final product is manufactured under one roof. The other extreme is buying everything from others and putting them together and selling the assembled product. The right way is to be selective in manufacturing and buying the non-critical items from the market. Vertical integration means that whatever sub-units, components / materials, fixtures, etc. needed for manufacturing a product are all manufactured by the same organization. Materials available in the market are not used. Efforts are made to manufacture all that is needed in-house. They don't look at aspects such as the cost effectiveness, specialization, etc. In this method, they have to spend more for manufacturing non-critical items available, with better quality and at a lower cost from other sources. The pride of ownership of everything overtakes other considerations. This led organizations to waste their efforts in manufacturing standard parts, which could have been easily bought from others who were specializing and selling at much lower costs and with the right quality. This type of vertical integration practiced in the 1970s failed to deliver and gave way to virtual enterprise or virtual organization.

Requirement For Virtual Enterprise The following steps are involved in running a virtual enterprise:

(a) Identify the most critical part/s
(b) Identify the other parts
(c) Develop/identify vendors for the other parts
(d) Continuously increase sub-contracting.

These requirements are discussed briefly in the following paragraphs.

(a) Identify the most critical part/s The first task is to identify the most critical parts of a system to be manufactured. The critical parts should be vital few from the many trivial parts, which are the core or the nucleus for the product or service. It is easy to identify the critical parts in each system. For instance, the motherboard in case of a PC system is the critical part. In case of motorcars, it is the engine, which is the key part. Thus, the critical part is the one in which others are not specializing. The strength of the organization should lie in developing and manufacturing the critical part, in the most competitive manner. In a business environment, cost and quality are the major considerations for selling. Therefore, the organization should have the best engineers, who specialize in designing and manufacturing critical parts. Since only bulk production will bring in more profits, everybody should try to concentrate and manufacture in large numbers. Therefore, the organization has to identify their core product. The core product is in turn the critical product or crucial product. The core product will fetch more revenue compared to the secondary products or materials of sub-assemblies since there are so many others who are specializing in making them. The organization should identify its primary product or service and put in all efforts in manufacturing them more efficiently.

(b) Identify the other parts The next task is to identify all other items or materials, which will enable delivering a product or service. The organization should then formulate specifications for all the secondary items. It should do a market survey and identify all those suppliers who can deliver them with quality and at competitive prices and schedules.

(c) Develop / identify vendors for the other parts It is very important to concentrate on developing good vendors, rather than trying to carry out vertical integration. Developing vendors and buying from vendors is definitely cheaper than making them all under one roof, due to their specialization and bulk manufacture and thereby reduced costs. Therefore, the task of the organization is to identify good vendors and enter into agreements or contracts, so that they will be able to get the materials of the right specifications, just in time and with zero defects.

(d) Continuously increase sub-contracting Times have changed and it is the day of virtual corporations. Therefore, the organization should try to sub-contract more and more items, retaining the core of the system for its own manufacturing. The aim is to sub-contract as much as possible. This will reduce the time, energy, money and infrastructure to do better in business, day by day. Therefore, the aim of virtual corporations is to shed the unnecessary manufacturing activity for earning more profits.

The same strategy may not work in all the organizations in the same manner. Therefore, strategies are to be selected or tailored to suit the unique nature of the organization.

SUMMARY

Total Quality Management (TQM) is an umbrella concept encompassing many good management techniques. TQM is a management approach of an organization centered on quality, based on the participation of all employees and aiming at long-term success. This will result in customer satisfaction and benefit to all employees and society.

TQM is

- Management approach of an organization
- Quality is the nucleus
- Involvement of every employee is essential
- Aims at long-term success
- Aims at customer satisfaction and benefits to the employees and society
- Most effective way to achieve the objectives of the organization
- Management philosophy and organization practices
- Aimed at harnessing human and material resources of the organization

Nine elements of quality management are essential for TQM implementation. Out of these, leadership is the most important one. Top management should lead the organization into TQM.

As Crosby says senior management is 100 per cent responsible for the problem with quality and their continuance [3]. According to Harrington [4], between 70 and 85 per cent of all errors can only be corrected by management. Thus, leadership for TQM is essential. TQM has to be led by the top management. Their commitment to TQM is the most important ingredient for TQM to be successful in any organization.

Deming's 14 points for top management have been given to the Japanese management in the 1950s. The points are relevant even today. The effectiveness of the points could be judged from the success of Japan.

Then we discussed about the following 10 strategies, which could be adopted by the CEO for leading the organization on TQM principles. They are given below:

- Proactive management
- Adventurous and Bold change management
- Do Right Things and Do It Right First Time
- Continuous preventive action
- Caring for little things and accumulate gains
- Ensure economic performance
- Management by walking around (MBWA)
- Measure for success
- Never rest on laurels, continue to improve
- Build virtual organization

REVIEW QUESTIONS

I. Choose the most appropriate answer

1. TQM is
   (a) Cost effective quality management (b) Preventive quality management
   (c) Continuous quality improvement (d) All the above
2. Elements of TQM include
   (a) Quantitative methods (b) Focus on process
   (c) Leadership (d) All the above
3. Deming's 14 points include
   (a) Giving quantitative targets to workers (b) Depend on inspection
   (c) Institute training (d) None of the above
4. For TQM to happen, top management must
   (a) Be proactive (b) Communicate rarely
   (c) Maintain processes (d) All the above
5. Quality values include
   (a) Productivity first
   (b) Quality Assurance manager leads
   (c) Top management believes in continuous improvement
   (d) None of the above

6. Change is
   (a) Liked by everybody
   (b) Essential
   (c) Comfortable
   (d) A and B
7. Some of the measures of TQM could be
   (a) Customer perception about quality
   (b) Productivity
   (c) Quantum of rework
   (d) All the above
8. TQM gives benefit to
   (a) Customers
   (b) Employees
   (c) Society
   (d) All the above
9. Building virtual organization leads to
   (a) More employees
   (b) More trouble
   (c) Improved quality management
   (d) None of the above
10. In a TQM environment, changes will be
   (a) Frequent
   (b) Once in a year
   (c) Few
   (d) All the above
11. Right decision calls for
   (a) Fast action
   (b) Breaking teams
   (c) Involving concerned employees
   (d) All the above
12. Doing Right Things include
   (a) Reducing wages
   (b) Increasing working hours
   (c) Choosing right methods
   (d) None of the above
13. Why things go wrong? Because
   (a) Requirements are not defined correctly
   (b) Right tools are available
   (c) Lot of motivation to do the job
   (d) All the above

II. True or False

1. Before taking a right decision results should be foreseen.
2. Employees should not be involved in decision making.
3. Persistence is important for implementing decision.
4. Required accessories for each machinery can be purchased later.
5. Employee gets demotivated if things are done wrong.
6. Wherewithal should be provided by management.
7. Decision making is a process.
8. Doing right first time does not call for any special efforts.
9. Virtual organization has no relationship to TQM.
10. TQM is never ending.
11. PDSA cannot be applied for implementing measures.
12. MBWA disrupts peace in the organization.
13. Stakeholders will understand economics better.
14. CEO should care for obscure things.
15. TQM calls for reactive management.
16. Deming calls for break-down of barriers between staff areas.
17. Constancy of purpose of CEO is quite important for TQM to happen.
18. Responsibility for quality problems lies with top management.
19. Preventive action is not a one time activity.
20. Training is a waste.

21. New philosophy is Quality Control.
22. Depend on mass inspection.
23. Vendors should be selected on the basis of price alone.
24. Create fear in the organization for TQM.
25. Increase barriers between staff areas.
26. Slogans lead to TQM.
27. Give numeric targets for productivity.
28. Employees should not have pride of workmanship.
29. Encourage education and self improvement of employees .
30. Everyone likes change.
31. Corrective action is better than preventive action.
32. Ignore small gains.
33. Quality should increase productivity.

III. Explain Briefly

1. 9 elements of TQM.
2. Deming's 14 points for management .
3. Quality values for TQM.
4. Proactive management.
5. Continuous preventive action.
6. MBWA.
7. Measure for success.
8. Common thread in the 10 strategies for TQM implementation for top management.
9. Change and TQM.
10. DIRFT.
11. Right decision making.
12. Do right things.
13. Why top management leadership is essential for TQM?.
14. Advantages of virtual organization.

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(2) A Typology of *Virtual Organizations*: An Empirical Study: hsb.baylor.edu/ramsower/ais.ac.97/papers/palm_spe.htm**...** The emergence of the "*virtual organization*" as an *organizational* form has evolved from a futuristic concept to an identifiable structure across a variety of **...** (*MBWA*)

(3) Management By Wandering Around : **...** This concept very closely parallels the business concept of Management By Wandering Around (*MBWA*). This paper looks at the literature **...** Description: Describes the business concept of management by wandering around and details how it can be used in... Category: Reference > Libraries > ... > User Services > Reference Services www.michaellorenzen.com/mbwa.html.

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Chapter 4

TQM Implementation

Every day you may make progress. Every step may be fruitful. Yet there will stretch out before you an ever-lengthening, ever-ascending, ever-improving path. You know you will never get to the end of the journey. But this, so far from discouraging, only adds to the joy and glory of the climb.

—Sir Winston Churchill

INTRODUCTION

The top management always leads the implementation of TQM. TQM is based on self-control, which should be embedded in each employee, team, division, etc. Pushing problem solving and decision making to the lower levels of the organization allows employees to both measure and take corrective action in order to deliver a product or service that exceeds customer expectations. The framework for TQM implementation should facilitate this and involve every employee. Most organizations establish a quality council or a steering committee for systematic transfer of responsibility for improvement to every employee in the organization. This committee is assisted by a separate cell established for coordination of implementing TQM with a TQM facilitator. However, the real initiative for improvement comes from the top management. Therefore, the CEO has to commit not only the organization's resources for making TQM happen, but also be prepared to invest his own time for making things happen. If the CEO cannot spare time for the TQM activity, then it will be a failure. Therefore, the most important requirement for TQM to function in any organization is 100 per cent commitment by the top management, which should have the time, skills and above all the determination to implement TQM. There is no way to push TQM if the top management is not convinced, committed or determined to implement it. This should be clearly understood before venturing into TQM. In this chapter, we will learn about establishing the organizational framework and overview of strategies to be adopted for implementing TQM.

TQM TOOLS AND TECHNIQUES

TQM involves application of the right tools in the organization for the continuous improvement of quality. Therefore, each organization may require a different mix of tools and techniques depending on the business, quality of employees, culture and the customer profile. The tools and techniques that are available for TQM implementation are given in Table 4.1 as follows:

Table 4.1 TQM Tools and Techniques

Type	*Tools & Techniques*
Methodologies	SPC, JIT, Taguchi methods–DOE, QFD, TPM
System	ISO 9000
Human Resources	Total Employee Involvement (TPE), Proactive management and Quality circles
Motivation	Quality improvement awards such as Malcolm Baldridge, Deming Award, European Quality Award, Rajiv Gandhi National Quality Award, etc.

The top management should select the required tools and techniques and introduce them in a phased manner.

Similarly, the teachings of any one of the quality gurus may not be adequate for implementing TQM in an organization. For instance, the contribution of quality gurus can be broadly classified into the overlapping areas of TQM as given in Table 4.2 as follows:

Table 4.2 Contribution of Gurus for TQM

Areas of TQM	*Gurus*
Statistical	Gauss, Pareto, Shewart, Fisher
Management	Juran, Crossby, Feigenbaum
Execution	Deming, Taguchi

The management may use the various suggestions given by the quality gurus for the benefit of their own organization. In this chapter, we will discuss an organizational framework and overview of strategies, for TQM implementation.

PDSA TQM IMPLEMENTATION

Shewart developed Plan, Do, Check, Act (PDCA) cycle for improvement of processes. Deming modified it as PDSA cycle. There are four phases—Plan, Do, Study and Act shown in Fig. 4.1 as follows:

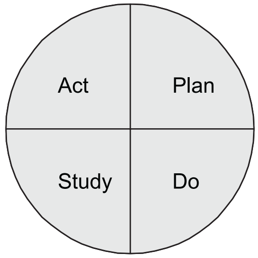

Figure 4.1 PDSA Cycle

PDSA cycle is suitable for process improvement projects. Each process improvement should be organized as a project. PDSA typically involves the following:

The 'planning' phase is the preparation phase where the actions proposed to be taken for implementation of TQM are determined and documented after a detailed analysis.

The 'do' phase involves implementation of the actions on a pilot basis.

The 'study' phase is where the results of pilot implementation are measured and analyzed to see whether there is a real improvement. During this phase one has to understand which plan worked and which did not. This may either lead to confirming the new process in the 'act' phase or modifying the plan and revising the cycle again. The PDSA cycle repeats itself for each improvement action proposed.

The important actions taken during each phase of PDSA are given below:

Plan

- Establish objectives
- Establish a plan that will facilitate achieving the goal
- Establish a measurement system

Do

- Plan for implementation and measurements
- Implement the plan on pilot basis

Study

- Compare the results with the objectives
- Identify gaps
- Analyze the causes for gaps and exceptional results, if any

Act

- Standardize the procedure that met or exceeded the goal
- If there were gaps, improve the plan and carry out PDSA again

In the following paragraphs, an overview of TQM implementation using the PDSA cycle is given.

PLANNING PHASE OF TQM

Before the planning phase, it is assumed that the organization after analyzing the pros and cons has decided to implement TQM. The CEO is prepared to commit the resources and his time. Therefore, there should not be any looking back or reconsideration whether TQM or not at this stage. The prerequisite for the planning phase is that the organization has set its goal to achieve TQM for long-term success.

Announcement The CEO will be able to convince the workers and the junior employees about practicing TQM quite easily as they tend to have an open mind. But he may have problems in convincing the first line managers and the senior managers[1]. According to Harrington, "They (first-line and middle managers) admit that participative management is good for the employee and good for the organization, but they don't view it as being beneficial to themselves. In fact, they see it as a threat, taking away some of their authority". Therefore, before the CEO announces his intention of going in for TQM, he can discuss with the senior managers and carry out brainstorming as to the whys and hows of TQM. The CEO should remove the fears in the minds of the senior executives that once TQM is implemented, their authority will vanish.

After detailed discussions with the senior managers, the CEO has to convey and convince all the employees in the organization about the importance of practicing TQM. The CEO can announce the decision about practicing TQM in a meeting, where all the employees are present. He should bring out the advantages of TQM and highlight the hard work the organization has to put in to practice TQM. He should be honest and should neither give a rosy nor a gloomy picture. The CEO should also explain to the employees that both the organization and the staff stand to gain by practicing TQM. The CEO should also highlight that adopting TQM does not mean working harder, but working smarter. He should also highlight that by practicing TQM, employees will be more satisfied as they will be free from hassles, the customers will also be equally happy and the organization is bound to grow and prosper.

Select Consultant Consultants having advantage of being independent, will be able to put forth the new ideas to change the organizational culture. If a consultant moots an idea, it could easily find the acceptance amongst the employees, unlike an idea given by an employee in the organization (even if the idea of the employee is much better than that of the consultant!) Therefore, a competent consultant can be hired for help in implementation of TQM. Though the senior managers may be asked to assist in selecting a competent consultant, the CEO should select the right person personally because of the important role he is going to play. He should analyze the consultant's past experience, credentials, values, outlook, abilities, communication skills and other attributes before selecting the consultant. The consultant will not do all the jobs himself, he will only put forth the ideas to the employees. He would, no doubt out of his experience, know what will work and what will not and accordingly he will be able to advise the employees as well as the management about things to be done and not to be done.

Corporate Strategic Planning The next step would be planning the strategy as to how the organization is going to get into TQM. So it has to carry out the strategic planning with the help of the senior management and consultant. The important activities in strategic planning are formulating vision, mission and objectives for the organization by the CEO. The three essential statements are explained below:

Vision Statement Vision statement is the vision of the CEO about where the organization should be in the long run. It may not have any relation to the current status with regard to the products or services of the organization, but what the organization should be capable of in the future. It is an achievable dream of the top management. The vision statement should be concise so that it is easily comprehensible by all the employees. It should be inspiring as well as challenging the employees also. Vision is the long-term goal relevant to the organization. The vision statement should appeal to all the stakeholders namely "the employees, customers, suppliers, shareholders and the society".

Here are a few examples of vision statements:

ETDC, Chennai[1]

> The long-term objective of the center is to become a world-class calibration, testing and quality education/management services organization.

Rane Brake Linings Ltd, Chennai[2]

> To remain market leader in India and to become a global player, through superior, environment friendly technology and people competence.

Mission Statement The mission statement describes the purpose for which the organization is in business and provides the strategies to achieve this purpose. The mission statement should communicate the guiding principles and values held common by the organization. Here is one example of a mission statement:

ETDC, Chennai[1]

> "Quality will not only be preached, but practiced in every activity of the Centre resulting in Total Quality Management".

The above example not only highlights the guiding principles of the organization but also the means of achieving it, i.e. it should preach as well as practice quality, so that TQM can be achieved in the organization. All the characteristics of a vision statement like being brief, short, inspiring, motivating and challenging apply to the mission statement as well.

The Mission statement of Rane Brake Linings Ltd, Chennai [2]

> **MISSION AND VALUE**
>
> - Provide superior products and services to our customers and maintain market leadership.
> - Evolve as an institution that serves the best interests of all stakeholders.
> - Pursue excellence through Total Quality Management.
> - Ensure the highest standards of ethics and integrity in all our actions.

It is not a bad idea to get the views of the employees while preparing the mission statements. The executives may be taken out of the normal working place and everyone asked to give one achievement, which he wants the organization to make in the next five years. The executives can be divided into a number of groups. Each group can have a brainstorming session of individual ideas of the group members and these ideas can be presented along with the reasons for the assigned priority. Then all the groups can sit together and prioritize all the ideas of all groups. In this manner, the CEO will get large number of ideas from the employees. The CEO can then choose the ideas, which coincide with his thoughts and prepare the mission statement. The mission statement should be concise and clearly convey the expectation of the top management about the quality of the product or service delivered and their expectation from employees for resulting in customer satisfaction. It should be a tool for decision making in the organization.

Quality Policy The quality policy should clearly convey the views of the management on dealing with the customers and achieving customer satisfaction. The quality policy is aimed at improving the customers perceptions about the organization and thereby improving the organization's image. It should also be like a guide for each section of the organization for developing their own quality objectives. The quality policy should also be ambitious. For instance, it could be one of the objectives that the organization will reduce the total quality costs by 50 per cent every year as compared to the previous year or that they should double their production every two years. These are clear objectives for any organization and the employees should strive to achieve them. The most important point to be noted is that the policy should be clear and unambiguous. Stipulation of numerical goals and time frame for the same as given above, will be beneficial to the organization. This will facilitate verification of progress at regular intervals as well as achievement of the objectives.

It should also be ensured that there is a link between the vision, mission and policy. They should not contradict each other; rather they should aid each other. CEO should formulate these statements and circulate to the employees under his signature.

> As soon as the vision statements are finalized, it does not mean that each employee will understand, even if it is signed by the Chief Executive and advised to read it. Quite often, the employees may not have the time to read the statements! Therefore, the management should try to coach the employees on the need for understanding and achieving the vision of the CEO.

Plan for establishing communications framework As part of the strategic planning, the organization should plan for a corporate-wide framework for communications. A typical framework for communications is given in Fig. 4.2 below:

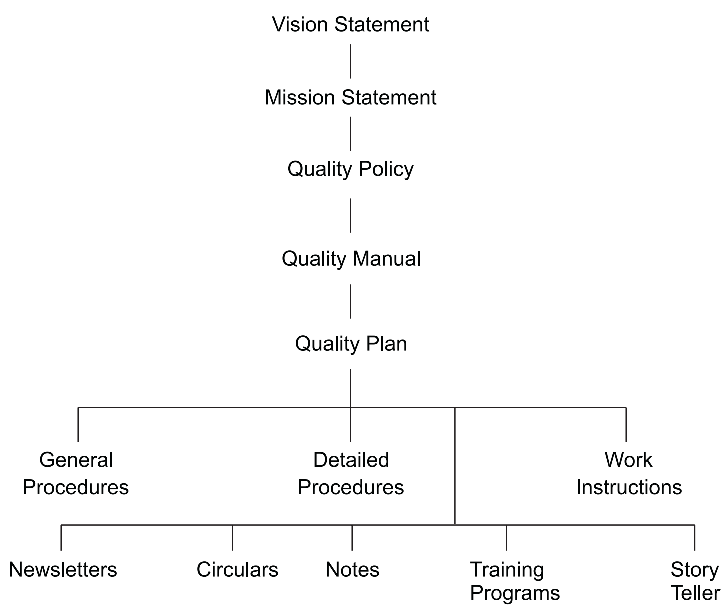

Figure 4.2 Corporate-wide Communications Framework

The communications framework starts from the vision, mission and policy statements as finalized by the CEO. The important document for communications within the organization is the quality manual. If the organization is already certified under ISO 9000 standards, then the same quality manual can be used. Below the quality manual, the next tier of document is quality plan. While quality manual says what is to be done, quality plan says how it is to be done. Based on the quality manual and quality plan, the process documents are to be prepared. The process document may consist of the following:

1. General procedures, which cut across the entire organization, involving one or more processes.
2. The documents specific to particular process such as detailed procedures and work instructions.

However, these documents are not sufficient for communications within the organization. In addition to this, the organization should plan for periodic newsletters highlighting the important developments/achievements. The organization should also communicate as much as possible, through circulars, notes, minutes of meetings, etc. The information technology can be effectively used for speedier communications. Each organization depending upon its operation can have a number of stories programmed in the computer through Story Teller or PowerPoint Presentations. Every new employee should be asked to view the story, which could pictorially depict problems observed in the organization and how they were solved. Whenever an employee is found to be committing errors, then he can be advised to look at the story before he resumes his work. This is a very good strategy because people would be interested in reading stories rather than reading from the procedures or written instructions. The training programs conducted for employees are a powerful tool for communications. Through all these mechanisms, the organization can communicate the vision, mission and the values held common by the organization. It is quite important also to repeat the messages, because people generally forget very soon. Therefore, it is essential that the organization plans for establishing a proper communication framework.

Plan for Quality Council (QC) The TQM project should be steered by a Quality Council (QC). Depending on the size of the organization, there can be a one or two-tier quality council. The typical QC in a larger organization is given in Fig. 4.3.

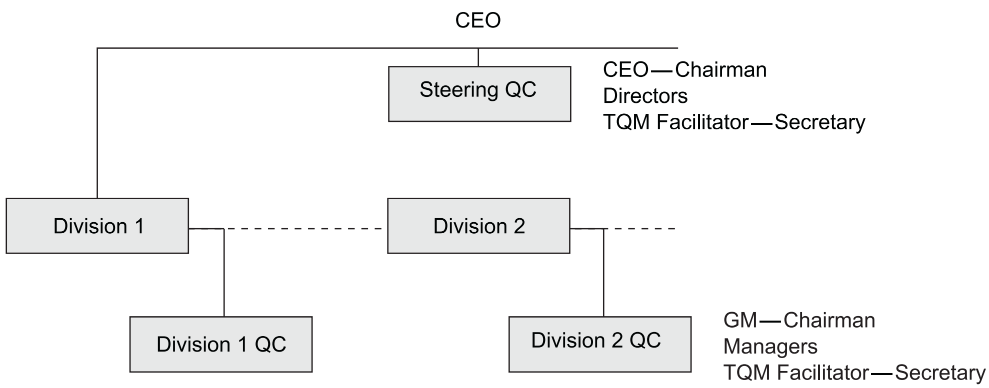

Figure 4.3 Quality council in a large organization

The apex quality council can be called the Steering Quality Council and the others the Divisional Quality Council. The Steering Quality Council consists of CEO and the Directors. The TQM facilitator, whose responsibilities we will discuss later, will act as the secretary to the Steering Quality Council. The

Divisional Quality Councils are for each division under General Managers in which TQM facilitator will also be a member. In a smaller organization, there would be only one QC chaired by the CEO, with the managers and TQM facilitators being the members of the QC. The QC are the corporate structures for implementation of TQM. While the Chairman, members of the quality council are ex-officio, the TQM facilitator is a full time employee working for the implementation of the TQM in the organization.

Selection of TQM Facilitator TQM facilitator should be an independent person and he should not be made responsible for normal production. Only then will he be able to carry out the difficult task successfully. The TQM facilitator should be a coach and not a player. He should encourage ideas in group meetings, avoid expressing his own ideas and be tactful. He should take on the responsibility for coordinating TQM implementation across the organization. This is not a one-time job, but a continuous one which tests limits of the energy. The TQM facilitator has to provide continuity to the QC meetings and should be able to understand the entire operation in the organization. Therefore, right at the planning stage of the TQM implementation, the management should select the TQM facilitator and assign him clear responsibilities. The TQM facilitator is a nodal person for all improvement and related matters, including convening meetings of the QC. He may need some assistants, which could be identified at the planning stage. The TQM facilitator and corporate quality council should be decided upon before the organization goes on to the next stage.

Role of Quality Council (QC) The roles and responsibilities of each member of QC in TQM are given below:

- They should have personal commitment to quality and TQM. The members of the quality council should be convinced that continuous improvement is possible in the organization.
- They should constitute the right teams, which can be called as Process Improvement Teams (PIT) for solving each problem. Since the abbreviation does not sound good, we will call them Process Action Teams (PAT).
- They should attend QC meetings after adequate preparation.
- They should keep track of the steps taken by the teams towards improvement on a regular basis.
- They may discuss with the customers and suppliers to get first hand information about what is happening in the organization. Hence, it would be better to adopt Tom Peters "Management By Walking Around" (MBWA) to know the facts.
- They should facilitate training of the employees as well as the improvement of the team members.
- They should be champions for quality in the organization and should be willing to sponsor quality related initiatives.
- They should always be on the look out for related information and provide resources continuously for quality improvement.
- Last, but not the least, they should walk the talk, i.e. they should lead by example.

Strategic Quality Plan MBNQA advocates that the strategic business plan and quality plan should be integrated. The strategic business plan involves the proposed market share, goals, business value, profits, diversification to new areas of business, investment thereof, etc. The strategic quality planning is the formulation of strategies to achieve TQM in the organization.

Some strategies for TQM implementation are:

- Training for top management—members of quality council, senior management — executives, employees.
- Forming improvement teams for specific problems.

- The consultant can train the quality council members. The TQM facilitator can also undergo the training along with the quality council members. Thereafter, the TQM facilitator should take the lead and conduct training for as many employees as possible on TQM principles and how to go about TQM.

Employee Involvement Every improvement action has to be carefully considered and approved by the QC. However, employees should be encouraged to give suggestions for improvement. The ideas will be discussed in the QC meeting and it will decide whether a suggestion has to be considered or not. Improvement plans require a lot of detailed and intelligent work to be carried out. For carrying out such tasks, cross-functional teams, PATs will be formed by the QC. Each team should be assigned clear responsibilities and in particular specific deliverables by the teams be defined. They have to provide the resources for accomplishing the tasks. However, just providing resources alone may not help the teams to deliver, as there may be hidden barriers to improvement. So it is the responsibility of the members of the QC to detect these hidden barriers and remove them. The QC, no doubt should create a sense of urgency, but they have to give adequate time for the completion of each job. The team may not have the same vision, as that of the members of the QC. They may not also feel confident about doing the job. Therefore, it is the responsibility of the TQM facilitator and members of the QC to guide and facilitate them, so that they can complete the job confidently. The QC must track the progress of PATs and instruct the teams to report on a regular basis. This will help the teams to progress as per schedule and complete the job as early as possible.

While carrying out the tasks, the team members may like to give their opinion as to how to go about finding a solution. The QC members should give a patient hearing to these suggestions and advise the team members appropriately. It should keep everyone informed and should have a mechanism for communicating results of improvement actions. The QC plays a nodal role in implementing continuous improvement program. However, it is important to involve the employees in the improvement tasks in the form of PAT. It should also device a methodology for the involvement of employees in the improvement activity at the appropriate stages. This will be a morale booster for the employees. It will also bring down resistance to change by the employees.

Constitution of PAT The formal structure for TQM consists of the QC, the TQM facilitator and the support staff. Improvement teams are formed for each improvement task. Therefore, the management should plan for constituting PATs, empowering them and supporting them. The improvement teams will be formed for solving a given problem on part-time basis and will be dissolved as soon as the job has been completed. Therefore, improvement teams are not a permanent establishment. The improvement teams could be proposed by the TQM facilitator, but should be approved by the QC. It is better to constitute cross-functional improvement teams to result in better solutions. Every employee should get a chance to be part of the improvement team. In software CMM level five organizations, 70 per cent of the employees serve in the improvement teams.

Identify Process The QC should plan to identify processes for improvement. Business process benchmarking helps in identification of the potential processes for improvement. The potential processes are those, which yield higher return on investment.

APPLY PDSA FOR IMPROVEMENT

We have come across two types of planning activities. The higher level of planning involves formulating policies, selection of a consultant, selection of TQM facilitator, constitution of QC, formulating plans and procedures for various activities and training of personnel in the organization. This can be called overall planning or corporate-wide strategic planning before entering into TQM. At the lower level, planning is encountered when the organization has to decide where to improve, or what steps to improvement have to be taken. Each improvement action has to be planned and executed following the PDSA cycle. Thus, the former one addresses the entire organization; and the latter addresses each improvement action.

Do Phase of TQM

After successful planning, the Do phase starts. The first task in the Do phase is the meeting of the QC. In the first meeting, the various plans as given above should be authorized by the QC.

Study Phase of TQM

In every meeting of the QC, the results achieved through the implementation of TQM should be studied. Wherever plans are to be changed, they should be discussed and decisions taken.

Act Phase of TQM

In the Act phase, the plans for implementing TQM should be confirmed.
This PDSA cycle should be repeated continuously.

SELECT PROCESS FOR IMPROVEMENT

As a first step, TQM needs the establishment of a documented system for quality in the organization. This could be the system established for the purpose of meeting ISO 9000 standards. Nevertheless, once the initial system is established, documented and implemented, then it will be easier for making progress. In other words, improvement can be made only after a system is established. The improvement actions are aimed at achieving one or more of the following goals:

- Attaining technical excellence
- Improving quality
- Reducing defects
- Increasing productivity
- Reducing quality cost
- Improving uptime of equipment
- Reducing overhead costs
- Reducing delivery time

The triggers for improvement may come from many sources. Some of the known sources are internal quality auditing, management review, MBWA, employee feedback, customer feedback, supplier feedback, in-process data and field failure data. Based on these triggers and other data collected from formal and informal channels, the QC identifies the processes for improvement.

Following the business process benchmarking concept will help the organization / QC to prioritize the processes for improvement when there are a large number of processes needing improvement. Once the QC decides to improve a process, then the improvement team will be formed. Once an improvement team is constituted for improvement of a particular process, they also adopt PDSA for the specific improvement action.

PDSA for Continuous Improvement

We have two PDSA cycles, one for the TQM journey as a whole in the organization and the other for each improvement action as given in Fig. 4.4.

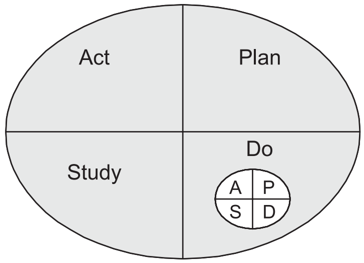

Figure 4.4 PDSA within PDSA

The outer PDSA is for TQM for the whole organization. The PDSA in the Do phase of TQM is that for the improvement action. Once an improvement project is chosen, a team is formed and a clear goal set, then the improvement team studies the process in depth, carries out brainstorming, consults experts and comes out with suggested strategy and action plan. The QC should analyze the proposed solution of the improvement team. A PAT will execute each improvement action. Each PAT will adopt PDSA for the improvement project it takes up.

Plan The improvement team has to make a plan addressing the following points, in particular:

- What is the current situation / level of performance?
- What are the expected results / level of performance?
- How do they propose to go ahead to find out the best solution?

Do After the QC has given its seal of approval, the approved action plan has to be implemented in the *Do* phase on a pilot basis.

Study Phase Once an improvement action is implemented on a trial basis then the Do phase is completed and the Study phase starts. In this phase, the improvement team members have to assess the effectiveness of the suggested solutions. The process owners may also check whether the improved process is yielding better results. The improved process has to be continuously monitored during the trial period. Performance data should be collected at regular intervals. The improvement team should analyze the data during the study phase. Only if the improvement team is satisfied with the improved process, they inform the QC.

Act Phase If the QC is convinced that the process has been improved and the expected results are achieved, then the Act phase commences. In this phase procedures are modified and issued. Thus, new processes as are defined and implemented on a continuing basis in the Act phase.

Agenda for QC Meetings TQM is a process of continuous change and improvement. Every process within an organization has to be assessed for possible improvement. However, the processes, which give higher return on investment, should be taken up first. Hence, at any time, depending upon the size of the organization, many improvement teams will be active. Therefore, the QC has to meet at regular intervals. Each meeting will consider the following:

(a) Approving new initiatives for improvement and forming teams
(b) Discussing progress of on-going improvement actions
(c) Approving solutions suggested
(d) Reviewing the effects of past actions, etc.

They should also clearly mark the beginning and end of each improvement action. As discussed earlier, the improvement teams are need based and carry out the task in addition to their normal activities. They exist as long as the work is in progress for improving the assigned processes. Once the process is confirmed, the QC disbands the improvement team.

Schedules for Improvement Actions Schedules are not only important for normal operations, but also for improvement activities. At the planning stage for each improvement action, a detailed report should be formulated by the improvement team indicating the time schedule for finding out solutions, putting into practice, assessment and confirmation. The improvement team should stick to the schedules. The TQM facilitator should also keep a watch on the schedules and take corrective actions where necessary. Unless schedules are maintained, improvement teams may take years. The improvement action unless implemented in a time-bound manner, is going to be futile. As the organization evolves continuously, the problems will also arise accordingly. Therefore, the improvement team should be fast enough to suggest solutions and implement them, so that the interest of the process owners and the QC are kept intact.

Communicating Success Stories Appreciation of the CEO or the QC will definitely motivate the employees to improve. Such motivation may only stay for a while; the permanent motivation can come only through employees coming to know of success stories due to the TQM program in their organization. Therefore, one of the jobs of TQM facilitator is to communicate the improvements made and its benefits to all the stakeholders. Such success stories should be widely circulated within the organization and even outside. This will bring in motivation for the improvement team members as well as the process owners to strive hard to improve the processes further.

Implementation Tips for Winning Organizations According to Tom Peters[3], the following are the requirements of winning organization:

1. Total Quality Management
2. Reengineering
3. Leveraging knowledge (sharing information rather than hoarding it)
4. Curious cannibalistic corporation (adventurous and bold)
5. Virtual organization
6. Empowerment

We will discuss about all the above factors for success in detail in the forthcoming chapters. TQM needs sharing of information by all the employees. It is a difficult task to make everyone share the information. But with a continued emphasis on teamwork and transparent management, it should be possible to make people share the information regarding things that should be done and things that should not be done. TQM has to be implemented in a bold and adventurous manner. Without these two strides it will be impossible to move forward in the TQM journey. Virtual organization is the order of the day and the organization should try to sub-contract items, which are not crucial so that they can concentrate on a few vital processes and attain leadership position. TQM may start with the management but eventually every individual in the organization has to practice it. This can occur only through training of the employees and their empowerment. While implementing TQM, the organization should be clear about its real requirements. Quite often, they get confused. Hence, Table 4.3 indicates what TQM is and what it is not.

Table 4.3 Total Quality Management

Is	*Not*
A cultural change	An overnight cure
Responsibility of top management	QA manager is responsible
A systematic way to improve processes	A new program
Structured approach to solving problems	Fire fighting
Proactive organization	Reactive
Action speaks	Slogan speaks
Practiced by every one	A specialized discipline
Team involved	Only one person or department involved

The differences between organization practicing TQM and others are given in Table 4.4.

Table 4.4 TQM Company versus Others

	TQM Company	*Others*
Training	Investment	Expensive
Change	Way of life	Resisted
Defects	Zero	Inevitable
Effort	Long-term	Short-term
Performance	Customer requirements	Cost and schedule as agreed to
Communications	Horizontal and Vertical	Vertical
Performance goals	Better than yesterday	Organization Standards
Management role	Coach	Enforcer

GETTING THINGS DONE

TQM has to be implemented by the employees. In every organization, management has the responsibility to ensure that the employees do their duty. Some of the points, which will help in getting things done by employees so as to result in TQM, are briefly discussed below:

1. Recognition Recognition of the contributors, both employees and suppliers, will lead to accelerated implementation of TQM. Recognition is a must in order to motivate the employees to bring out solutions to the problems in the organization. It may also be required to distinguish between the performers and the non-performers. The idea is to make the non-performers to perform and the performers to perform still better. For this purpose, recognition is a useful tool. Recognition need not necessarily be a cash award but something, which will add to the employee's pride. Even appreciation at the right forum may be a big motivator.

2. Praise and Punish There are 4 types of management techniques as given below:

(a) Authoritative
(b) Authoritative and benevolent
(c) Consultative
(d) Participative

While most organizations prefer to have an authoritative type of management, such an approach will not work in the TQM environment. The ideal would be participative management, but it may not be possible straightaway. Therefore, it is better to start the TQM journey with the second type of management, namely, authoritative and benevolent. The management is benevolent, which means it tries to fulfill the aspirations of the employees, at the same time; the management also demands that the employees should do their best for the organization. This could be the starting point and as the employees understand their responsibility and improve their work culture, the other types of management could also be considered. Of course, the training and the quality system of the organization should be such that there is no need for the management to be authoritative.

3. 80 per cent of Success will be Due to Personal Contact The improvement teams alone cannot cause improvement. The empowered teams also may not cause improvement by themselves. It is the support of the QC members and the CEO, which would help the process owners to cross the barriers and improve the process, since resistance to change is a universal phenomenon. The support of the management will help the process owners to overcome the resistance to change. Therefore the CEO and the QC members should maintain personal contact with the employees. No number of circulars or statements are going to bring about the improvement, which personal contact will. In other words, the management should stand behind the people at times of improvement and at times of stress. The management should be willing to take up the responsibility for the failures, while allowing the employees to take up the credit for success.

4. Accumulate Small Gains Continual improvement means incremental improvements. One improvement at a time can lead to a big success over time. But, such small improvements should follow each other, and the management should accumulate these improvements. Even after business process re-engineering, continuous improvements are to be made. Management should realize that many small improvements would only lead to bigger improvements and should encourage and appreciate small improvements made in the organization.

5. Build Credibility—Inside and Outside TQM will help the organizations to improve their reputation and credibility not only within the organization but also amongst it's customers. This should be harnessed by adopting appropriate strategies. One of the strategies should be to talk about success on account of TQM within the organization and the public forums. The image building exercise is crucial for the success of TQM in the organization and CEO and the senior executives have the responsibility to do so.

6. Persist The QC members and the CEO should be consistent. They should take decisions based on detailed analysis. They should weigh the pros and cons before taking any decision. They can consult as many employees as possible, but once a decision is taken, they should not look back and should be consistent. Once an action is taken for improvement and if that is found to be effective, they should persist. During their visits to the work areas of the organization, they should ensure that all the employees are following the improved methods. If the employees are motivated to adapt to new methods, they will get used to it. At the transition stage, the employees may be tempted to go back to the old method, finding faults in the new methods of the improved process. However, they should be given confidence, supervised and motivated till they follow the improved process and understand that the improvement is for their betterment. Only this can sustain improvement. Therefore, persistence and consistency are important characteristics for any CEO.

BARRIERS TO TQM IMPLEMENTATION

There could be many barriers to TQM implementation in an organization. Some of the commonly found barriers are listed below:

- Lack of top management commitment
- Lack of employee involvement

- Non-cooperation of first line managers and middle management
- Lack of clarity in vision
- Losing track of business performance
- Not involving customers and suppliers
- Belief that training leads to employee attrition
- Resistance to change at all levels
- Ineffective TQM facilitator
- Wrong consultant
- Lack of consistency and persistence by the management
- Haste and thereby waste
- Looking for immediate gains
- Not investing adequate resources
- Adhoc organization
- Quick obsolescence of products
- Loosing confidence in the middle of the journey due to various reasons
- Working harder than smarter
- Tough competition leading to frequent price war
- Unable to find champions within the organization
- Not properly staffed—too many or too less number of employees

The barriers can be overcome by dedicated work force with a strong and committed leadership

CASE STUDY (From the Internet)

Total Quality Management in the Xerox Corporation

By Jennifer Zook (Edited)

Total Quality Management in the Xerox Corporation includes programs such as benchmarking, reduced supplier base, and leadership teams (Evans-Correia, 1991). In the following paragraphs, Xerox's strategies for TQM, the Baldrige Award, and the effects of TQM on the Xerox Corporation will be discussed. The Xerox Corporation started its thrive towards TQM in the 1970s.

The Xerox Corporation focuses on benchmarking, a reduced supplier base, and leadership teams as a way of producing Total Quality Management. Benchmarking is a "standard or point of reference in measuring or judging quality, value, etc." (Webster, 1979). Xerox looks at what the competition is doing and sets a level of quality and value that all of its products are compared against. Once the standard that has been set is met then a new and higher standard is set so that the organization is continually striving to do better and have a higher quality product.

The second method Xerox is using in its thrive for TQM is to reduce its supplier base. Xerox has gone from individual suppliers for each of the different manufacturing facilities to a consolidated group of suppliers for all of the manufacturing facilities (Evens-Correia, 1991). This has drastically cut the amount of suppliers needed which increase accountability of the suppliers to get the materials to Xerox on time and it decreases some overhead costs because of shipping reductions and economies of scale discounts. The smaller supplier base also gives Xerox more control in the corporation's decision processes. Furthermore, there are a reduced amount of people needed in overseeing the ordering process from the suppliers which allows for a decrease in positions and less of a chance for error.

The third method Xerox used to help Total Quality Management is leadership teams. These teams consist of a group of people with different areas of specialty. The main functions of the teams are to produce a product for the lowest possible cost with the highest quality. These teams can have jobs that range from finding ways to cut costs all the way to how to handle difficult employees and anything in between. The teams generally decide on what special project they are going to work on. Leadership teams are put together to train other people how to work in teams and how to take an active role in the workplace with their job. Xerox has established a program called Leadership Through Quality (LTQ) and a Quality Training Task Force for its organization's leadership teams. "Today, more than 100,000 Xerox employees worldwide have been trained in this process, which stresses continuous improvement and defines quality precisely as meeting customer requirements" (Evans-Correia, 1997, 135).

Through Xerox's effort with TQM, the corporation has won the Baldrige Award as well as a few other awards. The Baldrige Award "has come to signify a standard of excellence in total quality management, and the practices and achievements of each year's award winners have been examined with considerable interest" (Internal Auditor, 1992,38).

The Baldrige Award is only one of the effects of Total Quality Management for the Xerox Corporation. Another example of the effects of TQM on the Xerox Corporation is the employee and customer support given to the organization. Xerox hosts a teamwork day in which teams are able to come in and show off the projects that they are working on to other employees and to the visitors. In the first year the number of teams that attended was thirty. The next year the number of teams doubled and there were five hundred visitors attending as well. There are no incentives for the teams to take part. The only recognition the people get from the day are thank-you notes (Pell, 1994). This is an excellent example of how TQM is working within the organization. The workers want to take part in this activity because of a competitive spirit which encourage them to come up with the best ideas and take pride in the work the team has done. These are the kind of employees that help make a corporation become a success and stay a success.

The third effect of TQM is the amount of knowledge the organization has learned by implementing the new procedures. Xerox conducts surveys among its customers, stockholders and employees as part of this research. These surveys ask questions about the efficiency of the products and enquire about improvements that can be made to the products. The surveys also take into consideration the suggestions made by the employees to improve the products and to improve the production process. "Xerox and other leading TQM organizations have similar processes of surveying employees, mass media, government, and investors on a ongoing basis and sharing the information in the organization" (Grostedt, 1996). These surveys keep the employees informed about their quality of their job and how they can improve their performance. This allows empowerment of the employees and increases the improvement time and it increases the rate in which improvements are made. These surveys help to strengthen the corporation because of the fact that the organization responds to them and the corporation's image is improved because of good customer relations developed. The surveys work well in the Xerox Corporation because they are taken seriously and are responded to. The organization wants to be the best it can be and it is shown partly through these surveys.

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SUMMARY

An organization should enter into TQM only after a thorough analysis of the requirements of resources, changes to be made in the management of the organization and the benefits the organization is going to get out of TQM. They should realize that TQM is a never-ending process and it will take some time to see success. They should not adopt TQM unless they are convinced about TQM. They should also realize that there is no other alternative through TQM, the CEO would be creating hundreds of empowered teams to take on the TQM journey in a continuous manner. The formal organizational framework for TQM consists of the QC members who are ex-officio and one full time TQM facilitator assisted by a few support staff. During the initial stage, the organization needs to have a consultant, since consultants will be able to enable changes easily. The consultant will also train the QC members and TQM facilitators. Later on, the TQM facilitator should be able to take on the training responsibility for the rest of the employees in the organization. TQM implementation needs careful planning about the organizational framework for communications, vision, mission and objectives of the organization, policy for constituting improvement teams, procedure for improvements and the methodology for their implementation. The CEO and QC members have to invest time for TQM to happen. It also calls for putting quality at the centrestage of management of the organization. Every improvement action should follow the PDSA cycle so as to implement improvements without creating confusion in the organization. Although, initially TQM may call for more efforts, as it evolves, it will result in reducing non-value adding processes and waste.

In this chapter we discussed about the organizational framework for implementing TQM. The specific tools or techniques for implementation of TQM are discused in the following chapters.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. The leadership for implementing TQM has to remain with
   (a) Consultant (b) All employees
   (c) CEO (d) None of the above
2. PDSA cycle includes
   (a) Act (b) Check
   (c) Cost (d) All the above

3. TQM methodologies include
   (a) JIT (b) DOE
   (c) QFD (d) All the above
4. The long term objective of the organization is contained in
   (a) Vision (b) Mission
   (c) Quality Policy (d) None of the above
5. The quality council is chaired by
   (a) TQM facilitator (b) CEO
   (c) All the above (d) None of the above

II. Say True or False

1. Quality Council is essential for implementation of TQM
2. ISO 9000 is not relevant to TQM
3. The CEO has to invest time for TQM to happen
4. Process improvement team is chaired by CEO
5. A cross-functional team is better for improvement of processes.
6. Vision statement provides strategy for achieving mission.
7. The TQM facilitator should sign quality policy.
8. Vision statement should be as long as possible.
9. Middle management may resist involvement of employees
10. Quality Council approves changes
11. Quality Council forms team for process improvement
12. Success stories should not be shared with public
13. Senior management should be persistent for TQM to happen
14. Work instruction do not form part of communications framework of an organization
15. Vertical communication only needed for TQM
16. Study phase precedes plan phase
17. Consultant should not be employed for implementing TQM
18. Schedules shall not be laid down for improvement actions.
19. Management By Walking Around (MBWA) is not relevant to TQM
20. Coaching employees is essential for TQM
21. Benchmarking can be used for prioritizing processes for improvement

III. Match the following

A	B
PDSA	Quality Function Deployment
PDCA	Edwards Deming
QFD	Design Of Experiment
DOE	Shewart
JIT	Just-In-Time

IV. Write short notes on

1. Communication framework for TQM

2. PDSA
3. TQM implementation tips
4. Vision, Mission and Quality Policy
5. Employee involvement for TQM to happen
6. TQM tools and techniques
7. Steps involved in TQM planning
8. Organization for TQM
9. Role of CEO for TQM to happen
10. Role of TQM facilitator
11. Barriers to TQM
12. Requirements for a winning organization
13. Area wise contribution of quality gurus for TQM
14. Give a sequence of events for any improvement action in a TQM company
15. Quality requirements for TQM facilitator

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Section II

TQM Principles & Strategies

In this section, we will discuss the principles of TQM and strategies for the implementation of TQM. Overlap between the strategic management and TQM cannot be avoided since TQM is the way in which an organization has to be managed. This section contains a number of TQM principles and strategies, which if implemented correctly, will result in success for any organization. The TQM principles and strategies discussed in this section are:

We discuss the principles governing these concepts along with some strategies for success. They are all guidelines or one method of implementation. There may be many different ways. However, the key to success lies in implementing them based on the profiles of:

- Customers
- Employees
- Suppliers
- Society and culture

Implementation is the responsibility of every employee of the organization. However, it has to be led by the CEO. Only an organization headed by a capable leader and CEO flourishes. Therefore, every organization requires a unique solution that is provided by the CEO.

Chapter 5

Customer Satisfaction

One customer, well taken care of, could be more valuable than $10 000 worth of advertising.

—Jim Rohn

Customers are the greatest need of any organization. Hence it is obvious that they should be satisfied. Satisfying customers requires adoption of PDCA. Every organization needs to carry out PDCA as given below so that the customers are satisfied.

- Plan for satisfying customers
- Implement the identified measures to satisfy them
- Check whether they are really satisfied
- If not take corrective action
- If so take preventive action
- Revisit the plan.

In this chapter, we will discuss some useful tips for enhancing customer satisfaction through TQM principles and strategies. It may be a surprise to many, but the fact is that a vast majority people are engaged in providing services. Even in case of manufacturing industries, a large number of persons are involved in providing services. Hence service quality is quite important for customer satisfaction. It is applicable to every organization, irrespective of the nature of their business, whether engaged in manufacturing the products or providing services.

We will discuss the following in this chapter:

- Service Quality
- Customer Delight
- Kano Model
- Agreed Customer Requirements
- Customer Perceived Quality
- Customer feedback and complaints resolution

SERVICE QUALITY

Definition of Service

The definition of service as per the international standard, ISO 9000 follows:

"The results generated, by activities at the interface between the organization and the customer and by the organization's internal activities, to meet customer needs".

The result generated in the case of manufacturing is a product. However, in the case of service, it may be a product or may not be a product. The definition of service could be understood easily by visualizing a few common services. For instance an organization supplying electricity to a household is a service organization. The objective of the organization is supplying electricity for various purposes. In achieving its objective, the organization undertakes internal activities such as generation, transmission and distribution, so that the power is available at the customer's doorsteps. The customer could only benefit from the presence of electric power, but not see it or feel it! Thus, definitely electric power is an intangible product, provided as a service by the electricity provider.

Importance of Service

There are numerous service providers, such as colleges, schools, Internet café, hospitals, restaurants, hotels, banks, government departments, transport organization, insurance agencies, chartered accountants, publishers, software organizations, telecommunication service, real estate agencies, security services, house-keeping services, taxi services, training organizations, test laboratories, etc.

Many persons are engaged in providing services. For instance, a service that hires a large number of people in every country is the government service. Nothing is manufactured in a government department. They only provide various kinds of services. According to Deming, in the United States of America, 75 per cent of the people are employed in service organizations. In addition, even in the manufacturing industries, some people are engaged in providing service. If this is also taken into account, 86 per cent of persons are engaged in providing services[1]. This is the importance of service. Therefore, the quality of services is important for all organizations, including the manufacturing industries where sale of products is also a service. In a service organization service content will be large, whereas in manufacturing it will be rather small, in terms of percentage of employees engaged. In this section, we discuss the concepts pertaining to quality of service, which is crucial for customer satisfaction.

FEATURES OF SERVICES

There are a number of unique features, which characterize a service (be in the manufacturing sector or service sector). We will look at some of them.

Speed

The requirements are always made known to the service providers only at the last moment. Hence, it becomes imperative for the service providers to offer the service as fast as possible without compromising on quality. Furthermore, the demand will be fluctuating and there will be peak periods. For instance, the demand for transport is high at the peak hours. Therefore, design which enable speed and delivery with appropriate staffing are critical requirements for success in the service industry.

Delivery Schedule

Usually, the service is directly delivered to the customer. Every delivery is associated with a delivery schedule. If someone has to catch a flight and he calls for a taxi at 6.00 pm, the taxi should reach him before 6.00 pm. If not, the customer is put to inconvenience. Therefore, adhering to a time schedule is quite critical in the service industry. Many projects fail due to the failure to keep up to a time schedule. The customer may not accept a service if the delivery is delayed. Such delays result in loss of money and can even lead to the closure of the service organization.

Care in Handling

The deliverables have to be handled carefully. The customers should also be handled carefully. If the deliverables are not handled carefully, they may break or perish. The mishandling of customers will also cause hardship in the form of the loss of goodwill and repetition of orders. Therefore, it calls for extreme care in handling of both the deliverables as well as the customers.

Each Service Offering is Different

This is true in the case of services and usually not true in the case of manufacturing operation. In manufacturing, production of products as per a specification is taken up in bulk quantities. In the case of manufacturing one should manufacture in large quantities for cost effectiveness. However, in service industries, to procure two orders of service with identical requirements on the same day may be difficult. Therefore, each service offering is different. Each service requirement is different as it depends upon the personal preferences of individual. Take an example of a restaurant, each person's order will be different. Even every cup of coffee ordered will be different, without sugar, or with more sugar, strong coffee with more sugar, etc. as each person's taste is different. Therefore, each service offering is designed to fulfil the individual needs of customers.

Customer Requirements are Difficult to Comprehend

Since each service offering is different, service provider has to make efforts to understand the requirements of each customer correctly. This applies to manufacturing as well. One has to communicate effectively with the customer to know his true requirements. Therefore, it requires a lot of tact and intelligence to understand the requirements. Understanding customer's requirement is a tricky affair in a service industry.

Difficulty in Estimating Cost

Since each service offering is different, every time the service industry has to estimate the charges payable by the customer for the service offered. It is unlike a product, where the price is stamped on the product itself. But, in the case of service, because of the varied requirements, the materials used and time taken for each service offering may be different. Similarly, the expenditure incurred on account of manpower utilized for each service may also vary. Service charges essentially comprise of the cost of materials, the man-hours, machine hours that will be utilized and the cost of overhead. Hence, before finalizing the service offering, the detailed cost estimation has to be carried out every time. Unless the service organization organizes the work around a database and has a systematic working, it will not be able to quickly calculate the estimated charges. Furthermore, the organization has to prove to every customer that it is consistent. Hence, every organization should have a system for arriving at the charges for each offering. System should be simple and unambiguous.

Difficulty in Measuring Performance of Services

A product is manufactured as per the documented specifications formulated by the organization. A service, which may be delivered as per the documented specifications, will be different at each time of delivery. In manufacturing, the specifications must be formulated unambiguously, clearly and without any subjective element. But in the case of a service organization, it is extremely difficult to avoid the subjective element. Therefore, it is very difficult to assess the performance of service deliverables. One has to formulate indirect parameters for measuring the quality of services. The process could be clearly defined with a number of sub-processes. The operators should measure the performance of the sub-processes. Then depending upon the performance, of the sub-processes the quality of service delivered could be determined. However, the service organization should try to control the quality of all the four M's, i.e. Men, Machine, Method and Materials. Even then, the service organization will not be able to say definitely whether the service delivered, meets the requirements or not. This is not the case with the manufactured products, because, it is able to meet all the requirements specified. However, the quality of service delivered can only be judged by the actual user. Hence, it becomes important to carry out measurement of quality of the service delivered through customer feedback. Thus, unlike services it is easy to measure the performance of the manufactured products.

Difficulty in Marketing Services

Even in the process of marketing, there is a wide difference between service and manufacturing. If a product is manufactured and if publicity is given, then there will be a good demand, provided the quality of the product is good. Such a straightforward approach is not possible in the service industry. Service industry cannot hope to sell millions of service deliveries of the same type. It can only hope to sell a limited number of services with more profit. Any amount of advertising will not reach its customers. Therefore, the service industry has to do two things for marketing of the services namely

(1) personal contact with potential buyers
(2) building credibility of the organization by good services consistently. The latter is very crucial in the case of a service industry. People can be attracted to avail services only through the image of the service organization built through actual services rendered. There is no harm in sending newsletters or participating in exhibitions or giving video coverage, but its effectiveness will depend upon the real ability and reputation of the service organization. This is the basic difference in marketing of service industry vis-à-vis manufacturing industries.

Difficulty in Measuring Customer Satisfaction

In the manufacturing sector, the product has to be designed with quality, reliability and with good aesthetics and the manufacturer should have a good after sales service to attract the customer. If these are met, then it will be rather easier for an organization to sell and the customers will definitely be satisfied. But, the problem arises because determining customer satisfaction in case of a service industry is more of a psychological problem. It is very difficult to read the minds of the people. Therefore, the service organization cannot rely on normal methods of assessment of the customer satisfaction. It has to device a number of methods. When all of them are put together, one may get the right idea about the satisfaction of the customers. Measuring customer satisfaction is quite important to every business.

Psychology of Customers

The most important requirement for success in any industry is to understand the psychology of the customers. It may be difficult to follow one simple rule for all the customers. While some customers will be nice, willing to listen and cooperate, others may be unreasonable. The organization may think of saying “no” to such customers. But this customer may stop 10 other good customers who are willing to avail the services. Therefore, the organization cannot say no to such customers. At the same time, such customers may cause irritation to the customer contact employees. Therefore, such customers have to be handled tactfully. Even for winning a bid or contract, the customer contact employees should not mislead them. They should not give false hope to the customers. If they follow such principles, there will be no surprises for the customers. It is better to lose a customer by telling the truth rather than getting a customer by giving false promises. This should be clearly understood to reduce a problems in a service organization. The time schedule would have been adhered to, but then after the service contract has been received, some problem would have been noticed, which will postpone the delivery schedule. There are two ways of handling this unforeseen situation. One way is to keep calm and when the customer comes, tell him the reasons for the delay. Although there might be absolute truth in the statement of customer contact employees and also the customer may be willing to accept the reasons for the delay, he will still not excuse the customer contact employees, since they have not told him in advance. Second option is that as soon as they notice that due to some reason the project could be delayed, they should immediately contact the customer and inform him that the job is likely to be delayed and for what reasons. If this is done, then the customer will definitely understand and may be willing to give some more time to complete the job. Therefore, the customer should not be given surprises. A similar strategy is applicable in the case of escalation of costs. But, the speed with which the customer is informed about the escalation of costs is important. There could be some error in finalizing the contract. As soon as the error is found, the customer contact employees can tell the customer that they have done a wrong calculation and that it would cost them some more money. In such a situation, the customer will definitely agree to pay the difference. But if the customer contact employees wait till the service delivery period, then the customer may feel that he is taken for a ride. Therefore it is essential to train the customer contact employees in handling the customers effectively.

CUSTOMER DELIGHT

Business Thrives on Customers

Customers are the very reason for being in business. Profits can be reaped only if an organization has customers who will pay for the products or services on a continuing basis. It depends on the ability of the entrepreneur to get into the right areas of business for success. In fact, successful entrepreneurs are those who create a market of their own. They may not compete with existing providers or share their market. Even before venturing into a business, the entrepreneurs should study the market; carry out market research and only thereafter, should choose a right business. Therefore, any organization should identify the customers first and orient their business towards satisfying the customers. Customer orientation means, running a business with the sole motive of serving more and more customers and satisfying them. This happens when there is a win-win situation between the organization and the buyer. The business will be a successful only if it can give the highest return on investment. This is possible only if the enterprise is oriented towards customers.

Although many organizations may start with good customer orientation, as time goes by and as businesses flourish, over-confidence may set in. This results in lack of the same spirit with which the customers were served in the beginning. Initial falling of standards of customer orientation, may not land a business into trouble immediately. In some organizations due to its monopolistic operations, lack of customer orientation may not affect the business for quite some time. But, all these are temporary and customer orientation will only see the organization through in the competitive business environment and reduce uncertainty of the future of the business.

Tom Peters[2] gives an interesting account of customer satisfaction

He illustrates the superior customer orientation of the staff at Hotel Orient in Bangkok. For instance, the staff at the fourteenth floor concierge desk pushes the down button as you leave your room so that you and the elevator car arrive at the fourteenth floor simultaneously! The customer's delight in such situations knows no bounds.

Customer Attrition

Some organizations may be able to attract new customers, but existing customers may leave. It is relevant to recall an old saying in this context.

" If product is good then customer will come back (again);
If not, the product will come back (returned)".

Quite often the number of new customers may be much more than the attrition of customers. This may give a false confidence that the customers are happy and the organization is doing well. Therefore, in order to get a true picture, every organization has to find out, at any given time how many customers have been lost rather than how many customers they are serving at that time. The losing of a higher number of customers indicates falling standards with regard to quality of services provided. According to Tom Peters, the customers leave because of the following reasons[2]:

15 per cent because of quality problems
15 per cent because of higher price
70 per cent did not enjoy doing business with the organizations.

This indicates the importance of maintaining good interpersonal relationship with the customers. It is not very difficult to manufacture a product or design a service, but it is rather difficult to attract customers and retain them forever.

50 Per Cent of Problems are Due to Misunderstood Requirements

One of the major problems in a service industry is identifying the real requirements of the customers. In many computer software development projects, 50 per cent of the defects are caused due to a misunderstanding of the requirements. This statistics may also apply equally to any other service industry. Therefore, every effort should be made by the customer contact personnel, for identifying not only the stated, but also, the implied customer requirements.

Contractual and Non-Contractual Requirements of Customers

Customer satisfaction has to be analyzed, with regard to both contractual and non-contractual requirements of the customers as well as non-contractual expectations of the customers. The contractual requirements are most of the times documented in the form of 'Requirement Statement' jointly agreed to and signed between the customer and the organization. Whenever a service contract is finalized the customer requirements have to be understood, documented and agreed to by both the parties. If it is not carried out, there could be hassles later. The documented customer requirements are basically the contractual requirements. The contractual requirements could include the following parameters:

- Quality: service / product characteristics
- Time schedule for delivery
- Price
- Services such as responsibility for installation, service during warranty and post warranty, etc.
- Documentation support
- Training support

While, in most cases, it may be possible to meet all the contractual requirements of the customer, it is quite difficult to find out the non-contractual expectations of the customer. The non-contractual expectations include the following parameters:

- Quality (not documented before)
- Implied requirements
- Value for the money spent
- Environment of conducting business and the friendliness of the customer service personnel of the organization, etc.

To make it simple, the staff at Hotel Orient, on his own synchronizing the arrival of the elevator with that of the customer is not a contractual requirement or expectation, whereas if the customer before leaving his room calls up the staff to call the lift, then the staff is contractually obliged to press the call button.

Delighting Customers

If the organization just tries to satisfy only the written requirements, then it is unlikely to delight the customer and retain them forever. The organization should be familiar with general human nature and try to understand the hidden requirements of their customers. It may be helpful to carry out a market survey and find out the additional small things that are delivered by the competitors. If such hidden requirements can be unmasked and if the organization fulfills them, then it will satisfy the customer. In a service organization, customers do not generally mind paying more, but they definitely mind how they are received, dealt with and the quality of the product or service. Therefore, it is better to educate the customers regarding the facilities that can be added to the requirements free of cost and what incur at additional cost. This will also increase the sales value. No customer would dislike such indirect marketing. If the customer is educated and enlightened about the services offered, it always leads to more business to the organization. At the time of delivery of the product or service, the organization can give pleasant surprises to the customer by giving additional features or items for resulting in customer delight. Another way of delighting customers is offering customers what they won't have expected. Thus, service organizations should look for such opportunities for delighting the customers, since it is only in their own interest to delight the customers by fulfilling their unstated needs and become their friend.

Customer Contact Personnel

The customer orientation dictates that customer contact personnel should be specifically chosen. There should always be a separate set of people to talk to and accept orders from the customers. They could be different from the actual producers since manufacturing and customer service are two distinct chore requiring different caliber. Manufacturing requires appropriate tools, machinery, materials and skills to manufacture. Customer service is totally different. Customer service relies more on interpersonal communications and satisfying the customers. It cannot be done by a computer. Whereas, a product can be definitely manufactured by a computer in the modern era, customer service requires human face to attract the customer, every time. It is therefore essential that the customer contact employees are separate and they are trained in customer handling. It is also essential that each person selected in the customer service, possess the ability to communicate effectively. The customer service personnel should have pleasant and persuasive skills. In fact, the customers are to be comfortable or in other words customer service personnel have to give comfort to the customers while they are dealing with them. According to D.H. Stamatis **COMFORT** stands for the following customer service attributes[3]:

C for Caring The customer service employees should not only be, but perceived to be very interested in finding out the real needs of the customers and help them to buy what they really intend to buy, product or service. They should not drive away customers. They should also be ready to answer, both the relevant and irrelevant queries and go out of the way to help the customers in solving their problems. In case, an organization cannot meet a particular requirement of a customer, the customer contact personnel can suggest the right source that can meet the requirement. This way the customer's goodwill can be accumulated by the organization. They should make the customers feel at ease, so that the customer will come out with his implied requirements. The customer contact employees should patiently listen to the customers and if necessary note down the points to be clarified later on, without interrupting them.

O for Observant Each customer service personnel should be a good observer. The customer contact person should pay attention to the body language of the customers and should also be able to read their requirements. This will help him to understand the customer requirements better. A good customer service person will take notes while the customer is talking. If queries are promptly answered, the customer will feel that the customer service person is really knowledgeable in the field.

M for Mindful The customer contact employees have to remember that the organization is dependent on its customer. The organization has to strive to meet the customers needs. In the service industry, the customer is always late. This is true in every service organization. At the same time, the service organization may not be able to complete the job immediately due to genuine reasons. However, the urgency of the customer has to be considered. The customer contact employee should be sensitive to the urgency and the expectations of the customers. They should give importance to the requirements of the customers even if the request was received very late. At all such times, the customer contact personnel should remind themselves that they are on the job because of the customers and not vice versa. Therefore, they should treat the customers with due respect and give them the feeling that they are always right. It does not mean that the organization gives in to the demand of customer where it is not possible or not necessary. However, good interpersonal relationship costs nothing and hence should be maintained.

F for Friendly The customer service employees have to be friendly with the customers. At times, if the customers or their representatives are not very friendly, then, such situations have to be tactfully handled by the customer service employees. They should give as much information as possible to the customers and greet them with a smile. All these small things will improve the relationship with the customers and retaining the customers for their lifetime.

O for Obliging The organization should feel obliged that the customer has visited them with an enquiry. It may so happen that the customer may not be serious about giving a business. He may just be comparing the price for a job already finalized with some other provider. The customer contact employees should answer the customer queries even in such cases, as it may add to the marketing efforts of the organization. Quite often, discussing the requirements with customer or sending a proposal in a service organization might be time consuming. It may be required to send 10 to 50 pages of a proposal for a non-serious query, and all the proposals may not meet success. But, attempts to answer all queries are worth because some of them can be rewarding.

R for Responsible While the proposals are being submitted, the organization should feel responsible for successfully accomplishing the proposal if accepted by the customer. It is better to subject the proposals for "contract review" before sending. The contract review should not be an obstacle for innovative ideas and it should not cause delay. The organization should not send a proposal to just win the bid in the competition or in the hope that it would not materialize. It should ensure that the service can really meet the expected quality, time schedule and price. There could be risk factors in any proposal. Such risks should be identified and documented in the internal files. Along with the risks, the organization may also document contingency plans to overcome the risks. The organization cannot under-quote. It cannot commit lower than achievable time schedule and later on stretch the time. If that happens the customers will be dissatisfied. It is better to always set a realistic time schedule and stick to it. The organizations have to be courageous to set a realistic time schedule and stick to it. There can be many reasons why an organization does not adhere to the schedule, such as an employee going on leave suddenly, due to power cuts, those unanticipated failure of an equipment and so on. Only organizations deliver on time despite these obstacles can succeed. If the organization manages to meet the schedule despite all these odds, then the reputation of the organization will improve. An organization has to be determined for satisfying the customers at all costs. Therefore it is very important that the organization feels the responsibility of fulfilling the quality requirements, time schedule requirements, delivery requirements and service requirements as well as price requirements.

T for Tactful The customer is supreme. But this does not mean that they cannot be wrong. The organization should tactfully handle such situations. Whatever is asked for after a contract is signed should incur additional cost. Such a strategy will not only satisfy the customer, but also at the same time discourage changes to the originally agreed requirements. If a change in requirements is not going to cost any thing to the organization, such changes could be accepted as a goodwill measure.

In a service organization, generally, the customers would demand that the job should be completed in a very short time. In such situations, customer contact employees should explain in detail how much time is really required for providing the service. Tactful handling of customers will make the customers understand and cooperate in completing the jobs successfully.

THE KANO MODEL

In the late 1970s, Dr Nariaki Kano of Tokyo Rika University came out with an interesting and practical model for understanding customer satisfaction, known as the Kano Model. He developed the model from Hertzberg's 'Motivator-Hygiene Theory[4] (discussed in the next chapter). Generally, quality is considered to be one dimensional in nature as given in Fig. 5.1.

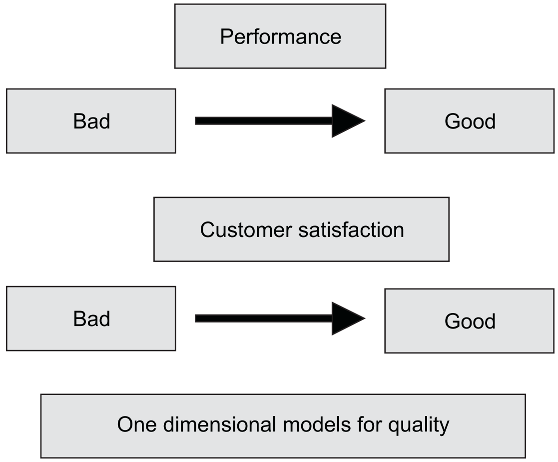
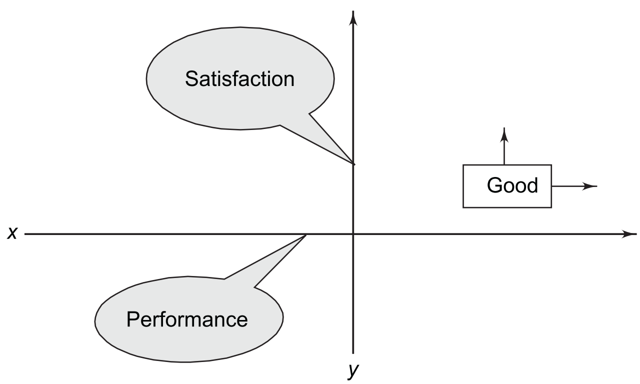


Figure 5.1

When we measure the performance of a product, we rate them as good or bad. Similarly, when we rate the satisfaction of the customer, we rate them as good or bad. This is a one dimensional quality model. Dr Kano proposed the two-dimensional model for quality. In Kano's model, there are two axes as given in Fig. 5.2.



Two Dimensional Quality Model

Figure 5.2

The *x* axis represents the performance of the product or service or degree of implementing the product function. On the *x* axis the extreme left point indicates that the product function is absent. On the extreme right point, the product function is fully implemented.

The *y* axis represents the level of customer satisfaction. On the top-most point, the customer is highly satisfied; on the bottom-most the customer satisfaction is quite low.

Thus, the two-dimensional model combines two characteristics pertaining to quality namely implementing the product function or degree of implementing the features of a product or service and the level of satisfaction of the customer. Combining both the quality parameters, namely the performance and customer satisfaction in a two-dimensional plot facilitates understanding quality in a more sophisticated and holistic manner. (See Fig. 5.3.)

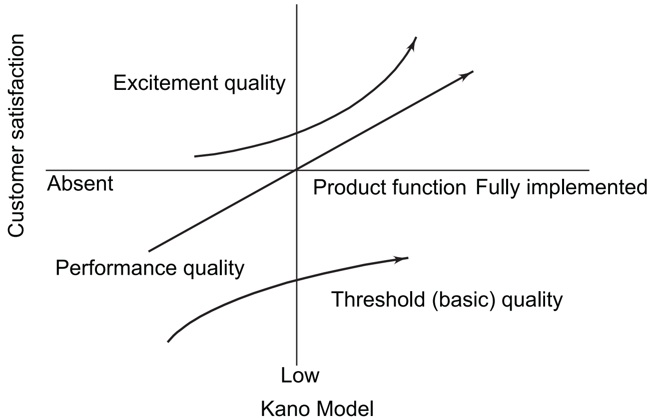


Figure 5.3

The above figure is the Kano model for representing three levels of quality. There are three graphs in the plot and they represent three different quality levels. In fact, the graph is three types of responses of a customer with regard to quality of a product or service—these are basic quality, performance quality, and excitement quality.

Basic Quality

The basic quality is also called threshold quality. As the graph indicates, if the functions are not implemented as agreed, then it results in lower levels of satisfaction as compared to higher levels of satisfaction, when fully implemented. It should be noted that providing additional functionality does not increase customer satisfaction much. The reason for this quality type is that the customer expects that his requirements will be implemented in any case. For instance, a buyer of an automobile expects a vehicle to start easily, provide a safe driving environment and be free from rattles and noises. If a vehicle satisfies all these, then the customer is not dissatisfied. But, if they are not met, the customer will be definitely dissatisfied. Fulfilling the basic quality saves the supplier from down side risk, but does not provide much for customer satisfaction. Customers will definitely complain if the basic quality attributes are not fulfilled. But they will not appreciate the supplier for fulfilling the basic quality features. Fulfilling the basic quality is measured by the following:

- Customer complaints
- Warranty data
- Product recalls
- Number of lawsuits

- Things gone wrong
- Other failure reports

The basic quality represents unspoken or minimum expected requirements.

Performance Quality

Look at the linear graph. This measures satisfaction proportionate to the performance of the product. Performance quality attributes generally cause linear response. Increased levels of achievements cause increased levels of satisfaction. The customer requirements for performance quality can be found from the customer surveys. Customers freely express their desires, when they are asked for. This is also called as voice of customer. This can be found through Quality Function Deployment (QFD), which will be discussed later. For instance, a customer of a car expects the vehicle to have a good engine performance. A buyer of a two-wheeler will compare the performance with reference to other two-wheeler vehicles available in the market. They won't compare the model with reference to a car. Within the same range of products, the customer will be satisfied more if a particular product gives a better performance. For instance, if three two-wheelers give a mileage of 40 kms, 60 kms and 80 kms per litre of gasoline, then the satisfaction of the customer will be proportional to the mileage. Similarly, if the performance is 20 kms, then the customer will be dissatisfied. So a linear increase in customer satisfaction can be expected in the performance quality.

> The rule is: better the performance, the greater the satisfaction.

Excitement Quality

The third quality type is the excitement quality. Excitement is generated because the customer received some feature or attribute that they did not expect or think of. Customers generally do not articulate excitement attributes in customer surveys, because they do not know that they want them. In order to generate excitement and brand loyalty, organizations must leverage their creative resources to identify ideas and innovations that cause customer excitement. Excitement quality becomes the special reason why customers make a specific organization the default choice over its competitor and return to buy again and again. Excitement attributes cause an exponential response. Small improvements in providing excitement items cause relatively large increases in satisfaction. Several small excitement features may accumulate and generate sheer delight on the part of customers. For instance, taxis in Mumbai providing free newspapers to passengers or an auto-rickshaw in Chennai playing radio. However, very soon the excitement quality may become an expected quality. Therefore, organizations have to be continuously doing research in finding out what will excite the customers. Thus, the graph depicted in Fig. 5.3 represents a given time. As time passes, the excitement level may become performance level and performance level may become a threshold level or basic level. Thus, the customer satisfaction is quite dynamic. Therefore, the organization has to be quite alert in providing new features. They should also be more tactful in not adding those features, which are not going to increase the satisfaction level.

Therefore, the organizations have to identify the following:

- Basic features, which must be provided, which if not provided, will dissatisfy the customers
- The features, which give linearly proportional customer satisfaction
- The features that will excite the customers and give exponential increase in customer satisfaction

If this analysis is carried out continually, then the organizations will be able to satisfy the customers at optimum costs.

AGREED CUSTOMER REQUIREMENTS

Invest Time for Understanding Customers Requirements

Every business should meet the requirements of its customers. However, the requirements of customers are the most difficult to comprehend, especially in the service industry. Every service offering is different which dictates that determining customer requirements is not a one time affair. Even in manufacturing, requirements of customers may change suddenly. Therefore, organizations should invest time for understanding each customer's complete requirements. But organizations generally overlook this point and do not provide adequate resources. They do not put in efforts to understand the real requirements; instead they jump into implementation straight away. Such projects end in disasters such as customers not taking delivery, rework arising out of realization of the actual requirements at the fag end of the project, unnecessary protracted correspondence, legal battles, etc. Therefore, the organization, instead of trying to save resources should provide adequate resources for understanding the correct requirements.

Find out the Right Requirements First

In the service industry, the problem is compounded because, it is very difficult to describe the end product in clear terms. One of the reasons for this phenomenon is that the service offering is more easily described through subjective parameters rather than objective parameters. For example, nobody will be able to describe objectively a recipe. Therefore, service industry poses much greater challenges for the customer service personnel for understanding the customers requirements. This is one aspect of the requirements problem. The other aspect of the problem, which is due to human beings, is described below.

Normally, in a service industry, the customers meet the service provider and express their requirements orally. The success of such verbal communication depends on both the parties. The representative of the service provider should be inquisitive, without giving an impression that he is so. He has to put the necessary questions to the customer, without annoying him. If it is not done, doubts may arise later regrding the expressed requirements of the customer. They may not be able to clarify the doubts with the customer later due to the following reasons:

- Customer may not be available till the delivery time
- Ego interfering with communication
- Too busy with other jobs in hand
- Belief that communication may lead to more work without additional payment
- Due to fear of creating bad reputation for the organization
- Fear of senior management coming to know about the ''problem''

Some or all of the above reasons may force the service organization to assume part of the specifications on their own, without consulting the customer. Such assumptions could be wrong most of the time and hence should not be attempted. Even while discussing, customer may mean something and say something else; customer may say something and organization will perceive it differently. This arises because the customer and organization hail from different backgrounds. Hence the organization should make every effort to find out the correct requirements of the customer, every time.

> There was a message from a service provider to their client abroad stating that the item is ready and being shipped. The customer replied saying that the item is required urgently and should be sent by air cargo. Supplier informed they are "shipping" right away. Customer again pleaded to send by air cargo. Customer repeated earlier message. This went on till the supplier informed that in fact they are shipping by air cargo.

Checklist for Eliminating Communication Gap

The service provider could give a checklist to the customers, which should be filled up, before, they discuss about the service to be provided. It is important that the checklist is not too long, but, it contains all relevant details which are required to understand the service requirements clearly, without ambiguity. Since some customers may find it difficult to fill up the checklist, it may be a good idea to give a model checklist. If the customer does not understand how to fill up the checklist even with a model in hand, he can be helped by the customer service personnel of the service provider in this task. Once the checklist is filled up, the customer will also have to decide what he really wants from the service provider. After the checklist is filled the service provider can discuss the contracts after a brief perusal. Wherever he has a doubt on the requirements, he can politely request the customer to throw more light. After the discussions, the customer, if necessary could redraft the service request. This will improve understanding of customers requirements.

Review the Contract/Requirements

The customer should also get a contract review done, in his organization before the service request is given to the service provider. Similarly, when the service request is received by the service provider, they should also be subjected to a contract review, in the service organization before final acceptance. Such contract reviews, both at the service organization and customer's organization should be carried out successfully. If carried out, definitely, the required service would have been more clearly defined.

Foresee and Provide for Amendments

It is not always possible to arrive at all the requirements correctly before the contract is finalized. Hence, before even agreeing to provide the service, the customer and the service provider should agree upon how to amend the service agreement later on, if necessary. In a service organization, there may arise new points while the job is being executed. Therefore, such eventualities should be foreseen and methodology for handling them should be documented. It is also quite common that whenever a service provider approaches a customer for changing specifications, the customer would like to push in additional requirements. Such tactics used by the customers have to be handled by the service provider tactfully. The service provider cannot afford to say "No'' to new requirements of a customer. But if additional requirements can still be incorporated, he should agree to provide the additional services at an additional cost. This way, the customer's additional requirements could be tactfully handled by the service provider.

Documented Policy

As Deming said, it is not meeting our own requirements, but, the customers, for success of business. Therefore, each organization should have a documented policy for handling customers in a pleasant manner, finding out their correct requirements and converting them into the requirements, which would be understood by employees in the organization. The requirements of the customer should be clearly documented and agreed upon in letter and spirit, both by the customer and the service provider. This is an important requirement for improving quality and also for practising Total Quality Management (TQM). Therefore, the organization should document its policy and procedure for methodology for requirements elicitation from the customer including methodology for communication, review of contracts and handling conflicts between customer and organization.

Code of Good Customer Handling Practices

The past experiences gained in implementing services should be accumulated, so that the mistakes are not repeated again. There are two checkpoints in a service requirement finalization. The first one is the initial discussion the customer contact person has with the customer and the second one is the contract review in the organization. At these two stages, whatever pitfalls or mistakes are found by the organization should be identified and documented. In this process, over a course of time, a large number of such pitfalls would have been observed and documented. A senior management person should consolidate the past experiences from these observations and formulate the 'Code of Good Customer Handling 'Practices'. The document should be thoroughly understood by the customer contact employee. New persons, before deployment for customer contact, should thoroughly understand the various points given in the document and should be able to steer clear of the pitfalls. They can also be trained by senior management personnel in customer service with the use of documents. This will help the organization to overcome the problems in identifying the requirements in the future. The service organization has to continuously strive to understand all aspects of the customer's requirements before reaching agreement with the customers. Documentation of, the 'Code of Good Customer Handling Practice' is essential for this to happen.

CUSTOMER PERCEIVED QUALITY

Importance of Measuring Customer Satisfaction

Unless an organization evolves specific methods for measuring customer satisfaction and quantify the results, it may be difficult to say whether the customers are satisfied or not; whether customer satisfaction is improving or not. It is also very essential to measure customer satisfaction so as to stay ahead of competition. Each business unit has to conduct its business in such a way that it is able to achieve more customer satisfaction than its competitors at all times as the competitors would also try to satisfy their customers more and more, day by day. Therefore, to face and win the competition, every organization should continue to improve their products and services and attain higher levels of customer satisfaction.

The continuous improvement of customer satisfaction can only be confirmed by objective measurement. For the purpose of ensuring objectivity in measurement of customer satisfaction, it is essential to arrive at clear strategies for measurement, determine parameters to be measured, methods of measurements and then develop documented procedure for measuring customer satisfaction involving all the above. An organization has to thereafter measure customer satisfaction as per the documented procedures and strive hard to improve the same. Depending on the competition, a service provider could reengineer the business processes and achieve quantum jump in customer satisfaction. This is the only a logical way to survive in spite of the competition and become a market leader. Therefore, measuring customer satisfaction objectively is quite important for every business.

No Hard and Fast Rule for Identifying Measures

There is no hard and fast rule, for evolving measures for determining customer satisfaction. While, some may feel that customer satisfaction is delivering products or service at the lowest cost, actually it is not. The customer is satisfied when the value of product or service is worth the cost of the item. It is always the value for money spent on the products which satisfies the customers. Every organization should identify carefully the various parameters, which may be indicative of the satisfaction of their customers. The measures could vary from business to business. For instance, the measures for a computer software business will be different from computer hardware business. Therefore, every organization has to identify measures that are unique to their business and customer profile.

Identify Vital Few Measures

The senior executives of the organization should sit together and carry out a brainstorming session to find out the measures for determining customer satisfaction, appropriate to their business and the spectrum of their customers. Initially it may be difficult to identify the measures, but a couple of brainstorming sessions should be able to bring out the measures which will represent customer satisfaction. Selection of a few vital measures is essential, since any effort to measure customer satisfaction is going to cost time, effort and thereby money. At the initial discussion, all possible measures could be noted down. Then the group can start eliminating the trivial measures and arrive at the vital few measures, which will truly represent the customer satisfaction index.

Arrive at Quantitative Indices

Although customer satisfaction is subjective, any subjective evaluation of the same is likely to be misleading. Therefore, the organization should make efforts to convert the evaluations into objective indices. All the indices need not have a common unit; it can have different units, depending upon the parameters. For instance, if we talk about defects, it could be parts per million. If we talk about delay in delivery, the measure could be in terms of number of days or hours and so on. Such indices could also be combined together with proper weighing factors to arrive at a single overall customer satisfaction index for the organization as a whole. Unless the organization tries to express the customer satisfaction measures in numbers, it may be difficult to comprehend the satisfaction levels.

Some Measures for Customer Satisfaction

The following provides some measures, which could be considered for inclusion in the evaluation of satisfaction of the customers of an organization.

Customer Perceived Quality

The prefix of "customer perceived" has been added to quality purposely. It is not the quality as perceived by the organization, but the quality of product or service as perceived by the customer. There will always be gaps in the perception of both the customers and the suppliers with regard to every product or service delivered. A feature, which satisfies one customer, can annoy another. Therefore, trying to estimate the customer's perceived quality is a ticklish job. Some of the parameters, which would help in determining customer perceived quality are:

- Defects in the product on delivery
- Number of requirements fulfilled
- Number of misunderstood requirement
- Frequency of defects (mean time between failures)
- Time taken for repair (mean time to repair)

Response Time

Response time is one of the most important parameters in service industry. It is in the interest of the organizations to reply to the queries as early as possible. Even two days is quite a long period for giving proposals. However, the customer contact employees might be postponing giving responses to the customers due to various reasons. Business delayed is business denied. Therefore, it is essential to keep a watch on the time schedule and be up-to-date in every activity. The human lethargy should not be allowed to overtake the quality of the organization and the response time should be monitored by the management at regular intervals.

Some of the parameters, pertaining to response time are given below:

- Delay in delivery
- Delay in installation
- Promptness in service
- Time taken for attending to service calls
- Number of reminders the customer made to his service provider
- Response time of the organization for the customer's additional requirement after delivery

If the service details are computerized, and available in database, it would be easier to calculate the average time taken for jobs and standard deviation for jobs of same nature. Such charts should be communicated to the employees every month. This feedback would motivate the employees themselves to bring down the average time taken and standard deviation. It is ideal if the average time achieved is lowest possible and if the standard deviation is lower than the average. If not, there is no proper system of handling jobs in the organization. One of the important tasks for management is to find out average time taken and standard deviation at each sub-process. Since in an organization, which has established customer supplier chains, the total process would have been divided into sub-processes, each sub-process should measure time taken for each job and record the same. Unless this is recorded, it may not be easy to analyze whether the processes are improving day by day or otherwise. Therefore, the management should look at each sub-process and try to find out the time taken for designing and delivery to the customers, both internal and external. A good measure of customer satisfaction in a service industry is the continual reduction of response time and defects. Quality and response time are both important and every effort should be made to deliver on time with quality. Response time is therefore one of the vital parameters for measuring customer satisfaction.

Errors in Documentation

It is not uncommon to see errors creeping into invoices, delivery notes and other such documents. According to Philip Crosby, 25 per cent of non-manufacturing work is redone to correct the defects[5]. No one would tolerate such errors. The organization may not deliver the item unless the payment is made by the customer. The customer may not be able to pay because the invoice contains errors. Therefore there should not be any error in the invoice, supply orders or delivery notes. This should be achieved by sending right invoice, to the right party, first time and every time. Therefore, one of the measures for customer satisfaction is the error in documents.

Errors in Delivery

Every international traveler has one anxiety namely that his or her baggage should reach the destination along with the passenger. Such an anxiety arises because quite a number of baggages go missing while traveling abroad. Such problems are to be corrected. If we analyze the reason, it will be found to be due to errors in handling the baggage at the airports. In bigger airports, a large number of baggages arrive at the same time and if the coordination is not proper in transferring the baggage from one plane to the other or from one complex to another it will result in such mishaps. All concerned should take every effort to see that the baggage is never missed. It is definitely possible to achieve zero defect on this score.

In a service industry, delivery is as important as the design and therefore, there should be no errors in delivery. Sometimes, the products might have been sent to wrong addresses. Sometimes, the addresses might not be complete wasting time for the delivery boys. The time spent in verifying the address is worth it. Any delay on account of wrong address will annoy the customer. Computerization helps the organization in achieving quality in delivery of service. Error in delivery is, therefore, another vital parameter in determining customer satisfaction. The errors in delivery could also include delivery of incorrect items or to incorrect address or both!

Delay in Execution

An organization may be tempted to delay execution of a job, due to various reasons. However, an organization cannot afford to delay the execution of a job. The organization should have plans to take alternate measures, when the planned action fails to materialize. If an assembly is carried out and if a conveyor is blocked, the supervisor immediately runs to the spot and clears off the block and rectifies the fault for the smooth running. Such should be the urgency in ensuring that the execution delays are eliminated. The delay in execution will definitely cause delay in probable date of completion (PDC), which will no doubt annoy the customer. Therefore, the organization should study and compute delays occurring in the execution of every job. This is a measure of customer satisfaction. It is also to be noted that a delay in any of the processes will force the organization to do two things

(1) Postpone the PDC
(2) Compromise on the quality. Therefore, the management should ensure that every action takes place as originally planned. In case of any problem in the process, action should be taken immediately to make alternate arrangements. Hence delay in execution is another performance measure.

Delay in Delivery

Any delay in delivery, whatever is the reason for delay, should be computed as a quality measure.

Measure Everyone's Satisfaction

Measuring customer satisfaction does not exclude the internal customers. Therefore, determination of satisfaction should be across the organization including the internal customers, the external customers and the ultimate users. This includes retailers, wholesalers and so on. Therefore, it is not enough if only external direct customer's satisfaction is gauged. The entire chain of people involved in delivery of the service to the ultimate customer should be taken into account while determining the customer satisfaction.

How to Overcome Difficulties in Measuring Customer Satisfaction?

It is certainly not easy, at least to start with, to compute indices for customer satisfaction. It requires innovative people, a determined management and additional efforts by the organization for this purpose. This will pay for more than itself in the ultimate analysis. Therefore the chief executive of the organization should be committed and persuasive in measuring customer satisfaction in the interest of the organization and provide resources for this task.

A brainstorming session with as many employees as possible should be held to find out the factors, which are important for customer satisfaction. Thereafter, the organization should select a few vital parameters to measure and once they are determined, then data collection should be instituted and at regular intervals the measures should be computed as realistically as possible. The organization should also see whether there is a consistent improvement in performance.

Whenever performance is measured, it should be communicated immediately to the employees. If it is not communicated and if it is simply filed by the Quality Assurance team, it will serve no purpose. Each measurement should lead to finding out the actual cause of the irritants, if any. The irritant could be one of the employees or one of the sub-contractors, one of the retailers, or one of the processes and so on. Therefore, the job of the chief executive is to find out such irritants and eradicate the irritants so that customer satisfaction improves day-by-day. The value of service delivered for money spent, should go on increasing. This is possible only through reduction of rework, scrap and unproductive work and so on. Therefore, organizations should aim at providing more value for the money spent, day-by-day. If the organizations increase the price without improving its quality, then it will lead to failure of the organization. Thus, determining the customer satisfaction and taking corrective action to improve the customer satisfaction continuously is most important.

CASE STUDY 1

Customer Satisfaction Survey of ETDC, Chennai

Electronics Test and Development Centre (ETDC), Chennai, India, is engaged in testing and calibration of electronic products. As a part of their TQM initiative, decided to measure customer satisfaction index (CSI) in the year 1996. After brainstorming with senior executives, the following four parameters were identified to measure customer satisfaction index.

1. Promptness of Service (P1)
2. Quality of Customer Service (P2)
3. Quality of Testing and Calibration (P3)
4. Quality of Test and Calibration Reports (P4)

A simple format was devised so that the customers will be motivated to give the feedback. Then at the end of the financial year, the CEO sent letters to 150 clients under his signature and enclosing the feedback form. He also assured that the feedback given would be kept strictly confidential. The customers were requested to rank the quality of ETDC services against each one of the above mentioned parameters in a scale of one to five, five being excellent and one being poor. About 35 per cent of the clients responded. Then a customer satisfaction index for each parameter was determined as a weighted average explained as follows.

Assume that ranking of 10 customers with report to promptness of service are as under:

Rank	No. of respondents
5 (excellent)	7
4	1
3	1
2	1
1 (poor)	0

Then, CSI for promptness $= \dfrac{5 \times 7 + 4 \times 1 + 3 \times 1 + 2 \times 1}{10}$

$= 44/10 = 4.4$

In this manner, the CSI was expressed in terms of the four parameters.

This exercise was repeated every year thereafter and the results obtained during the last three years are summarized below:

Year	*P1*	*P2*	*P3*	*P4*
2000–01	3.55	3.76	3.96	3.83
2001–02	4.27	4.11	4.19	4.04
2002–03	4.36	4.2	4.33	4.3

CASE STUDY 2

Customer Satisfaction Survey of Mercedes Benz

Mercedes Benz has published their customer satisfaction index for the month of April 2003 on the Internet as given below:

MBCV Dealer	*Sales*	*Service*	*Overall*
Cape Town	85.19	88.3	86.745
Centurion	81.67	84.82	83.25
Roodepoort	96.36	86.28	91.32

Their statements are also worth noting. They said, " Our customers are our existence whether they are individual operators or large national fleets. Our focus is on long-term relationships which we will earn through service excellence in all areas of our business".

CUSTOMER FEEDBACK AND COMPLAINTS RESOLUTION

In the previous section we focused our attention on measuring customer perception of quality and arriving at customer satisfaction index. We also discussed about some measures for arriving at CSI. In this section we will discuss about how to handle feedback and complaints to result in customer satisfaction and improving inefficient processes. Every organization should have a well-defined process and procedure for getting feedback and receiving complaints from the customers.

CUSTOMER FEEDBACK

Right customer feedback is the most difficult to obtain. It is common to see that as soon as a service is delivered, the customer will rush to carry out the other tasks elsewhere. He may be prepared to wait (of course, cursing the service provider!) even for longer time to take delivery of the item ordered, but, may not like to wait even for a second after the service is delivered. He is simply not interested to spend more time with the service provider, leave alone giving a feedback to the organization. The service provider cannot take the feedback when the customer is waiting for the service to be delivered, for obvious reasons. Later on, the customer has no time absolutely, to give a feedback! This is true for every service. If the customers do not give a feedback in time, then the market will unexpectedly give an adverse feedback. Therefore, it is very essential that the service organization adopts the right strategies for obtaining customer feedback.

Feedback Forms

The most common method of obtaining feedback is by giving a response sheet or a feedback form to the customers at the conclusion of delivery process and seeking feedback. Feedback form can be same as prescribed for measuring CSI. However, we look for more details (if possible) in the customer feedback to improve our processes. Hence, there can be another form, if necessary. If such forms are lengthy and complicated, the customer would not find the time to complete the feedback form. Therefore, the customer feedback form should be simplified to enable the customer to fill it up with the least difficulty. The customers should be motivated to give their feedback without wasting much time.

A sample quality feedback form is given below:

(i) Overall impressions about the quality of the product or service provided (tick one)
Excellent / Good / Fair / Poor

(ii) Whether the job was carried out as originally agreed (tick one)
Totally / Partially / Not at all

(iii) Whether delivered on time, as scheduled ("yes" or "no")

(iv) Whether the job was delivered on the scheduled date without reminders ("yes" or "no")

(v) Was the service provided by the customer contact personnel satisfactory? ("yes" or" no")

(vi) Were the other personnel in the organization prompt and friendly? ("yes" or "no")

(vii) Would the customer like to come back again for the same service? ("yes" or "no")

(viii) Is he considering an alternate source of supply? ("yes" or "no")

(ix) Is the customer satisfied with the price paid? ("yes" or "no")

(x) Compare the services of the organization with the services provided by any of its competitors? (Tick one)
(Better / equal / poorer)

(xi) Service specific queries:
(These are to be chosen depending upon the service provided. For instance, for training program the following could be added)
Was the faculty well informed? ("yes" or "no")
Could they motivate? ("yes" or "no")
Could they provide adequate case studies? ("yes" or "no")

Confidentiality

In order to get a true feedback, the feedback form should be kept confidential. Even where it is taken orally, the confidentiality of the feedback should be assured so as to get realistic feedback. When a customer is not satisfied with a service provider, he may not like to go to a different provider immediately unless a particular provider is quite bad. They may not like to annoy the people in the organization with whom they are dealing everyday, by giving them an adverse feedback. But if it is assured that the feedback will be kept confidential, then there are chances that the customer will give a free and frank feedback.

Display Results

The feedback data should be analyzed at regular intervals. The data collected could be converted into charts like pie charts, bar charts and displayed in the organization's notice boards. The display of the feedback is beneficial in two ways to the organization namely:

1. The customers come to know that their feedback is taken seriously by the organization
2. The employees in the organization know about where they really stand.

COMPLAINT RESOLUTION

While feedback from customers is to be dealt with in an independent manner, the resolution of complaint is to be handled by senior management personnel. It is also a good idea to open a number of channels for feedback and complaints, such as a suggestion box or nominating an authorized person independent of production and customer contact to receive complaints or feedback. The first task to be carried out in resolving complaints is their entry into the database or register of complaints. This is essential for the following reasons:

(i) To keep track of the complaints.
(ii) To carry out root cause analysis and take corrective action immediately so as to eliminate such problems in future.
(iii) To take preventive action.
(iv) To find out the cost of poor quality and other statistical purposes.

Every complaint should be duly acknowledged. It should receive the attention of the top management.

The complaints coordinator cannot be from the customer service or from production or operations to avoid conflict of interest. They could be from other services. In fact, it will be a good idea to designate the management representative or QA manager to be the coordinator for complaints resolution, if he has time. The coordinator has to initially make a quick analysis to find out whether the complaint should be further processed. If the complaint is unworthy, then it should be dropped at that stage itself. If a complaint is genuine, the following actions should be taken:

Analyze Independently

The complaint coordinator may designate a team or a person for studying the complaint thoroughly and independently. The team should study the complaint and verify whether it is true. The team should approach the complaint with an open mind and try to analyze whether such a mistake could have occurred in their organization. It should recommend to the top management to take corrective action immediately without waiting for the final findings of the team. Once the organization understands the cause of customer complaints, they should take immediate remidial action. If the action is delayed, then the customer may be disillusioned. So the team should try to have a brainstorming session to find out the root cause of the problems. Thereafter, they could recommend appropriate solutions to the top management.

Give Benefit of Doubt to Customers

Quite often, there may be variations in the statements made by the employees of the organization and the customers. Such a situation should be handled tactfully and the team should be able to find out the truth. However, in such cases, if there are doubts whether the cause of complaint is due to the customer or due to the organization, the benefit of doubt should definitely go to the customer. The resolution of the complaint does not mean that the organization always yields to the customer. Wherever the customer is right, the organization should definitely yield to the customer's point.

Satisfying Annoying Customers

If the organization is serving thousands of customers, there could be one or two customers who will be creating problem for the organization unnecessarily. If the organization puts all its efforts to curb it, then it will be wasting its time. Therefore, it may diplomatically handle the annoying customers and send them back as early as possible.

COMPLAINT RECOVERY PROCESS

Each organization has to establish a process for receiving complaints, processing them, communicating to customer and resolving the issue. This is called a complaint recovery process. This process is aimed at satisfying customers, resolving problems and take preventive actions. The problems of customers have to be recorded. They have to be resolved without delay to infuse confidence in the customers. The methodologies suggested in the previous paragraphs are aimed at complaint recovery. Every complaint is important and the CEO should know about the them. He should keep track of each complaint till it is resolved. The resolution should satisfy the customer and also the analysis of the complaint should bring out clearly the root cause of the problem. The root cause should be corrected immediately. The organization should gracefully accept the fault and take corrective action so that the customer is not put to inconvenience. The system should be such that the organization welcomes complaints and the senior management is receptive to them. The mechanism for receving complaints should also be simple like dropping written complaints in the box meant for it. Every complaint should be acknowledged immediately. The resolution of the complaint is carried out by the employees with the full knowledge of the top management. The complaints could also be ranked according to severity and appropriate priority should be given for resolving them. Customers should be treated with respect and courtesy even after they have complained. Hence, the source of complaint may be kept confidential. The organization should believe that the customer is always right even when they are complaining. This will give a positive outlook in the organization to deal with complaints. Doing things right first time, every time and a complaint recovery process will result in enhanced customer satisfaction. Therefore, organizations should always be receptive to complaints.

SUMMARY

The service industry all over the world employs more people than all the manufacturing industries put together although the latter may be responsible for generation of more wealth. Furthermore, service industry plays an important role in improving the quality of life of the human beings. However, the service industry has its unique problems. Each service offering is different which increases the paper work in the organization. Even, understanding the customer's requirement is much more difficult than the manufacturing sector. It is also difficult to estimate the cost. Each time a service offering is made, the costs are to be calculated. In many industries, preparation of quotations is taking more time. If one reads about the Business Process Reengineering (BPR), it will be found in some case studies that through BPR the time taken for giving quotations has been reduced from say 40 days to four days. Thus, preparation of quotations is one of the difficult tasks in the service industry. To add fuel to the fire, the customers are always late. They approach the service organization very late and put time pressure on the service organization even for small value services. The service provider cannot cut the delivery schedule by adding more people since the jobs in a service may have to be executed sequentially and a minimum period may be inescapable for completion of the job. To make the difficult job easier, the organization should have a clear understanding of the customers fundamental psychology. Hence, the organization should deploy selected people for customer contact. Measuring customer satisfaction is an important, but a difficult task. The above concepts are equally applicable to the service providers such as customer contact employees in every organization including the manufacturing sector.

Customer satisfaction is the most fundamental requirement for being in business. Therefore, every organization should plan the right strategies for dealing with customers, communicating with them, providing pleasant services and retaining them forever with specially chosen customer contact employees, all leading to their delight. Since most of the quality problems arise due to misunderstood requirements, it is essential to take steps to correctly understand, both the stated and implied requirements of the customers. The organization should not only fulfill the contracted requirements, but also make it a point to provide unanticipated additional services to delight the customers and retaining them forever. The most important point is that the organizations should provide COMFORT to the customers while serving them. Thus the business should be oriented towards satisfying customers.

The Kano Model for quality helps in understanding three types of quality namely, basic, performance and excitement. It is a two-dimensional model for quality unlike the traditional models which are one-dimensional. The model should be understood and applied for resulting in customer delight.

The service provider should have a systematic method for finding out the customers' stated and implied needs with the help of a checklist and code of "good customer handling practices". The requirements should be subjected to contract review for identifying the risks involved and formulating contingency plan to overcome the risks. All these demand adequate resources for the purpose of finalizing agreed customer requirements. The resources include the right and bright personnel chosen for this purpose, the right environment for conducting discussions with the customers, the right tools and above all a clear policy towards service. It should also be ensured that jobs are commenced after both the parties have agreed to requirements after review in both their organizations. Such agreed requirements will save the service providers from surprises and disasters.

Computing customer satisfaction is essential in every organization. There are no hard and fast rules for such measures and every organization should evolve their own measures. They should select a few vital measures from the many, identified by the executives after brainstorming. Efforts should be made to measure satisfaction in hard numbers. It is in the hands of the management to motivate the executives to work hard to compute the realistic customer satisfaction index. Such indices should be communicated within the organization regularly. This will facilitate self-correction and even prevention by the employees, leading to customer satisfaction and thereby prosperity all around. We also discussed some measures.

A feedback or a complaint criticizing the organization should be taken as a blessing in disguise and in the right spirit. If there is no direct feedback or complaint, then the organization should look for other ways for finding out the same, since feedback is one of the most important triggers for improvement. If complaints are made, the organization should seriously make efforts to see that the complaints are resolved to the satisfaction of the customers. Every complaint should lead to determined efforts by the organization to make improvements so as to result in non-recurrence of such complaints in the future. In short, the service provider should have a system to solicit feedback and complaints, deal with them dispassionately, rectify the defects immediately, compensate where not possible to rectify and analyze such mistakes to find out measures for their non-recurrence and implement the measures strictly. The above is also known as complaint recovery process.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. In service industry
   (a) Understanding customer requirement is easy
   (b) Each service offering is different
   (c) Measuring customer satisfaction is easy
   (d) None of the above
2. Difficulties in service industry include
   (a) Customer is always late (b) Marketing
   (c) Handling (d) All the above
3. Customers service personnel should be
   (a) Caring (b) Obliging
   (c) Tactful (d) All the above
4. Additional requirements of customers should be
   (a) Ignored (b) Accepted
   (c) Accepted with additional price (d) None of the above.
5. Customers leave because of
   (a) Unhappiness with customer service personnel
   (b) Higher cost
   (c) Found a provider next door
   (d) All the above

6. Non-contractual requirements include
   (a) Waiver of fee
   (b) Dismissal of an employee of organization
   (c) Value for money spent
   (d) All the above.
7. Requirements should be agreed to by
   (a) Customer
   (b) Supplier
   (c) Supplier and customer
   (d) None of the above.
8. Contract review is required in
   (a) Supplier organization
   (b) Customer
   (c) All the above
   (d) None of the above
9. Measures for customer satisfaction shall be identified by
   (a) Customers
   (b) Suppliers
   (c) The top management of the concerned organization
   (d) All the above
10. For computing Customer Satisfaction Index, identify
    (a) At least 10 measures
    (b) As many measures as possible
    (c) Vital few measure
    (d) None of the above
11. Examples of right measures include
    (a) Cycle time
    (b) Defects on delivery
    (c) Defects found during the process
    (d) All the above
12. Complaints can be handled by
    (a) Purchase department
    (b) Production department
    (c) QA division
    (d) None of the above
13. Complaints should be analyzed by
    (a) CEO
    (b) Authorized team
    (c) Purchase department
    (d) All the above
14. Feedback form should be
    (a) Clear
    (b) Unambiguous
    (c) Easy to fill
    (d) All the above

II True or False

1. Service sector employs the largest number of people
2. Software development is a service
3. Speed is more critical in service
4. Each service offering is different
5. Psychology of customers is difficult to predict
6. There are peak hours in service
7. It is easy to measure performance
8. Cost is constant for each service
9. Customer needs for service always remains same
10. BPR cannot be applied in a service industry
11. Customers thrive on businesses
12. Customer delight is not possible
13. 50 per cent of problems may be due to misunderstood requirement
14. Customer contact person should be tough with customers

15. Body language of customer should be noted
16. Customer attrition is mainly due to higher cost
17. Customer should be obliged to the organization
18. Customer requirements should be subjected to contract review
19. In service industries, usually customers arrive at the last minute
20. Additional requirements should always be accepted with a premium
21. Kano model is a two-dimensional model for quality
22. Excitement occurs when unexpected features are provided
23. Additional requirement of customer should be refused
24. Amendments are to be foreseen
25. Checklist for customers are helpful for understanding requirements
26. Code of good customer handling practices does not serve any purpose
27. Customer should provide for amendments to contract later
28. Poor communications is the cause for misunderstood requirements
29. Customer satisfaction should not be measured in hard numbers
30. There are specific guidelines for identifying measures
31. Identify large number of measures
32. Quantitative customer satisfaction index is better
33. Quality as perceived by the organization should be measured
34. Number of errors in documents can't be a measure at all
35. Complaint should be discouraged.
36. Feedback should be handled by a junior employee
37. Feedback causes interruption of work
38. Process improvement points will not emerge from feedback
39. Corrective action should be taken quickly
40. Complaints should be kept confidential
41. Written feedback should not be taken
42. Employees should be supported over customers where necessary
43. Customers have no time for giving feedback
44. Suggestion box can be used for receiving complaints

III. Explain Briefly

1. Characteristics of service
2. Psychology of customers
3. Importance of service industry
4. Importance of customer handling
5. Why speed is critical in service industry
6. Definition of service
7. COMFORT of customers
8. Customer delight with example
9. Why customers leave?
10. Why customer requirements are misunderstood?
11. Contractual and non-contractual requirements
12. Why customer contact employees should be tactful?

13. Kano Model
14. Agreed customer requirements
15. Checklist for requirements
16. Prepare a code of good customer handling for a restaurant
17. What are the requirements for finding requirements right first time and every time?
18. Methodology for Customer Satisfaction Index
19. Importance of CSI
20. Measures for customer perceived quality
21. How to overcome difficulty in measuring customer satisfaction?
22. Evolve a CSI for transport corporation.
23. Feedback for process improvement
24. Complaints and customer satisfaction
25. Complaint recovery process
26. Design a feedback form for hospital
27. Explain the system for handling feedback
28. Why should we give benefit of the doubt to customer?

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Chapter 6

Employee Involvement

I rate enthusiasm even above professional skill

—Sir Edward Appleton

INTRODUCTION

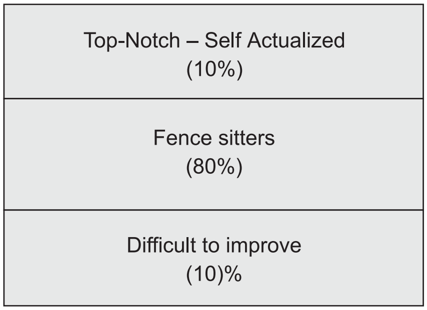
The employees are the strength of an organization. They are the prime contributors to its success. When an organization wants to expand its business or increase its profits, only the employees can make it happen. The only expandable resource in the organization are the employees. Any improvement will happen only because of the employees. Therefore, employee involvement is essential for TQM. In this chapter we will discuss the following TQM principles and strategies pertaining to employee involvement.

- Motivation
- Teamwork
- Training and Mentoring
- Recognition and Rewards
- Feedback and Performance appraisal
- Empowerment

EMPLOYEE MOTIVATION

Group Behaviour

Motivated teams lead to the success of organization. However, the concept of employee motivation is difficult to understand because human nature is quite complex. However, some behavioural patterns have emerged over the years. For instance, in every organization there are three categories of people as given below in Fig. 6.1.



Behaviour of employees

Figure 6.1

It is believed that about 5 to 10 per cent of the employees are self-motivated and whatever be the circumstances in the organization, they continue to do their best. They never get demotivated, even if there are demotivating factors in the organization. The bottom 5 to 10 per cent are the difficult people who do not want to get motivated. However, 80 to 90 per cent of the people are fence sitters. Their motivation level depends on management strategies. They join the top 10 per cent, if the management is effective; otherwise they join the bottom 10 per cent. Essentially, they look at the treatment received both by the top 10 per cent and the bottom 10 per cent. If the top 10 per cent are recognized, rewarded and treated well, then the middle 80 per cent are drawn to join them. If the management does not differentiate and treats everyone alike, then there is a likelihood that the middle rung may join the bottom 10 per cent causing organizational problems. Now, let us look at some of the theories about motivation of individuals.

MOTIVATION THEORY OF INDIVIDUAL EMPLOYEES

Theory X

Sigmund Freud is the author of Theory X. Theory X characterizes employees as given below:

- Avoid work
- No ambition
- No initiative
- Do not take responsibility
- Needs security

To make them work, the management has to do the following:

- Reward
- Coerce
- Intimidate
- Punish

If this theory is applicable to any employee, then the organization cannot function with such employees. This theory assumes that the employees cannot be trusted and the employees have to be supervised all the time.

Theory Y

Douglas McGregor is the author of Theory Y. McGregor's theory of people are given below:

- Want to learn
- Work is a natural activity
- Have self discipline
- Develop themselves

These employees do not get motivated as much by any reward, but they seek freedom to do difficult and challenging jobs, all by themselves. If the manager can guide the employees in identifying challenging jobs, the potentials of the employees will be realized. Some employees who can be characterized to have the characteristics of the top 10 per cent as per Fig. 6.1, belong to type Y. If all employees are of this type, then there is no need for supervision.

Theory Z

Abraham Maslow believes that good qualities are inherent in people, at least at birth; although later on they are gradually lost. He believes that five basic human needs, as illustrated in Fig. 6.2 motivate the employees:

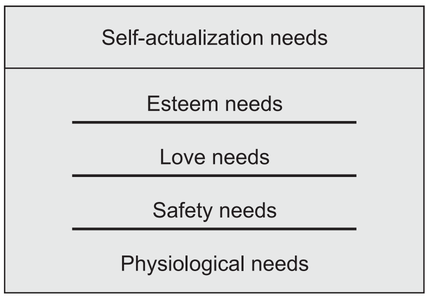


Figure 6.2 Human Motivational Needs

Self-actualizing Needs They are the greatest motivators for human beings. He believes that human beings are always dissatisfied and they would like to achieve more and more. That is the reason for achievements. Thus, Theory Z has some overlapping with Theory Y.

Physiological Needs (Lowest) This is the basic need for any human being. Every human being wants to earn a living for himself and his family. When the physiological needs are satisfied, the safety need takes over. At this stage, the human beings look for job security. After this, the need for love or belonging arises. Every human being wants to belong to a reputed organization. When all the above three are satisfied, then the human being looks for self-esteem and self-respect. He looks for recognition and appreciation. In the next stage, the human beings look for self-actualizing fulfillment. They would like to develop themselves as creative persons and want job satisfaction. Thus, an employee's need rises to the higher level when he attains satisfaction at the current level.

Herzberg's Theory

Frederick Herzberg has divided the motivational aspects of human beings into the following:

- Hygiene Theory
- Motivation

The hygiene theory is the minimum that every employee requires for not being dissatisfied. Without the above, the employee will get dissatisfied. These are the basic needs. Further efforts are needed to motivate the employees.

Hygiene Theory The hygiene factors include:

- The company
- Its policies and its administration
- The kind of supervision which people receive while on the job
- Working conditions
- Interpersonal relations
- Salary
- Status
- Security

Motivation The motivation factors include:

- Achievement
- Recognition for achievement
- Interest in the task
- Responsibility for enlarged task
- Growth and advancement to higher level tasks

Motivational Techniques

- It must be realized that all the employees do not fall into one category all the time. It is possible to motivate every employee to work for the organizational goals. However, the time taken to motivate each person depends on his current level of motivation. It is important to realize that each person develops certain attitudes depending on his/her background. This has to be kept in view while dealing with individuals. Therefore, it is a challenging task for the leaders to bring in harmony in the organization, where every employee works in the same manner for the benefit of the organization. The management has to enable the employees to work as much as they can. This can be the first step towards bringing order in the organization. Thereafter, each human resource has to be looked at, coached, motivated and enabled to be a performer.

The team helps the employees to rise to the level of the other members under the careful eye of the management. Nevertheless, it is very important to have a systematic approach to build and develop individuals. The poor performers can be motivated to perform better if the right environment is created. If the employees are treated fairly, their well being taken care off and the goals and objectives of the organization clearly defined, then the poor performers may also turn out to be good. Therefore, the greatest motivational technique for employees is the proper management of the organization. It is only the organization, which makes an employee good or bad. Every employee has a potential to be a leader and it is the responsibility of the organization to nurture it.

TEAMWORK

Why Teams?

Every organization may start initially with one person or a few people, one of them being the entrepreneur or the promoter. Personnel are added in the organization to do more work. Each person has to contribute to the business output of the organization. Each person is recruited for a specific job. As the organization grows, a formal structure is evolved to enable better management and communication. Teams are formed to fulfill the objectives. It is part of the regular organizational structure of the organization. The team coordinator will coordinate the day-to-day activities of the team. He may be called a manager, supervisor, team leader, head, team coordinator, etc. He is responsible for the output of his team while each member of the team is responsible for the work assigned to him.

Therefore, it is amply clear, that teams are made to do more work, which individuals can't. However, this concept erodes with time. When the organization gets larger, people start defeating the very purpose of increasing the manpower and the net output comes down. It is quite logical therefore that team members have to work together, in the interest of the organization in fulfilling the basic expectations of the employers.

Teamwork is not a Natural Human Function

At times, one may find that the team members are incompatible and it is difficult for them to work together. Therefore, every effort should be made to put together compatible persons as a team. Some employees may try to disrupt teamwork. Generally, left to themselves, the employees may like to work alone. Added to this, increasing personal needs of the modern world cause them to work individually and derive all the benefits an organization can bestow, individually.

Management's Role in Enabling Teamwork

It is the responsibility of the management to foster teamwork amongst employees. It requires clear definition of the following:

- Responsibility
- Authority
- Wherewithal for accomplishing the task
- Criteria of measurement of the work output.

Unless these are defined clearly and implemented, the teams cannot function effectively. The authority should commensurate with the responsibility and the wherewithal should match with the requirements to be fulfilled by the team.

It is the responsibility of the management to impress upon the employees to practice teamwork. Even when management forces employees to work as a team, some may drift apart since they feel that they are either much smarter than the rest or they are highly talented. Hence, like other TQM practices the management can only enable teamwork. The management by emphasizing teamwork and showing a real concern for teamwork can help the organization to practice teamwork. Some employees may try to impress upon the top management that the teams do not work at all and only one or two of them can carry out all the tasks in the organization. This is an oversimplified statement and as such should not be taken seriously by the top management. The top management should try to develop every individual to contribute to the organization and at the same time more talented individuals should be encouraged for achieving innovations and inventions.

All the employees will not be alike. They will not be having the same potential, or same level of intelligence, but by working as a team, if the strengths of all the employees can be pooled together, it will benefit the organization. The management should not work on the weakness of the employees. It should rather exploit the strength of each employee. It may be found quite often that some individuals in a team are responsible for sabotaging the teamwork. Such individuals, even if they are bright, should be tamed to practice teamwork. Management should not be seen in any way contributing to the break up of teams. Management should believe that the teamwork is only beneficial to the organization and not the divide and conquer philosophy. Divide and conquer may give temporary benefits or may appear to give benefits, but, certainly it is detrimental to the organization. The top management should also not force teamwork, rather they can encourage and persuade employees to practice teamwork. The management should gradually institute teamwork for success.

Teamwork Results in a Win-Win Situation

With proper training, the employees could be motivated to work as a team. Employees should be informed about the advantages of achieving a win-win situation. They should also be informed about the disadvantages of win-lose situation in which one member wins and the other loses. The win-lose situation occurs when people in a team have different views and decide that rather than trying to reach an agreement, they argue with a determination to get their way at all costs. The win-win situation demands that each employee respects the views of the other employees and regards the self-esteem of all the colleagues in the team. The employees may criticize the process, but not criticize the persons. The employee should realize that only by working together they can achieve more than what each person can do.

To summarize, the team can have the following benefits if they work for a win-win situation:

- achieve dramatic results ,which individuals can't
- make best use of skills of each member of the team
- make right decisions
- get more enjoyment and job satisfaction.

The problems of win-lose are summarized below:

- wastes time
- creates conflict
- stops people listening
- spoils happiness and health of team members.

Can the Japanese Success be Repeated?

There is a lot of discussions in management circles, as to why only the Japanese can practice teamwork and not the other management of the world. Experts believe that teamwork is possible in Japan, as there is no diversity among employees. This may be one of the reasons for the success of the Japanese teams, but the major deterrent for the teamwork elsewhere is the organizational culture, for which only the top management can be blamed. The top management should always encourage teamwork and discourage individualism in organizations. By working as a team, the bright individual will be able to contribute much more and probably will scale new heights easily with the help of his team members, however insignificant the contributions of others may be.

Do Rewards Disrupt Teamwork?

It is believed by some that rewards and awards break teamwork. However, this it is not quite true. On the contrary, rewards encourage people to practice teamwork. Awards should be given to motivate the team of people, who have contributed in a greater measure. It is to be noted that awards should be given to teams rather then individuals whenever possible. It is true that in a team, contributions of all the members may not be equal. One individual would have led the innovation and others would have contributed in varying degrees. The whole team should be appreciated and rewarded. Therefore, while giving awards or recognitions, the top management has to foster teamwork. In other words, the output of team should be given more importance than the output of the individuals. This should not curtail the innovation of individuals. The individual should be made to understand that by working in a team, he could do much better and get more awards. The top management should make it clear that they want the entire team to contribute although they know who are the star performers.

EFFECTIVE COMMUNICATIONS

Communication is a Three Way Process

Imagine for a while that all people in the world are dumb and deaf. Nothing worthwhile would have ever happened in such a world except eating, drinking and other natural biological functions. What makes the difference between the ancient human race and the modern human being, is the art of communications. Therefore, the communications should be proper, appropriate and pleasant.

In every organization, communication is a three way process for each employee, as given below:

(i) To one, employee is working for—supervisors/managers

(ii) To the persons working for him—subordinates/junior employees

(iii) To the persons one works with, the peers, counterparts, customers and suppliers (both internal and external)

Thus, communication is a three way process and every employee should communicate effectively in all the three roles.

Necessity for Communicating Upwards

Upward communication means communicating with seniors. The senior executives would have assigned specific tasks to their junior employees. In their busy schedule, they may or may not be able to check the progress in the task assigned. It is the duty of the junior employee to inform the senior at periodic intervals about the progress of the special task in hand. They may get stuck in the process and may not be able to progress further due to genuine problems. It is important at that stage to inform this to the senior and take his advise. There is nothing wrong about it. The senior will not mistake such communications as an unnecessary query posed by the employee. When the employee comes across an obstacle and is not able to cross it inspite of his best efforts, even with the help of peers, he should inform the senior at the earliest possible opportunity. The senior can quickly find a way out for the problem. The senior may not be able to explain the solution in great detail, again since he has no time. The junior should listen carefully; stop the senior when he does not understand. Later the junior should try out the idea given by the senior in all seriousness and report back to him. The employees should also inform the seniors when the job has been completed successfully.

Communication with Juniors

Every employee should communicate with juniors. The junior employee will not have the same education, experience or expertise as that of the senior. Therefore, the senior has to communicate with the junior patiently and in detail. The juniors may require repetition of the message at times. It is the responsibility of the seniors to align their juniors with the vision statement, mission statement and quality policy. Such alignment will come only out of hard work on the part of the senior and his allocating enough time for this purpose. The senior should not get agitated when the junior takes time to understand or implement. The communication is not restricted to shop floor work, but is also about the behaviour and mannerism of the employees. Sometimes it should be aimed at developing the personality of the juniors. Communication should emphasize teamwork, quality in all activities, total quality management and latest developments in the field of work. The senior should coach the employee to improve the skills day by day.

Communication with Peers

Communicating with peers is equally important. This has assumed significance since the organizations have to establish customer-supplier relationships to practice TQM. Adequate communications is essential between customers and suppliers. The suppliers should be told about the requirements. Similarly, the suppliers should give information to the customer about the product or service delivered, its strengths and (if unavoidable) weaknesses. The concepts discussed about external customer–supplier relationships apply equally to internal customers and suppliers. The relationship should be right. The customer has to bring out the defects in clear terms. It could be in a polite manner, but without losing the point. Instead of waiting for written communications, the suppliers can visit the customer to find out, initially the requirements and later whether the supplied item meets the requirements. Similarly, the customer can disturb the suppliers as many times as needed to clarify his doubts on the item. The employees should work for a win-win situation with peers, customers and suppliers.

Management should Devise Ways for Effective Communications

Communications is a never-ending process. The management should be a catalyst for effective communications across the organization. Monthly Board Meetings and Quality Council Meetings are the forums for communications. They should be used to share the views about quality and related information. There should be departmental and interdepartmental meetings, problem solving sessions which contribute to effective communications.

In addition, the organizations could bring out periodic newsletters, bulletin boards, etc. for enhancing communications. They could issue circulars periodically to popularize new ideas or share success and concerns.

TRAINING AND MENTORING

Necessity for Orientation Training

The employees in their formal education learn many techniques covering wide range of topics, from basic principles to advanced topics. They learn a little bit of everything. It is the responsibility of the educational institutions to develop the overall personality of the students, so that he or she gets a broad understanding of wide variety of subjects. Therefore, employee needs to be given orientation training to carry out his tasks correctly, on the first appointment, before they are deployed for actual work. The orientation training should help the employees to understand the following, in particular:

(i) Objectives of the organization
(ii) Requirements and expectations from his team with reference to the organization's objectives
(iii) His role
(iv) His responsibilities
(v) His authority
(vi) The know-how and know-why of the jobs to be undertaken on day-to-day basis
(vii) Familiarity and skill in operating the tools or machinery connected with the job in hand.

In addition, the employee should be assessed to see whether he has the abilities to perform the duties straightaway or is he required to be put as an apprentice under a mentor.

Experienced Recruits Need More Orientation

A fresh employee can be easily moulded as per the organization's goals and objectives since they are fresh and have no biases due to prior experience. But, an experienced person will definitely bring with him different ideas and work culture from the organizations where he served earlier. If the ideas are better than the organization's objectives and work culture, then he can become a role model in the new organization. If not? Then the experienced recruits need an orientation training. The only time the organization can orient such persons as per organization's goals, is before he settles down in the new job. Therefore, it is important that the top management invariably arranges for the orientation training both for the experienced as well as the new recruits.

Training is not a One-Time Activity

Almost all the Quality Gurus, like Philip Crosby, Edwards Deming, and Harrington have highlighted that training is not a one-time activity. In the service sector, obsolescence settles in fast. Therefore, there is a continual change in the business. This means, that the employees have to acquire the skills needed for designing, manufacturing, delivering and servicing the updated or new products or services. Some employees may be able to understand the changes quickly and adapt themselves accordingly. However, an average employee may not be able its do so. Therefore, such employees need to be given additional help, to cope up with the change. This is one of the reasons, why training is not a one-time activity.

Before the advent of ISO 9000, training of employees was not considered to be an essential part of the business, even the training activity was never taken seriously. Many employees did not undergo even one training program throughout their services spanning decades. However, thanks to the popularity of the ISO 9000 family of standards, the organizations were forced to realize that not only training of employees is essential, but, also the maintenance of records pertaining to training. They are now convinced that training employees is an essential part of the business. Therefore, organizations are on the lookout for providing training to their employees. Practicing TQM requires more training than that needed for practicing the Quality Systems meeting the ISO 9000 requirements. As already discussed, TQM is possible if the focus of the organization is on customers and employees. Every employee should be trained every year. The organization cannot decide across the board, common or similar training program for all the employees. The supervisor has to study the employee's ability and arrange for training programs to supplement their skills. In some cases, with additional training, employees can learn new skills that would be useful to the organization. Hence, the supervisor should personally involve himself in the identification of training programs for the employee and should not leave it to the Human Resource Development (HRD) division.

There is a reluctance on the part of management to send employees for training, due to some of the following reasons:

1. Excessive workload in the organization, which does not permit sending them for training.
2. Non-availability of appropriate training courses.
3. Fear of migration of employees after training.

The problems could be genuine. Nevertheless, these are to be overcome since training is an inescapable part of the main business. For instance in Japan, on an average an employee receives six weeks of training each year.

Training is a Formal Activity

Training should be a formal activity in every organization. Senior level executives in whatever designation they are addressed, should coordinate it. A bigger organization may need a separate department. At the beginning of every year, the HRD manager should evaluate the training needs of the employees across the organization in consultation with their supervisors and make an annual training plan for the organization. Then, he should identify the training providers for each of the training and get the training conducted inspite of various other commitment of the employees and the organization. Each training program should be evaluated for its effectiveness. The result of evaluation should be analyzed and put up to the Quality Council of the organization.

Mentoring

The training programs discussed so far are formal in nature. The employees are freed from normal work and are deputed for undergoing training. Such formal training, apart from normal work, once in a year is necessary, but not sufficient. The employees have to be continuously coached on the job to understand the organization's policies, objectives and goals. This is called mentoring. Therefore, the organization should not feel complacent about the fact that the training has been given once and be happy that the goal is accomplished. Training is only the beginning and only personal coaching or mentoring can sustain the momentum of the employees in working towards the goal. The training and mentoring of employees are the prerequisites of TQM.

PDCA for Training

Though training contributes to the prosperity of an organization, it also costs money. Therefore, PDCA should be used for training of employees in every organization.

Plan for Training Every employee needs training. Therefore, the training needs of every employee should be identified at regular intervals. Their training needs and the methodology should be planned and documented. It could be on the job training, training in an open course, in-house course, etc. What is important is that the training plan for each employee is available at the beginning of every year.

Provide Training Employees should be deputed for training as planned. If training could not take place as planned, alternate plan should be made at the earliest.

Measure Training Effectiveness After the employee undergoes training, the effectiveness of training should be assessed formally. The assessment finding should be recorded.

Improve Training Effectiveness Based on the above, both preventive and corrective actions should be taken for improving the effectiveness of the training programs.

RECOGNITION AND REWARD

Recognition of Achievement is Important

In a TQM environment, it is important to recognize achievement of employees, customers and suppliers. Every employee or supplier is to meet the requirements to satisfy his customers. However, there would be a few teams, and few suppliers, which will excel in their contributions. Meeting customer requirements is not enough for recognition. Exceeding customer requirements or satisfying customers, whether internal or external, can be considered to be an achievement. Such achievements, if they are recognized and appreciated, should enable the achievers to perform with more interest, enthusiasm and by putting in more efforts. If achievement is not recognized then they may drop from the normal level of performance. Recognition has to aim at transforming each employee as a performer and an achiever, as this is an important step towards achieving the goals and objectives of the organization. If the recognition is genuine and without any bias, such awards will not demotivate other employees in the organization. On the contrary, it should rather motivate others to improve their performance and quality for an award.

Select a Few Best Performers

It is quite important that awards are given to the real achievers but it should not be a routine affair. The selection of the awardees should be given due consideration, so that the few that have performed a top-notch job are awarded. Awards should cut across the entire organization and not be restricted to any particular discipline, or any particular department alone. The awardees should also be accepted by others. That is the litmus test for the award.

The attributes for selection of best performing employees in ETDC, Chennai are given below:

- commitment
- creativity
- flexibility
- adaptability
- determination
- responsibility

Reward Teams, Rather than Individuals

There is no harm in awarding an individual for his meritorious service. But it may cause hurdles in practicing teamwork in some cases. Hence, the organization should as far as possible, reward the teams. The organization should give emphasis on recognizing the teams as against the individuals, so that there is a good harmony in the organization.

If the performance is to be recognized, the organization should not try to measure the contribution of each member of the team. Even when the contribution by one member is very small, he should also be included in the award, if the team deserves an award.

Type of Awards

The organization should select the award appropriately. It could be appreciation in an annual meeting, certificates, mementos, and cash awards. No matter what is the type of award, the employees will definitely be motivated. However, the organization should be consistent in giving the awards. Whoever or whichever team exceeds that performance threshold, could be awarded the same type of award. The organization should not keep on changing the type of award.

Enable Happiness All Around

The recognition and award program should help the organization to enable happiness amongst all the employees. It should not lead to bitterness amongst employees and should not demotivate them. Hence, before venturing into the recognition program, the management has to give considerable thought and then only finalize the strategy for recognition and awards. It should not scare the management from venturing into the recognition scheme. It has been proved beyond doubt that recognition of the worthiest definitely leads not only to higher productivity and quality of the individual or team awarded, but also the entire organization. Since many good schemes fail due to problems in implementation and since recognition is a touchy issue, the management has to be very careful, transparent and bold to implement recognition and awards scheme. Recognition and awards is certainly a part of TQM. Without recognitions and reward, the organization will become stale. The employees should strive to achieve without looking for awards. The management should be looking forward to achievements made and give awards on its own. For TQM to happen, recognition and award is one of the major inputs.

FEEDBACK AND PERFORMANCE APPRAISAL

Feedback Essential Both for Employees and Management

It is more humane to be curious to know about the result of an action. Actions are taken not only by management, but also by junior employees in organizations. Therefore, both the management and the employees should look forward to getting a feedback on the action taken, the employees from the management and vice versa, in the interest of improving quality continuously. Such feedback should be analyzed by the concerned individuals, which would be a good input for the next decision to be taken. Feedback should not be undermined. The natural human nature of giving feedback should be encouraged. Unless feedback is given, the person concerned may not be very sure about the effect of his actions. Feedback is thus important for practicing Total Quality Management (TQM) in organizations, both for the employees and the management.

Management should Seek Feedback

It is the responsibility of the management to seek feedback. The management should therefore adopt suitable strategies to get the right feedback from the employees as well as customers. The management should adopt the Management By Walking Around (MBWA) concept advocated by Tom Peters to get the right feedback. Of course, MBWA should be practiced in the right manner for getting the desired results. Therefore, during MBWA the management should talk to employees and get feedback both from their verbal communication as well as their body language. The MBWA is one of the effective means of getting direct feedback on the actions taken. The management should not carry a notepad for noting down the feedback, for it will not enable free flow of communications from the employees. The discussions during MBWA should be informal and should put the employee at ease so that the employee will give true feedback fearlessly.

The management has many forums for getting feedback in their organization on quality matters. One of them is through the Quality Council where the management should encourage the members to talk freely. Only open talking will bring the true feedback. It should also be noted that higher the level of management, more difficult it becomes to get the correct information. This has to be kept in view, while receiving feedback from the employees.

Another important source for feedback is the monthly summary on quality submitted by the management representative. Such summaries should be analyzed thoroughly by the management. They should also peruse the analysis reports as well as the recommendations of the improvement teams set up for TQM implementation. The top management will get a large number of papers, reports, minutes, etc. and won't get the time to read all of them thoroughly. The management should select appropriate ones for perusal. Priority should be given for perusal of information, which provides feedback. The responsibility for giving feedback and getting feedback lies solely with the management like other management functions.

Feedback to the Employees

Every employee in the organization should receive a feedback on the quality of his output. Quality does not only mean the conformance of the product or service to the requirements, but also the timeliness, behavioural requirements and all attributes of TQM. It is important that every employee in the organization is given feedback. If it is not done, the employee will not realize the true quality of his output. The employees who are doing well as well as those who are not up to the mark, are to be given feedback. The feedback to an employee who has done well will definitely motivate him to do still better. Similarly, the feedback to an employee who is not doing well will give him a chance to analyze and correct himself quickly. Therefore, feedback should become one of the routine features of supervisors at all levels. Some of the features which would enable success in feedback for TQM, are described in the following paragraphs:

Giving Appropriate Feedback

When a feedback is given, it should be the most appropriate. The feedback should never be exaggerated or under played; it should be a correct feedback.

The persons giving feedback are at different levels in the hierarchy, IQ, education, knowledge and experience. Therefore, it is important that the person giving feedback uses a language easily understandable by the receiver. The person giving feedback should realize that unless the feedback is understandable by the employee concerned, it is not going to result in any improvement in the quality of his output. Therefore, the supervisor should change his style, reduce the level of technical jargons to that of the employee in front of him and then communicate in a simple and understandable manner.

The task of the management is to find out the right performance level of the employees and then give the feedback. The employee may be good in one aspect and may be wrong in all others. It should be clearly stated where he is good and where he has to improve. To make a lasting impression it is better to first appreciate the good actions before saying where the employee is weak. Therefore, it is very important that right feedback is given.

Timely Feedback

Feedback should never be accumulated forever. The feedback, as and when required, should be given at the appropriate time. The feedback session could be short and brief so that it will be taken seriously.

Watch Effect of Feedback

Each feedback session is a corrective action of the system, to use the terminology of ISO 9001. Therefore, the effect of feedback has to be monitored, studied and analyzed. If the feedback is given in an appropriate manner and if it is right then definitely the employee will be motivated to correct himself. As a result of feedback if the employee is not improving the performance, then the management has to find out the reasons, so as to give again the feedback of the employee's behaviour, workmanship, etc. Employees should be continuously monitored after the feedback is given to see that the employee improves and the feedback is useful to the organization. We have been discussing about feedback given to an erring employee. The effect of feedback on a good employee should also be studied and appropriate action taken.

Continuous Feedback

Like continuous improvement, feedback should also be given continuously. Some employees who are doing extremely well also need feedback. The feedback will be never ending for any of the supervisory persons, since the system will try to drift away from the set goals often and the management will be required to correct the system through the feedback mechanism. In a large organization, one employee may improve but another may deteriorate. It is the responsibility of the management therefore to look for feedback and give feedback. Thus, feedback is a continuous mechanism.

PERFORMANCE APPRAISAL

Performance appraisal is to be used for the development of employees. Deming does not advocate periodic performance appraisal. However, Philip Crosby speaks that by and large they serve the purpose. One has to adopt the PDSA technique even for the performance appraisal of employees. Usually in the beginning of the year, the supervisor discusses with the employee concerned and they jointly arrive at an action plan for the whole year with specific milestones for each quarter. At the end of every quarter, the supervisor and the employee discuss together about the achievements with regard to the plan. This meeting may result in revising the plan for the subsequent quarters. The performance against various tasks is to be assessed. Some may adopt a scale of one to five to indicate the quality of performance of the task. Some may use terms starting from unsatisfactory to excellent. A suitable performance evaluation form has to be designed by each organization. The quarterly review need not be kept confidential from the employees. In 90 per cent of the cases, this may not pose any problem. However, there may be cases, where the employee may be agitated that he has been treated unfairly. Such disputes are to be resolved tactfully. However, the supervisor should also be trained on evaluating the performance in an objective manner. The performance of each employee should be reviewed on a quarterly basis and the reports submitted to the management. Such reports should be used by the management, for various purposes as:

- Promotion
- Granting of additional increments
- Training the employees
- Reallocation of duties, etc.

The performance appraisal is a formal activity carried out by the supervisor for each employee. Innovative techniques can be used for motivating the employees, based on performance appraisal. It must be ensured that the performance appraisal in no way demotivates the employees. The most important requirement for carrying out performance appraisal is giving awards and continuing it successfully.

Empowerment

What is empowerment? Empowerment and ownership are synonymous. Empowerment of employees is one of the latest management techniques deployed to result in continuous improvement in the organizations. Empowerment means involvement of all the employees for improvement of processes on continual basis. Empowerment is just the opposite of strict hierarchical "do what I say" approach in the organizations. It is a new concept, which matches well with TQM. To understand the right implications of empowerment, the definition of empowerment, formulated by Xerox Corporate Management Institute[1] is reproduced below:

> *Empowerment is "an organizational state, where people are aligned with business direction and understand their performance boundaries, thus enabling them to take responsibility and ownership while seeking improvements, identifying the best course of action and initiating steps to satisfy customer requirements".*

Empowerment means transfer of responsibility of satisfying customers to employees. It means that the employees own the process of satisfying the customers. They conduct themselves as if they are the owners of the process who know that they cannot get profit if the customers, both internal and external, are not satisfied. The initiative for improvements have to be taken by employees themselves and they should not wait for the management to initiate. For this purpose, they have to identify the best course of action.

Such delegation of authority to employees cuts across the organization. The empowered teams should conduct themselves in a responsible manner, i.e. they should know their performance boundaries; or in other words, employees have to conduct themselves within delegated authority and responsibility. They have to align with the management's philosophy, approach to customer satisfaction and organization's mission. They cannot have their own way of doing things since management has to achieve cohesion in the organization and will have more information about the business than even the smartest employee and hence well equipped to formulate the policies and overall directions.

Empowerment is not without bounds Empowerment of employees is not without bounds or limitations. It should be structured and planned to achieve the corporate goals in the TQM way. The employees are aligned with the business direction as brought out in the vision and mission statements of the CEO. They have to be made to understand their performance boundaries and expected performance / results. It is the process of enabling employees to take responsibilities themselves to carry on the tasks of the organization in line with the vision, mission and objectives of the organization. The crux of the whole matter is that the employees own their processes, which means the employees themselves improve the quality of their processes, while the management is watching and ready to help them in difficult situations. Therefore empowering means the employee does what he is authorized to do and takes management approval before major changes.

Empower teams, not individuals A team of employees will be empowered not the individuals. Even when an individual is empowered, it is done so in his capacity as the coordinator of the team. It is not personal to the individual. The team has to achieve the objectives set forth by the management. The team has to identify the best course of action in every context. The team has to take decisions on its own within it's own boundaries. It also has to carry out mid-course corrections wherever required. The teams should function in a democratic manner to achieve success. The management support should be banked upon for any crisis. Normally, the team members themselves try to solve their problems within the organizational framework. The management although will not directly participate in the day-to-day activities, it should watch what is happening. The management should have a mechanism for obtaining feedback of the results of the processes. It is not the detachment of the teams from the management, but it is the process of equipping the teams with the wherewithal and motivating and encouraging them to carry out the assigned tasks, as per the requirements. In this manner, the teams have to manage themselves and hence such teams are also called 'self-managing teams'.

Training Needed before Empowerment

One of the fundamental requirements before embarking on forming self-managing teams, is training of all the employees in the team till they are perfect. They should learn to change. They should be able to manage change. Each member of the team should learn the good qualities of the other members of the team and establish a sound relationship with them. All the members should agree to sail together in discharging their duties in the best interests of the organization. They should cooperate with each other in improving their processes. They should be trained so that they can develop themselves as a self-managing team, pulling the organization forward with perfect harmony.

The employees should be trained in understanding corporate goals and their role in achieving them. Each employee should be encouraged to direct his efforts towards achieving the goals of the organization. For instance, a transporter could be educated in transporting items carefully, safely and tactfully. He should be educated in identifying fragile items and handling them. His mission should be that he delivers at the right place, at the earliest with due security and safety, first time and every time. He should be trained till he develops the skill to carry out the job independently and correctly. The employees should be helped to develop self-awareness and decision making ability. To improve decision-making ability they could be provided with checklist indicating, for instance, what the transporter should do if the addressee is not available. He could be provided with a road map and telephone numbers of the addressee. These small things will go a long way in practicing TQM. The checklist should match the skills of the employees. As time goes, when the employees come across different situations, which are not listed, they can be added in the checklist after approval of the team coordinator. In this manner, the decision-making ability of the employees should be enhanced systematically. The training should result in the employees fitting well into the system. Their ideology, as far as work is concerned, should match the organization's stated goals.

Before empowering, management has to train the employees, ask them to carry on and check whether they are going in the right direction and if so, empower them. This checking is also a continuous process. The evaluation of every employee of the team is essential before empowering. The employees should be encouraged to participate willingly in the improvement process. They should be encouraged to bring forth genuine problems fearlessly.

Steps Involved in Empowering

The following steps are involved in the operation of self-managed teams:
- Agree on what they will produce or carry out.
- Decide how to organize the team.
- Decide on the responsibility within the team.
- Decide on flow of work.
- Audit the process.
- Decide on improvements and restart.

Self-managed process teams can be organized in any type of business. It may consist of staff of any grade. It does not mean that only a particular level of people can be constituted as a team, allowed to be self-managed. It again does not mean that they can do what they want. They have to work within the boundaries set by the management. The most important contributor to make empowerment successful is the teamwork of the employees. If the employees cannot practice teamwork, empowerment cannot be implemented. The culture of "passing the buck" will be detrimental to empowerment. Hence, employees should come forward for sharing the responsibilities.

Fundamental Requirements of Management for Successful Empowerment

Empowerment does not mean that the management has no responsibility. In fact the management has more responsibilities. They have to continuously assess the skills required for carrying out the ever-changing complexity of the jobs of the teams. They should be willing to help when the team members are unable to solve the problems themselves. The responsibilities of the management is to control the processes and not the people. It has been estimated that the average productivity increase due to empowerment could be about 30 per cent. It is also reported that the average cost of process gets reduced by 40 per cent due to empowerment. Even if the philosophy of empowerment does not appeal to the management, the above statistics pertaining to improvement of quality and productivity should be able to attract management to venture into empowering employees. Empowerment also demands cultural change in the organizations. The employees should be encouraged to own the responsibility for their actions. In summary, the top management should take the following actions to practice empowerment.

1. Accept that teamwork is more beneficial than hierarchical management
2. Invest time and money on the team building and training before empowerment
3. Formulate a clear-cut, unambiguous vision and mission statement and the system for quality
4. Be prepared to spend more time at the initial stages and later on to listen to the problems of the team members
5. Prepare to wait patiently for the success of the empowered teams
6. Prepare to equip the teams with facts and trust them
7. Provide support and tools wherever required for problem solving
8. Reward worthy teams
9. Provide communications infrastructure and Information Technology infrastructure for the teams to carry on the tasks, without difficulty.

Responsibilities of the Team Members

The team members should realize that the management may withdraw the delegated authority, if the teams do not show results. There will always be individuals who would not be willing to work as part of the team. Such problems should be handled tactfully. The team members should agree upon a collective decision-making process so that every employee in the team is involved in the decision making process. The most important is the faith of each team member in teamwork and empowerment.

Empowerment and Flat Organization

Empowerment and ownership should provide a viable solution for establishing flat organization. In flat organizations, more than 20 persons may report to a person. This will be impossible to visualize, but for the empowerment of self-managed teams. A supervisor cannot manage 20 persons in the conventional system of management. Therefore, empowerment is a prerequisite for flat organization. Quality cannot be achieved in a flat organization without empowerment. However, time can only say whether flat organizations and empowerment are there to stay, or will management revert back to the old hierarchical pyramidal structure of organizations.

Barriers to Success

Like other TQM concepts, empowerment is also not easily implementable. It requires the strongest management commitment to overcome the hurdles to success. Some of the hurdles and how to overcome them are discussed below:

Difficulty of Supervisor and Team Members in New Roles Empowerment calls for a change in the management style, which was hitherto not practiced. Till then, the supervisor decided and the others were simply following the orders. Organizations were following "boss is right" syndrome all along. This will no longer hold good in the empowered scenario. Empowerment calls for a totally different approach. Team coordinator is only first among equals. Generally, the former supervisors are designed as team coordinator in the empowered organization. Therefore, the supervisor has to change his approach to get the work done. He has to treat the employees as colleagues rather than subordinates. Similarly, the employees who were under tight supervision will not be able to realize the correct implication of the new relationship quickly and may not assume responsibility. Some over enthusiastic team members may be demanding and start disrupting teamwork since there is no strict supervision. Added to this, they have to learn to raise their level to self-managed team member. All these will lead to resistance due to fear of managing change, both from the supervisor and the other employees. The top management will be able to remove this barrier with a lot of coaching and abundant motivation.

Supervisor Resistance It may be rather easier to convince the team members or junior employees about the new approach. They have to be further trained in carrying out the jobs more independently which is an achievable task. If they have any problem with the new setup, they should express it fearlessly. Therefore, the management will know the apprehensions and clear the same. But, the supervisors won't come out openly with their problems of the new setup. They may not tell the problem to the top management. They may tell juniors that it is not going to work and even scare them. This is a psychological problem which arises out of insecurity of the seniors. They have been comfortable in their previous role of keeping themselves busy in managing the work of others. The new role will need them to learn new techniques or new area of work and their doing work on their own. The management has to understand this kind of psychological barrier of the supervisors and try to solve them. They could convince them that empowerment is in the interest of the organization and the supervisor will be able to adapt very soon with dedicated efforts.

Misalignment Another problem in the empowerment process is misalignment of team members. Such misalignment will not help in achieving teamwork. If empowered teams cannot practice teamwork, it will affect the productivity and quality of the organization. The management may feel on seeing such results that it may be due to the failure of empowerment in the organization. This will be a wrong conclusion. It is only due to the failure of teamwork. Therefore, the empowered teams have to be formed thoughtfully. The management can keep on experimenting till it is able to achieve proper alignment. This is essential because the matching of human beings cannot be estimated correctly at the first attempt. The management should also try to remove irritants in the team so that the teams can perform well.

CASE STUDY
Employee Involvement in Federal Express, USA

Federal Express is the world's largest transportation company founded in 1973 in USA[2]. Federal Express handles 3.3 million packages, employs over 200,000 people. They have the largest cargo airlines and serve more than 200 countries in the world. Their turnover is more than US $ 9 billion. They won the prestigious Malcolm Baldrige National Quality Award in the year 1990—the first service organization to do so. They were also certified under ISO 9000 in the year 1994. They recognized that the customer satisfaction begins with employee satisfaction and so people management is a critical element in their TQM strategy.

They believe that, "if you treat people fairly, train them, give them a fair pay and benefits package, communicate with them openly and act consistently with all the employees, then they will commit to your company's service goals and objectives. This in turn will guarantee profits for the company. This can then be ploughed back into the company to strengthen the business base and to improve employee conditions and the working environment"[2]. In support of their stated "people first" philosophy, the company's organizational structure is itself flat and non-hierarchical. They have an inverted pyramid structure with only five levels of management between their senior vice presidents and front-line employees. It is the job of management at every level to support the people they manage rather than the traditional approach which maintains that employees are there to support their manager!

Employee involvement is encouraged They set up Quality Action teams to solve some of the problems that the Service Quality Indicator information give them. Quality Action team techniques are taught in the employee training sessions and are put into practice regularly. One of the defining features of a Quality Action team is that it is cross-functional and non-hierarchical.

Employee Involvement – Leadership One of the key elements in a successful TQM program is leadership. Most people agree that TQM cannot succeed without good leadership. FedEx has its own "Leadership Institute", which all their managers must go through in their first six months as a FedEx manager, with subsequent follow-up courses.

Employee Involvement – Global Quality Month Every October they refocus on some aspects of quality, worldwide. They have a worldwide theme and different regions develop their own activities to involve everyone. The management team encourages staff to feel responsible for all aspects of the operation by treating each individual as an equal, in return, the staff do an excellent job and this increases their revenue.

Reward and Recognition Three times per year, all regions round the world are invited to submit their best Quality Success Stories. Selected papers are presented in the HQs. The CEO attends the presentation.

Measurement of Employee Satisfaction Because employee motivation, employee morale and employee satisfaction are so crucial, FedEx has a unique program which actually measures these things on an on-going basis. In FedEx it's a way of life and an important management and leadership tool, which has a very practical application and use.

SUMMARY

Employee motivation is a subject, which is difficult to understand. However, a brief introduction to the same has been given. The behaviour of the employees in an organization typically follows three patterns —the top-notch, who are self-actualized, the middle one who are fence sitters, and the bottom most, who do not want to get motivated. The fence sitters join any one of the other groups depending upon the way in which the organization is managed.

Theories X, Y and Z characterize the individual human behaviour. The X theory assumes that the human beings by their very nature are unwilling to work. The Y theory assumes the contrary. Maslow's theory rejects the X theory. He brings out five levels of human needs. Each human being looks for the next level need, when the lower level need is satisfied. The self-actualized level is the top-most one and the physiological needs are the lowest. At higher states, the behaviour of the employee is similar to the Y theory. Hertzberg gives the minimum requirements for an employee for not being dissatisfied, which he calls hygiene theory. For real motivation, he suggests additional factors such as achievement, recognition, etc. Since an organization is a collection of large number of people and each individual will have different characteristics, it is the responsibility of the leader to identify the person's current level of motivation and make efforts to bring up his motivation level. At the minimum, the management should ensure that each employee is facilitated to contribute as much as he can.

Teamwork is beneficial both to the individual employees as well as the organization. However, working in teams is not a natural human function. Therefore, the management should make it happen through various strategies such as training, forming homogeneous teams, taming team breaks, rewarding teams rather than individuals, etc. Teams can achieve what individual cannot. Teamwork facilitates win-win situation. Win-lose creates conflicts and hassles and affects the organization. Therefore, TQM should lead to practicing teamwork and then empowered teams. If management is committed to teamwork it will certainly happen.

Appropriate communications is vital in the organization for long-term success. Communication is a three way process for every employee. He has to communicate with superiors, subordinates and peers. Peers include both internal and external customers and suppliers. Communications in all three directions should be appropriate and pleasant. Management should devise appropriate communications within the organization as well as outside through innovative methods. Effective communications is the goal of TQM organization.

Training of employees provides the highest return on investment. Every employee recruited should undergo orientation training, before his or her actual deployment on the job. Orientation is required even for experienced recruits. The employees also can be attached to the mentors to provide on the job training. Training is a formal activity and should be coordinated by HRD function in the organization. The HRD function shall identify the training needs of every employee in the organization in the beginning of every year and make efforts to train them as per schedule. Each training program should also be evaluated for its effectiveness. Training is not a one-time activity but has to be periodically reinforced. In view of the importance of training for success of the organization, as well as the costs involved, training programs should be organized using PDCA cycle.

Recognition of achievement is an important management function. The best performers—employees, customers, and suppliers — should be recognized and rewarded. If the recognition is genuine and without any bias, such rewards will not demotivate others. The management should select few deserving performers. While doing so, it is better to reward teams rather than the individuals. The awards could range from appreciation in annual meeting, certificate, mementos or even cash awards. The award should lead to happiness in the whole organization.

Feedback is quite important for developing employees. Management should also seek feedback on improvement actions taken. The feedback should be appropriate and timely. The management should watch the effect of feedback.

The topic of empowerment is given at the end of this chapter consciously. This is to indicate that the activities explained before this topic should be carried out before empowering employees. It is essential to empower the deserving teams rather than individuals. Empowerment is transferring ownership to the employees. The empowerment process should define the responsibility of the empowered teams clearly and unambiguously. The management should also wait for sometime to see the success of empowerment. For empowerment to be successful, both the employer and the employee have to contribute. The supervisor's resistance for empowerment should be handled appropriately. Misaligned teams cannot be successful. Therefore, management should form teams after studying the attitudes of the employees. Empowerment is a modern management concept, which leads to flat organizations.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. According to Theory X, people
   (a) Are lazy
   (b) Hate to work
   (c) Don't take responsibility
   (d) All the above
2. According to Theory Y, employees
   (a) Want to learn
   (b) Want to do difficult and challenging work
   (c) Develop self-discipline
   (d) All the above
3. The motivational needs according to Hygiene theory are
   (a) Salary
   (b) Security
   (c) Status
   (d) None of the above
4. The needs and various states of employees according to Maslow are
   (a) Physiological
   (b) Esteem
   (c) Self-actualization
   (d) All the above
5. Win-lose relationship
   (a) Generates more output
   (b) Wastes time
   (c) Fosters good relationship between colleagues
   (d) None of the above
6. Win-win happens
   (a) When each employee respects the view of other employees
   (b) Employees criticize the process not the person
   (c) When teamwork is practiced
   (d) All the above
7. Every employee should communicate with
   (a) Peers
   (b) Subordinates
   (c) Seniors
   (d) All the above

8. Proper communications is facilitated by
   (a) Discussions during tea time (b) Newsletters
   (c) Union meetings (d) None of the above
9. Orientation training should address
   (a) Objectives of the organization (b) Skills needed for the job in question
   (c) Specialized trainings on the job (d) All the above
10. Training program should be
    (a) Formal activity (b) Evaluated at the end
    (c) Must for every one (d) All the above
11. Recognition is conveyed through
    (a) Appreciation letters (b) Cash awards
    (c) Oral appreciation in annual meetings (d) All the above
12. Rewards
    (a) Are detrimental to the organization (b) Disrupt teamwork
    (c) Should not be given to teams (d) None of the above
13. Feedback to employees
    (a) Demotivates them (b) Improve their performance
    (c) Can be given by peers (d) None of the above
14. Empowerment is an organizational state where employees
    (a) Are aligned with organizational goal (b) Take responsibility for improvement
    (c) Function as empowered teams (d) All the above
15. Empowerment may fail due to
    (a) Supervisor resistance (b) Lack of training
    (c) Lack of management sponsorship (d) All the above

II. True or False

1. In an organization, 80% of the employees are top-notch
2. If Theory X were true, lot of inventions would have taken place
3. The Theory Y assumes that people are lazy
4. The lowest level in the Theory Z is safety needs
5. Hertzberg's motivators include recognition and achievements
6. The motivational level of employees depends on their circumstances
7. Organization has a bigger role to play in the motivation of employees
8. Teams are formed to carry out the work, which individuals can't
9. Teamwork is a natural human function
10. Management does not have a role in enabling teamwork
11. Teamwork does not forbid innovations
12. Teamwork results in win-lose situation
13. Teams can make better decisions than individuals
14. Win-lose creates conflict between employees
15. Teamwork cannot be practiced outside Japan
16. Communications is a two-way process
17. Communication is always with the juniors
18. Quality Council meeting is aimed at improving communications

19. Newsletters do not contribute to communications.
20. Communication is an art.
21. Less communication is better
22. Oral communications should be avoided
23. Orientation training is not necessary for experienced recruits
24. Orientation training can be given after a year of service
25. Training is a one time activity
26. Senior Managers do not require training
27. Mentoring is training on the job
28. Mentors have to be trained
29. Award should be given to every employee in the organization
30. Best performers can be given even cash award
31. Awards will disrupt the teams
32. Awards will cause bitterness on its employees
33. Award is detrimental to TQM.
34. Performance appraisal affects enthusiasm of employees
35. Feedback is important to management
36. Feedback is not important to employees
37. Feedback should be timely
38. Feedback should be periodic
39. The supervisor himself carries out performance appraisal.
40. There is no role for management in empowered organizations
41. Empower individuals
42. Empowerment is without bounds
43. Productivity decreases when empowered
44. Empowered teams are democratic
45. Flat organization needs empowerment
46. Hierarchy is more in empowered organizations
47. Empowerment does not work in manufacturing

III. Explain briefly/Write Short Notes on

1. (a) Maslow's theory
   (b) Hertzberg's theory
   (c) Group behaviour.
2. What are the motivational techniques for employees?
3. Importance of Teamwork
4. The role of management for teamwork
5. Ways to improve communications within an organization
6. Contents of a newsletter of an organization
7. Three way communications
8. Why communication is important for TQM?
9. Mentoring
10. Why management is not interested in training employees?
11. Why training is a formal activity?

12. Why training is important?
13. Rewards and recognition for motivating employees.
14. Describe some attributes of best performing employee
15. What are the effects of rewards?
16. What are the requirements to make rewards successful?
17. Why Feedback to employees is essential?
18. What is the purpose of performance appraisal?
19. How should it be carried out?
20. Why should management look for feedback?
21. What are the features of good feedback mechanism?
22. Differentiate between feedback and performance appraisal.
23. What are the fundamental requirements for success of empowerment?
24. Why empowerment fails?
25. Describe the steps involved in empowerment
26. How does flat organizations function?
27. What are the responsibilities of empowered teams?
28. Why supervisors resist empowerment?

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Chapter 7

Process Approach

There will be no output without input

INTRODUCTION

Problems occur in the organizations, not because of the employees, but because of the failure of management to foresee the importance of a system in the organization. Some recognized it, but did not spend time to establish or did not implement it correctly. A system can be established correctly only if the organization realizes the activities from receiving materials till delivery to customer as a set of processes. Every organization should therefore be a well-knit collection of processes so as to practice TQM and be competitive and successful. This concept is also advocated by the ISO 9001:2000 standard. The Japanese perfected a number of process models and derived maximum benefits. In this chapter we will discuss some process models and approaches. The models are deceptively simple to understand, but require a lot of determination on the part of management to practice them. Process approach in the organization is essential to make continuous improvement, get ISO 9000 certification as well as practicing TQM. Above all it, is important to reduce costs and increase profits.

Product and Service Quality Depend on Processes

Traditionally, manufacturing and service organizations were measuring, confirming and analyzing quality with reference to the final product alone. They checked only the quality of the final products. In such cases, if there was no time for final inspection, the defective products slipped into the market. If a product did not pass the final test, the organization tried to repair the item or scrap it. The matter ended there and no further analysis was carried out thereafter. If most of the products passed the requirements, they concluded that there was nothing wrong with the process; otherwise they attributed the failure to a tough inspector or other unscientific causes. They didn't accept that they did not adequately control the process. They were so unscientific that they could not definitely say whether a product would pass or not based on how they performed or how the processes were controlled. They were not sure till the inspector cleared the item as meeting the requirements. Any amount of inspection of the product is not going to improve the quality of the product. The product orientation does not take into account the quality of the processes. This approach is not effective in quality assurance of the products. Hence, it was realized that product orientation is necessary but not sufficient. Hence process orientation should be adopted for Total Quality Management (TQM). Process orientation is the right strategy to be adopted for practicing quality as well as management of organizations so that the producer can be certain about the quality of the products or services even before the final inspection. An organization should be organized as a collection of processes. A process is nothing but a repeatable sequence of events.

Process Orientation Helps in Finding Defects Early

Quality should be built into the product or service right from the early stages. If a defect cannot be corrected early in the process, it cannot be removed at the final stages. Therefore, the defects are to be found early. In the product orientation, the defects are found only at the final stages, whereas in the process orientation, defects could be prevented totally by eliminating the cause of failure in the process. Therefore, every employee should be educated to understand the activity they are performing in terms of processes. Such an orientation should be inculcated in the organization by training and coaching of employees to visualize products as output of clearly distinguishable processes. The operators should be able to predict the quality of the end product by monitoring the process parameters at the time of manufacturing or service design. Such confidence, if developed further, will lead an organization to reduce dependence on inspection as advocated by Deming in his 14 points.

MODEL FOR PROCESS DEFINITION

The process model is quite simple. It contains three clearly distinguishable elements, as given below:

1. Input/s to the process
2. Output/s of the process
3. The process or task

The process orientation helps the organizations in identifying all the inputs, documenting them and having a control over the quality of the product (output) by having a control over all the inputs and the process parameters. Any product manufacturing or service preparation and delivery can be modeled in this manner. A little analysis of every process will bring out clearly all the three elements.

Input of the Process

The various inputs required for any process are:

(a) Bill of materials
(b) Specification for each material
(c) Requirements for inspection for the incoming materials
(d) Procedure for receipt of materials.

Output of the Process

The output of process consists of the following:

(a) The products or service to be delivered
(b) Documents to be delivered

(c) The specifications for all the above
(d) Method of measurements for verifying conformance to the specifications
(e) Criteria for acceptance / rejection.

Thus, both the input and the output of processes will need specifications for materials received and product delivered. They should also contain, details such as persons authorized to receive/deliver, quantity and quality, etc. Thus, the process orientation also helps in the identification and implementation of internal customer-supplier relationship. The process owner receives inputs from the suppliers and delivers the output to the customers.

Value Addition in the Process

Every organization attains profit only through value addition to its processes. Therefore, the primary goal of the organization is value addition. It, in turn, applies to every process in the organization. Each process should help in value addition at the lowest cost, without any defects or hassles. In fact, the organization should not have any process, which does not add value.

The process may need machinery, infrastructure or techniques for achieving the desired value addition as per the goals and objectives of the process. Again the documented specifications for the machinery, infrastructure and the methodology should be available. The performance of the machinery as per the specifications should be checked periodically. This will help in achieving continuous improvement of quality of the process as well as value addition. The process owners and the other employees attached to the process for carrying out the assigned tasks should be clearly identified and documented, along with their authority and responsibility. They should also be trained adequately, so that they are able to handle the processes without constant supervision. They should also be given guidelines for handling emergencies. They should also be educated and trained in monitoring the process parameters and carrying out preventive maintenance themselves or at least in identifying when the process is out of order, or likely to be.

ETX MODEL

The most popular process model is ETX as shown in Fig. 7.1:

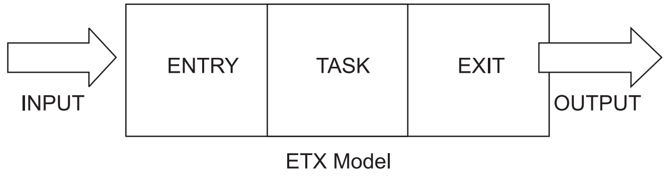


Figure 7.1

ETX stands for Entry, Task and Exit. The value adding process is called Task. The new items in the diagram are Entry and Exit

Entry –Conditions to be satisfied before the task is undertaken

Exit–Conditions to be fulfilled before the task is considered as completed.

Thus, it is a refined model than the one discussed in the previous section. The entire organization should be depicted as an unbroken chain of processes expressed in the ETX form.

Training for Process Orientation

The most important requirement for transforming the employees from product orientation to process orientation is training and coaching. Even the lowest paid employee in the organization should be encouraged to look at his activities as a process, own it, and align his process with the overall process of the organization. Employees should also be given an overview of the entire process with flowchart of the processes in the organization. This will help them to easily place their process in the organization-wide process and assuming their role in ensuring quality in the organization. They should also be helped to identify their customers and suppliers and coached as how to conduct themselves in the roles of customers as well as suppliers.

Measure Process

Before giving a go ahead for normal production, the process parameters should be studied, statistical analysis made and only then the process should be authorized for normal deployment. This should be repeated at regular intervals. This will improve the confidence of the process owners as well as that of their customers and suppliers. Results of such process studies should be displayed on the notice board and should be circulated amongst the members of the staff. Control of the process is very important and the process owner should take the responsibility for the same. It means that the process owner will continuously monitor the process himself without any external initiative and decide whether the process is under control or not. If the process is not under control, the process should be immediately stopped and analyzed and corrective action should be taken, before resuming. Monitoring the process parameters will be a continuing exercise even after it stabilizes and it can never be stopped because any process can go bad at any time in spite of maximum care and periodic preventive maintenance.

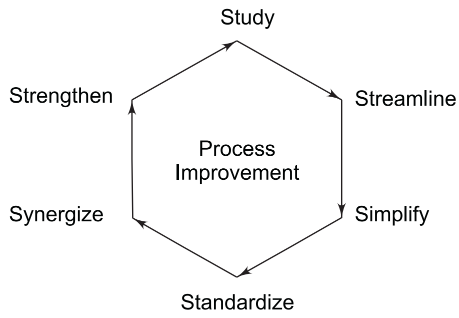
Improve Process Continuously

In line with the TQM philosophy, the processes should be improved continuously. Efforts should be put in for continuous process improvement. This will help manufacturing or service organization to achieve much higher yields.

If they achieve a yield of say 50 per cent at the beginning, the other 50 per cent is going to be wasted. The employees should put in more efforts to curb the waste and achieve yields closer to 100 per cent. By doing so they will be saving a lot of resources. Hence, it is very much essential to improve the process continuously. If there is a constant vigil of processes, achieving 100 per cent yield all the time is certainly possible. Therefore, the goal of each process is to ensure 100 per cent yield at the earliest and maintain it continuously.

SUBBURAJ'S 6S MODEL FOR PROCESS IMPROVEMENT

Since 1991, the author has been heading ETDC, Chennai which is a testing and calibration service provider, offering services to more than 700 organizations in a year. The Centre has 50 employees. The author declared the year 1993 as a TQM Year for the organization. As part of TQM journey, the author developed and practiced 6S model for process improvement, as indicated in Fig. 7.2:



Subburaj's 6S for Process Improvement

Figure 7.2

The important tasks during each one of the six phases of process improvement as outlined in the diagram are described briefly:

Study

The current performance level of the processes triggers improvement. It could be the defects found (both internal and external), cycle time achieved, customer feedback/complaint, employee feedback, customer waiting time, hassles of the employees or customers, etc. Therefore, it is important to study the process and document the details as necessary. The current performance level has to be measured and documented.

Streamline

Streamlining means that the process should offer the least resistance to motion in the organization. Quite often, some processes cause delay or hassles leading to problems either to the customer or to the employees. Therefore, it is important to first document the current sequence of events and then eliminate unnecessary or non-value adding processes. For instance, before embarking on TQM, the CEO of the organization was formally issuing the test and calibration reports under his signature. Due to his busy schedules, the issue of reports was getting delayed. Therefore, by including appropriate quality checks, this non-value adding activity was dispensed with by delegating the responsibility to middle managers. However, the CEO looks at the samples of the reports issued to make sure that the system works.

Simplify

Once the essential processes are identified, they are to be simplified. One should always question whether the current procedure is efficient? Are there no better methods? There has to be a constant quest for simplifying the processes. Therefore, one has to formulate a simplified procedure for carrying out the task without increasing the cost and compromising on quality. In the author's experience, simplifying processes improves quality. Initially an activity might be carried out in a cumbersome manner. Once the employee understands the process more and more, it will be certainly possible to simplify the same. For instance, the organization was making three copies of the test reports – one for the customer, one for use as a duplicate if the report was not received by the customer for any reasons and the third as a record. By analysis and by making appropriate arrangements, it was reduced to preparing one copy for issue to customer and the same was stored in electronic media for record purposes. This step reduced the work, saved paper and above all simplified the work.

Standardize

Standardization essentially permits performing the process in the same way by every employee at all times. Therefore, it requires a documented procedure. During this phase, the documented procedures of the new approach have to be formulated and issued formally under the umbrella of the quality system.

Synergize

No process is a stand-alone activity in any organization. A process may interact with at least two other processes – customer and supplier processes. Therefore, it is important that the effect of revision on other processes is checked. During this phase a perfect synergy is worked out between this process and other processes interacting with it. This may call for modifications in the other processes also. It may lead to fine tuning of the modified process, in some cases.

Strengthen

During this phase, a number of activities are carried out:

- Educating and convincing the process owners, their customers and suppliers
- Periodic counseling and assuring that the new process will perform better than the old process
- Monitoring the results and confirming that the process transition has occurred, the employees are confident and that the process is practiced as documented.

Each of the phases is to be implemented in a sequence. Need may arise to revisit a phase already crossed in some cases.

This logical methodology was applied for many processes in the organization successfully. It can be applied in every organization, both manufacturing and services.

CASE STUDY
6S of Process Improvement

Electronics Test & Development Centre (ETDC), Chennai was calibrating a number of instruments of various makes and models. The improvement project undertaken to reduce the cycle time is given in the following paragraphs:

STUDY

The existing process of calibration was studied. One of the fundamental requirements for calibration is to estimate the tolerance/error claimed by the manufacturer of the instrument before calibrating the item. Calibration is carried out to confirm whether the instrument is functioning within the tolerance claimed. The tolerance claimed varies from instrument to instrument. Furthermore, tolerance is expressed in a complex manner in many digital instruments. Therefore, every time an instrument arrives for calibration,

- Profit growth
- CSI
- New customers
- Customer attritions

Employee satisfaction

- Employee productivity
- Employee absenteeism

PERFORMANCE MEASURE DESIGN

The performance measure should be designed to answer the following questions:

1. What is the measure?
2. What is the objective of the measure?
3. What is the expected output of the measure?
4. What is the required input?
5. How the measure is arrived at?
6. Who is the owner of the measure?
7. What is the information required for data collection?
   When?
   How?
   Where?
   From whom?
8. Reporting information-report to be given
   To whom?
   Where?
   How?
   When?
9. What records are to be maintained?

Define Measures This is a very detailed activity. Each measure should be clearly defined. The following should be defined for each measure.

- Who will measure?
- What will be measured?
- How it will be measured?
- Training required for measuring
- Data format and organization of results
- Quality checks on data
- Data analysis

Integrating with Process

The success lies in integrating the measures with the existing processes. Every employee should be given responsibility to measure in addition to executing the process. Thus, the measures should become internal part of the processes.

Use of 7 QC Tools for Performance Measurement and Analysis

The seven QC tools discussed in the next chapter should be used for presentation of process measures. The process flow chart can be used for selecting and defining measures, cause and effect diagram can be used for carrying out brainstorming to

(1) Select measures
(2) To discuss cause of poor performance as revealed by the measures.

The Pareto Diagram can be used to identify a few vital causes, which contribute either to success or failure. Capability studies should be carried out for all critical process and control charts will be useful for this purpose. Data collection can be carried out using Tally sheets.

Objectives of Performance Measurements

The following are some of the objectives of measuring performance:

- Assess performance against goals. If there are gaps, take action to improve.
- Achieving the goals to:
  - (i) Meet the competition
  - (ii) Enhance customer satisfaction
- Communicate goals
- Improve process by stimulating improvement and innovation
  - (i) Identifying opportunities for improvement
  - (ii) Motivating employees
  - (iii) Locating problem areas
- Feedback
  - (i) Enabling comparison with world's best practices
  - (ii) Recording achievements and fixing new goals
  - (iii) Giving a feedback about improvements needed
  - (iv) Transferring responsibility for improvement to employees

Tasks Involved in Measuring Performance

Establishing commitment The performance measures should have the backing of the middle and senior management. Therefore, the idea should be sold to them to get their commitment.

Setting strategic objectives The strategic objectives should be set taking into account the following:

- Vision, mission statements and objectives of the organization
- Benchmarking findings
- Undertaking survey about competitor's capabilities
- Undertaking survey about customer requirements
- Defining critical success factors
- Defining strategy to improve performance

Defining measures

- Defining measures for each key business process area

Ownership

- Defining the boundaries of the processes assigned to the owner for the measurement

Checklist for Performing Measures

The performance measurements should fulfill some of the criteria given below:

1. Performance measurements should be consistent.
2. The measure should lead to getting a balanced view leading to financial performance, customer satisfaction, internal quality, efficiency, productivity improvement.
3. They should be relevant to the activity.
4. They should be simple to understand.
5. It should be easy to collect data and arrive at conclusions.
6. They should be implementable by lowest level employees in the organization.
7. They should be measure with appropriate scale such as per cent defects, or per cent deviation, etc.
8. They sould be based on strategic objectives and making general goals more specific.
9. They should be a reflection of short and long-term objectives.
10. They should be oriented towards objectives of business process.
11. They should only be a few and vital.
12. They should be useful for stimulating improvement.
13. They should be dynamic, i.e. the measures should reflect the dynamic nature of the business.
14. They can be integrated into a management process and reward management systems.
15. They should be agreed to by employees and not imposed by management.
16. They should be fit for public display at prominent places in the organization.

Measures to be Avoided

Followings are the kind of measures that are best avoided.

- Expensive
- Difficult to implement
- Trivial or viewed as trivial
- Conflicting with other measures
- Producing misleading information
- Short-term in nature

We will now look at an effective tool for performance measures and management, namely the Balanced Scorecard.

BALANCED SCORECARD (BSC)

According to Stephen Covey[1], "People and their managers are working so hard to be sure things are done right, that they hardly have time to decide if they are doing the right things". For doing right things, an organization needs the right business strategies. Right strategies will result in continuously improving operations to deliver the products and services right the first time and every time. However, in many organizations, there is a gap between strategic planning and execution of strategies. That is the reason, why they fail to achieve their vision. According to 1998 Fortune Magazine article, an estimated 70 per cent failures of initiatives of senior executives are not caused by a poor strategy, rather by poor execution of the strategy. Many organizations look at the bottom line of balance sheets to determine success. No doubt, good financial results are the success of the strategies in the past. They are lagging indicators or delayed snapshots to know whether they were successful in the past. Therefore, an organization needs leading indicators for ensuring success in the future. The leading indicators provide an early indication of whether an organization will achieve its business goals or will it be able to sustain these achievements in the future. That should be the right business strategy.

History of the Balanced Scorecard

Robert S. Kaplan and David P. Norton published an article in the Harvard Business Review Jan-Feb. 1992, called "The Balanced Scorecard - Measures that Drive Performance"[2]. The article stressed the importance of not relying solely on financial measures to measure organizational success. It stressed the need for balance between short-term and long-term objectives, between financial and non-financial measures and between internal and external performance measures. Balance is necessary for efficient and effective movement of the organization and reaching the fullest potential. The performance measurement systems must achieve a balance, which supports progress of the organization vis-à-vis its objectives. This is essential because the financial results are enabled by a number of factors as follows:

- Customer satisfaction
- Supplier satisfaction
- Employee satisfaction
- Efficient processes
- Modern technology
- Good organizational culture

Balanced Scorecard Perspectives

Balanced Scorecard (BSC) is a conceptual framework for translating the organization's vision into a set of performance indicators distributed among four perspectives. The four perspectives are:

- Learning and Growth Perspective
- Business Process Perspective
- Customer Perspective
- Financial Perspective

Performance indicators are used to measure an organization's progress towards achieving its vision. An organization monitors both its current performance (financial, customer satisfaction and business process results) and its efforts to improve processes, motivate and educate employees and enhance information systems - its ability to learn and improve.

The balanced scorecard developed by Kaplan and Norton provides a strategic framework for identifying and linking the enablers with the desired results by defining the relationships between performance levels in four distinct perspectives. BSC can be applied both in commercial organizations as well as in the public sector.

Customer Perspective This perspective captures the ability of the organization to provide quality products and services, the effectiveness of their delivery systems and overall customer service and satisfaction. Customers include both internal as well as external. It must provide answer "To the question "To achieve our vision, how must we look our customers?"

Financial Perspective The financial perspective is different for public and private sector. Private sector's financial objective generally represents clear long-range targets for profits for the organizations. Success of public organizations should be measured by how effectively and efficiently they meet the needs of the target sector. Therefore, for the government, the financial perspective captures cost, efficiency, delivering maximum value to the customer, etc.

Internal Business Process Internal business processes are the mechanisms through which performance expectations are achieved. It should provide answer to "To satisfy our customers' value proposition as well as to satisfy our other stakeholders, what process must we excel at?" This perspective provides data regarding the internal business results against measures that lead to financial success and satisfied customers. To meet the organizational objectives and customer's expectations, organizations must identify the key business processes at which they must excel. Key processes are monitored to ensure that the outcomes are satisfactory.

For instance, a software organization must excel at the 18 key process areas (KPAs) of Software Capability Maturity Mode (SW-CMM) of Software Engineering Institute. Those organizations that excel at all KPAs are considered to be at level five. Level five software companies satisfy all stakeholders and achieve success in all the four perspectives. Thus, internal business process perspective is quite important.

Learning and Growth This perspective captures the ability of the employees, the quality of the information system and organizational alignment to manage the business and adaptability to change, in supporting accomplishment of organizational goals. Processes will be successful, only if adequately skilled and motivated employees are used and they are provided with accurate and timely information. In order to meet customer requirement and customer expectations, employees may be required to take on new responsibilities, which require skills, capabilities, technologies that were not available before. The employees should ask the question "If we are to succeed, what must we do to learn and improve?" To quote[2] Kaplan and Nortan, to satisfy this perspective of BSC, the organizations must ask "To achieve our vision, how will we sustain our ability to change and improve?".

Thus, Kaplan et. al. described the balanced scorecard as a framework for translating an organization's vision into a strategy by focusing on shareholders, customers, and internal and external processes and learning requirements, which collectively describe the strategy of an organization and how the strategy can be achieved.

Balanced Scorecard—a Management System

The balanced scorecard is a new approach to strategic management. The balanced scorecard is not only a measurement system, but also a management system. It enables organizations to clarify their vision and strategy and translate them into action. It provides feedback around both the internal business processes and external outcomes in order to continuously improve strategic performance results.

Kaplan and Norton describe the innovation of the balanced scorecard as follows:

> "The balanced scorecard retains traditional financial measures. But financial measures tell the story of past events, an adequate story for industrial age companies for which investments in long-term capabilities and customer relationships were not critical for success. These financial measures are inadequate, however, for guiding and evaluating the journey that information age companies, must make to create further value through investment in customers, suppliers, employees, processes, technology, and innovation".

There are software systems available for Supply Chain Management. Although the software is related to Enterprise Resources Planning (ERP), Supply Chain Management focuses on planning and ERP is focused on execution.

The performance of Supply Chain Management is to efficiently integrate suppliers, manufacturers, warehouses and retailers, so that the products are produced and distributed efficiently at optimal cost. Supply Chain Management plays an important role in satisfying the customers.

While the cost of production has been optimum in most cases, the cost of distribution is quite high. Industries should try to reduce the cost of distribution, so that the ultimate customer benefits. Supply Chain Management systems provide decision support for those decisions that must be made prior to execution of manufacturing. It performs the planning required to allow ERP systems to execute the plan. The primary function of an ERP system is to control the flow and execution of transactional information across the supply chain. Supply Chain Management Software Solutions are available from a number of organizations such as Manugistics, i2 and Logility and Demand Solutions.

ERP Solutions are available from SAP, PeopleSoft, Baan and many more.

For greater advantage, organizations must implement the closed-loop Supply Chain Management that interacts with its ERP system. Thus, success lies in integrating ERP with Supply Chain Management.

Benefits of SCM

Effective Supply Chain Management is the key to a competitive business advantage. The eight major benefits of effective Supply Chain Management can be summarized as follows:

(1) Improved customer service : having the right products, available for delivery when requested, at a good price.
(2) Reduction of costs across the supply chain and more efficient management of working capital.
(3) More efficient management of raw materials, WIP and finished good inventory.
(4) Increased efficiency in the transactions between supply chain partners.
(5) Better manufacturing resource management.
(6) Optimized manufacturing schedules.
(7) Optimal distribution of existing inventory across the supply chain.
(8) Enhanced customer value, often in the form of lower prices.

Just-In-Time (JIT) Manufacturing

The product should not be old and stocked one over the other, waiting for the orders. The products should be made order, just in time for immediate delivery to the customers. The materials, which go into the product or service, should also arrive on just time, before the manufacturing starts. Some feel that it is extremely difficult to do such a thing since it is difficult to foresee the demand. They also feel that the customer cannot wait for the actual manufacturing of the product, if it is made to order. However, Toyota in Japan has been practicing this concept successfully for many years. Therefore, it is definitely possible to practice Just-In-Time manufacturing.

Definition

Just-In-Time manufacturing is defined as "a philosophy that focused attention on eliminating waste by purchasing or manufacturing just enough of the right items Just-In-Time ". Zero inventories are a synonym to Just-In-Time. Just-In-Time philosophy is based on the following two principles:

- Production and supply of required number of parts when needed.
- JI DOKA (self-actualization), which means utilizing the full capacity of the workforce.

JIT is also known as Zero Inventories program. This means that no surplus inventory of materials, sub-assemblies or product exist at any time in the organization. This requires a perfect work culture with Zero defects and excellent suppliers, machinery and infrastructure.

Objectives of Just-In-Time

- Development of optimal process and be competitive
- Streamlining of operations and eliminating unwanted processes
- Continuous improvement
- Reducing the levels of wasted materials, time and effort
- Increasing efficiency of production process

Just-In-Time can be practiced by defining and implementing several concepts such as:

- Kaizen
- Team work
- Multi-function work-force
- Optimizing plant layout
- Eliminating wastages
- Reduced set up time
- Kanban
- Material Requirement Planning (MRP)
- Manufacturing Resources Planning (MRP II), etc.
- Involvement of people
- Plant optimization

Thus, Just-In-Time is also an umbrella concept like TQM, but it is a subset of TQM.

Benefits of Just-In-Time

- Reduction of wastes
- Reduction of Work-In-Progress (WIP)
- Establishing proper customer-supplier relationship
- Reduction in lead-time
- Less-inventory of raw materials
- Improvement in flexibility
- Lower cost and high productivity
- Enhanced customer satisfaction due to lower price owing to elimination of wastes
- Improved employee morale owing to a perfect system without waiting
- Improved satisfaction of shareholders due to high profit
- Reduced space requirements on account of total elimination of WIP and buffer stock of materials, sub-assemblies and products
- Improved productivity and improved quality

Not following JIT Increases Cost

JIT does not mean that the products are made when needed, but that no materials are stocked for years waiting to be used. In fact, the reason for JIT is to reduce inventory costs. If materials are stored for an year it means a great amount of money is blocked in materials. No company runs on charity or on huge subsidies. Therefore, the money invested on the materials adds to the interest burden every day. Therefore, stocking inventories for years means a lot of money is blocked and a high rate of interest has to be paid. This expenditure will be eliminated if JIT is practiced. There are many hidden problems of not following the JIT strategy. For instance, if the material received is an year old, precautions have to be taken for storing, handling, and security. Therefore, the company has to make additional space for storage. No material has a shelf life of many years. Therefore, during storage the material may deteriorate which will further add to the cost of manufacture of the products and the cost of the end product. The demand will naturally come down, if the end product is sold at a higher price. If the demand is low, profit cannot be earned. Therefore, the organization has to sell the products at a loss. All these problems are the result of not following JIT concept. JIT means that the materials arrive just in time, they are assembled and delivered just in time. It means, at no stage of designing or manufacturing, there is any hold up.

The organization should plan to get the materials just an hour before it is required in the company. Only through such tight rope walking, based upon planning, the company will be able to improve the overall productivity and quality.

Why Practice JIT?

The reason for practicing JIT above all is for more prosperity of the company and more profits for the company.

> Harrington gives an account of the effect of JIT. Joe Burger, manufacturing manager, Tektronix Inc., Portable Instrument Division, knows what JIT did for them. He said, "after one year inventories dropped 75 per cent, floor space was cut from 15,000 to 7000 square feet, work-in-progress was reduced 50 per cent, cycle time cut from 30-40 days to 12 days and customer delivery time cut from 14-15 weeks to 2 weeks"[1]. James Harrington also indicated that companies like IBM, Ford, General Motors, Chrysler, Hewlett-Packard, Motorola and Westinghouse are using JIT concept and hence it should be sound and practical.

Requirements of JIT

The most fundamental requirement for JIT manufacturing are all those that will lead to reduction of lead-time before starting a particular job. Some of them are:

- Practicing TQM
- Documented system
- Trustworthy suppliers who also practice TQM
- Efficient customer handling processes to know the demand just in time
- People are educated, trained and coached continuously
- Competitive people at all positions in the company
- Machinery, which are maintained periodically and updated continuously
- Proper operating environment for machinery and people
- Excellent system of support and infrastructure
- Proper layout of machinery and manufacturing
- Housekeeping, which reduces the confusion

- Identification of an item should be as fast as possible
- Employee should be sure about the quality of the material, and the process
- They should be able to know, when the machinery has to be taken out of service for maintenance
- They should be thorough with routine and preventive maintenance schedules of the machinery
- They should be thorough with the process
- They should be familiar with process parameters and how to inspect the materials, sub-assemblies and in-process measurements.
- The employee should know the quality requirements of the product or service
- Support of good Information Technology infrastructure.
- Reordering of materials should be automatic when the inventory level goes down. The software should be built to automatically order parts, when the total quantity of products to be delivered is determined.
- The company needs to automate the delivery process

All these will help in reducing the bottlenecks in practicing JIT strategy. Above all, it requires the determination of the top management to practice JIT, in the interest of the organization.

LEAN MANUFACTURING

The International Motor Vehicle Program (IMVP) was created at MIT, USA to study the techniques used in automobile production around the world. IMVP researcher John Krafcik commented that the Toyota system was lean because of the following reason:

> half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in fewer defects, and produces a greater and ever growing variety of products."[2]

That is the advantage of lean manufacturing. Lean manufacturing enables JIT manufacturing. It is also an umbrella concept, which is being practiced in Japan. Many manufacturers outside Japan are also critically evaluating their processes to determine their effectiveness in bringing maximum value to customers, by cutting down unnecessary cost. Lean manufacturing addresses efficient management of factories. It is an application of more efficient methods that greatly minimize delays, reduce costs and improve quality. Thus, lean manufacturing is a whole systems approach that creates a culture in which everyone in the organization continuously improves processes and production. The major tenets of lean manufacturing are listed in Table 7.1.

Table 7.1 Major Tenets of Lean manufacturing

Quick Changeover/Setup Reduction	Pull/Kanban Systems	Workplace Organization 5S System
Value Stream Analysis	Total Productive Maintenance (TPM)	Cellular Manufacturing

The support strategies of concepts are given in Table 7.2

Table 7.2 Supporting strategies and Concepts

One Piece Flow	Visual Controls TAKT Time	Team Building Balanced Flow
Quality at the source	Employee Involvement	Stabilized Operations
Standardized	Continuous Improvement	Equipment Replacement

Thus, lean manufacturing comprises many good concepts, all of them are principles/strategies of Total Quality Management (TQM) and some of them are concepts of Six Sigma.

We will briefly look at the following tenets and concepts of lean manufacturing, in this section.

- Kanban Systems
- Cellular Manufacturing
- One Piece Flow

Some other strategies are discussed in the other parts of the book.

Kanban Systems

What is Kanban?

The Kanban system was developed by Mr Taiichi Ohno, Vice President of Toyota, to achieve objectives that included:

- Reducing costs by eliminating waste/scrap
- Try to create work sites that can respond to changes quickly
- Facilitate the methods of achieving and assuring quality control
- Design work sites according to human dignity, mutual trust and support and allowing workers to reach their maximum potential.

It was originally developed by Toyota in the 1950s as a way of managing material flow on the assembly line. Over the past three decades, the Kanban process, is recognized as a 'highly efficient and effective factory production system', and has developed into an optimum-manufacturing environment leading to global competitiveness.

Kanban stands for Kan-card, Ban-signal. The Japanese refer to Kanban as a parts-movement system that depends on cards and boxes/containers to take parts from one workstation to another on a production line. The essence of the Kanban concept is that a supplier or the warehouse should only deliver components to the production line as and when they are needed, so that there is no storage in the production area.

A Kanban is a card containing all the information required for the jobs to be carried out on a product at each stage along its path to completion and which parts are needed at subsequent processes. These cards are used to control work-in-progress (WIP), production and inventory flow. A Kanban system allows a company to use Just-In-Time (JIT) production and ordering systems, which allow them to minimize their inventories while still satisfying customer demands. It consists of a set of these cards, with one being allocated for each part being manufactured, that travel between preceding and subsequent processes.

There are two most common types of Kanbans used:

(i) Withdrawal Kanban
(ii) Production Kanban

Withdrawal Kanban The main function of a withdrawal Kanban is to pass the authorization for the movement of parts from one state to another. It gets the parts from the preceding process and moves them to the next process, remaining with the parts until the last part has been consumed by the next process. The withdrawal Kanban then travels back to the preceding process to get parts, thus creating a cycle.

A withdrawal Kanban usually carries the following information: part number, part name, lot size, routing process, name of the next process, location of the next process, name of the preceding process, location of the preceding process, container type, container capacity, and number of containers released. The withdrawal Kanban layout can be designed in many ways in order to display this information.

Production Kanban The main function of the production Kanban is to release an order to the preceding stage to build the lot size indicated on the card. The production Kanban card should have the following information:

- Materials required as inputs at the preceding stage
- Parts required as inputs at the preceding stage
- Information pertaining to withdrawal Kanban as given in the previous paragraph.

A Kanban system consists of a tandem network of workstations, distributed amongst production stages. Each production stage consists of one or more workstations and Kanbans. In order for a part to enter into production stage, it must first acquire a free Kanban (withdrawal Kanban). Once the part has entered the workstation, it receives a new production Kanban which remains attached to the part while until all work steps associated with the Kanban card have been completed.

Within this system, workstations located along production lines only produce/deliver desired components when they receive a card and an empty container, indicating that more parts will be needed in production. In case of line interruptions, each workstation will only produce enough components to fill the container and then stop. In addition, Kanban limits the amount of inventory in the process by acting as an authorization to produce more inventories. Since Kanban is a chain process in which orders flow from one process to another, the production and delivery of components are pulled to the production line, in contrast to the traditional forecast oriented method, where parts are pushed to the line. Most Japanese manufacturing companies view the making of a product as continuous from design, manufacture, sales and distribution as well as customer service. For many Japanese companies, the heart of this process is the Kanban, which directly or indirectly drives much of the manufacturing organization.

The Japanese Kanban process of production is sometimes incorrectly described as a simple JIT management technique, a concept, which attempts to maintain minimum inventory. It is a process which involves more than fine tuning production and supplier scheduling systems, where inventories are minimized by supplying these when needed in production and Work-In-Progress is closely monitored. It also encourages industrial reengineering, such as a 'module and cellular production' system and Japanese human resources management, where team members are responsible for specific work elements and employees are encouraged to effectively participate in continuously improving Kanban processes within the Kaizen concept. In the manufacturing field, the Kanban process is the most significant contributor to the Japanese success in materials management.

The Kanban process utilizes two different kinds of cards—transport Kanban and production Kanban. Both of the cards are not have to be used simultaneously in a production process.

The transport Kanban contains information from where the part/component originated and its destination. When only this card is used, it is known as a simple Kanban process. In this system, components are ordered and produced according to a daily schedule. The production kanban on the other hand, outlines to what extent and when work has to be accomplished by a specific station on the production line. Together with the transport Kanban, it is known as an Integrated Kanban Process. This system is often used between the corporation and its suppliers. Here, the corporation's transport *Kanban* is the card, which regulates the supplier's production *Kanban*. The same amounts of components are produced as used in production and the maximum stock level is determined by the number of cards that are in circulation.

In the case of many manufacturing plants, the supplier is the warehouse and the customer is the assembly line. In this case, one box of components goes to the correct station at the assembly line at a time. When the box is empty, an operator takes it back to the warehouse and this automatically triggers the delivery of the next box of components. Since only the transport kanban is used, this example represents the application of the simple *Kanban* system.

Toyota of Japan has taken the example discussed above a step further. Here, certain components are directly supplied from suppliers to the production line. Stock levels are therefore kept low and factory overhead can be reduced.

Kanban Process Features

The principle aim of the *Kanban* process is maintaining smooth production without any wastage. To make this happen, the following rules are followed:

- Parts travel from one process to the next process
- Parts are received from the preceding process as per details in the *Kanban* such as the type and time when required
- Kanban must always be attached to the parts
- The parts should be produced according to the information on *Kanban*
- The quantity produced should match the requirement of the subsequent process
- No extra pieces are produced
- If no *Kanban* is attached to a product, no manufacturing should be made
- In case if defective items are produced, they should not be transferred to the subsequent process. This will assist in the elimination of defective parts on the line. This way the defective parts are stopped as and when it is found
- It should be ensured that the parts that are placed in the container should be defect free. The number of *Kanban* used in the production floor should be minimized. This will prevent buildup of inventory.
- The *Kanban* can be used to respond to changes in demand by increasing or decreasing the number of units to be produced. Thus kanban is quite useful when the demand fluctuates.

Advantages of Kanban Process

- A simple and understandable process
- Provides quick and precise information
- Low costs associated with the transfer of information
- Provides quick response to changes
- Avoids overproduction
- Minimizies waste
- Control can be maintained
- Delegates responsibility to line workers

A *Kanban* system is a system of inventory and production control (pull inventory system), which uses *Kanbans* as the principal information transmission device. A *Kanban* is a card or a tag usually attached to Work-In-Process parts and it is used to facilitate the proper movement of these parts. This movement may be within the same manufacturing plant or between plants. The advantage of *Kanban* is that it is used as a means for process improvement. The role played by *Kanban* in production control is to tie the different manufacturing processes together and to ensure that the necessary amount of materials and parts arrive at the appropriate time and place.

An express *Kanban* is used when a subsequent workstation or assembly line is in danger of having to stop due to shortage of one out of many items being used.

A cart *Kanban* is used for the withdrawal of large items, such as complete engines, where the cart would normally be used to transport the item. After using each engine, the subsequent workstation will send the empty cart to the preceding workstation. The preceding workstation will continue to assemble engines as long as there is at least one empty cart to load.

CELLULAR MANUFACTURING

A cell is configured normally for speed and minimal material handling and can reap substantial benefits in cost saving, time compression and inventory reduction. It is a group of workstations, machines or equipment arranged such that a product or sub-assembly can be processed progressively from one workstation to another without having to wait for a batch to be completed or requiring additional handling between operations. A cell may produce one type of component or a sub-assembly or a product. Single piece flow can be implemented in cells in a natural manner.

Cellular manufacturing and work cells are at the heart of lean manufacturing. Their benefits are many and varied. They increase productivity and quality. Cells simplify material flow, management and accounting systems.

A work cell is a work unit larger than an individual machine or workstation but smaller than the usual departments or assembly lines. Typically it employs 3-12 people and 5-15 workstations in a compact arrangement. Cellular configuration can be in the form of straight line or U-shape, but equipment contained within the cell, or workstations, are normally configured in close proximity to compress time and space. Material handling within a cell may be by a robot; conveyor or it can even be manual. When robotic applications or automated conveyance are used, a cell supervisory computer is required to control movement between the individual pieces of equipment and the automated conveyance. The cells can have a substantial impact on a company's productivity and throughput. Flexible cells can be very effective when applied in an environment of low volume and wide breadth of manufacturing. However, very careful analysis is essential since cells may be expensive. Cellular layout is different from functional layout of plants. In a functional layout of plants, the assembly moves from one place to another and back and so on, but in a cellular layout, the movement of assembly is minimized and even if it moves, it moves within short distances. At the core of cellular manufacturing is the elimination of waste by linking each step in the manufacturing process to the following step. In a cell, most workstations are close together so that little or no time is required to move pallets of parts from one workstation to the next. Reducing the time to flow material through the cell in a factory usually reduces the cost to make the product.

To assure that excess inventory is reduced between steps in the process, many firms create Kanban that limit in-process inventory.

Table 7.3 Gives improvements made when the assembly was completed from batch build to cell build.

Table 7.3 Improvement in efficiency cell build vs batch build
(Example from a fitness equipment manufacturer)

Resource	*Batch build*	*Cell build*	*Improvement*
Direct labour	11 hours	10 hours	9%
Floor space	12,000 sq. ft.	3000 sq.ft.	42%
Lead time	12 weeks	2 weeks	83%
Inventory	$ 564,000	$ 279,000	51%
Scrap and rework	$ 23,040	$ 12,030	48%

Ref: CIRAS News, Vol.31, No.4, Summer1997
www.ciras.iastate.edu/publications/CIRASNews/summer97/cellular.htm

Batch build is a component function based manufacturing, where the entire batch, say 10 or 100 pieces are produced in one station and passed on to the next station, which may be far off from the current workstation.

The advantages many companies derive from linking processes in cells include improved quality and reduced rework costs because the material produced in one operation is tested for fit in the next process. For example, if a hole is drilled undersize and the next step in the cell inserts a screw in the hole, it is quickly apparent what problem exists. Thus, the cell build takes one piece and complete all the jobs in the cell and passes on to the next cell.

Single Piece Flow

Cellular manufacturing demands single piece flow methodology. This is also called one-piece flow or continuous flow manufacturing. It is a technique used to manufacture components in a cellular environment. A cell is an area, where everything that is needed to process the part are within easy reach and no part is allowed to go to the next operation until the previous operation has been completed.

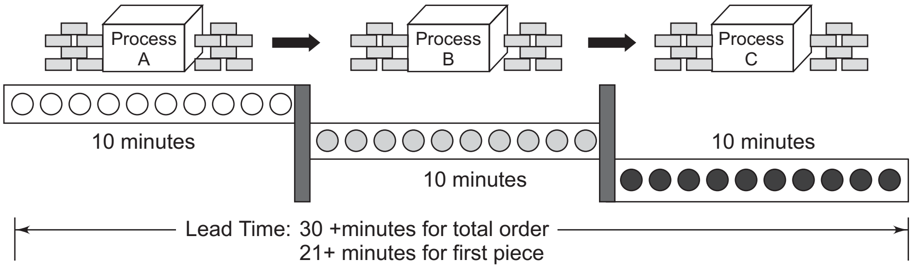
The goals of one piece however are : to make one part at a time correctly all the time without lengthy queue.

Flow Manufacturing vs. Batch Production

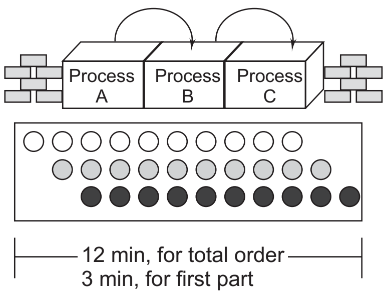
The opposite of one-piece flow is large-lot production. Although, many companies produce goods in large lots or batches, it builds delays into the process. No items can move on to the next process, until all the items in the lot have been processed. The larger the lot, the longer the items sit and wait between processes. Larger lot production can lower a company's profitability in several ways as given below:

- The lead time between customer orders and delivery of products is lengthened
- Labour, energy and space are required to store and transport the lot
- The chances for product damage and /or deterioration are increased

One-piece flow production can help in solving these problems. The following illustrations will make clear how the single piece flow is more advantageous.



A Batch and Queue Processing



B Continuous Flow Processing

Figure 7.3

The difference between Figure A and Figure B is explained below:

In both the batch and continuous flow processing it takes one minute for manufacturing one part and in the batch processing 10 parts are manufactured at a time. Therefore, it takes 10 minutes for processing the process in A, it takes 10 minutes in B and then it is sent to the process C. Thus, the first piece will come out in the 21^{st} minute and it takes 30 minutes of fabricating 10 pieces. It takes only 12 minutes for the total order, when we adopt one-piece flow as given in Figure B. A case study is given below to illustrate the concept of single piece flow:

CASE STUDY
Frontier Electronic Systems—Stillwater, OK

Original Date: 04/14/2003

Best Practice : Single Piece Flow in Printed Circuit Board Area

Frontier Electronic Systems has implemented the Single Piece Flow in Printed Circuit Board Area to develop a smooth continuous flow for circuit card assemblies and create a cleaner and brighter work area for employees. The result is a decrease in production cycle time, which directly relates to significant savings in direct labor costs.

Over the years, Frontier Electronic Systems (FES) had been continually upgrading its Printed Circuit Board (PCB) area. The addition of surface-mount equipment and an increased workload, however, resulted in a very complex and redundant flow of hardware through the assembly area. To address this issue, FES devised a set of objectives for the PCB area: develop a cleaner, brighter work area; develop a smooth continuous flow for circuit card assemblies (CCAs); reduce personnel /parts travel; increase available floor space; and reduce non-value added work. The result was the single piece flow in PCB Area.

FES first instituted a 5S program (sort, simplify, sweep, standardize, self-discipline) to obtain a cleaner, brighter work environment in the PCB area. Next, the company used a Value Stream Map (e.g. walk the process, map the flow and sequence of events) in conjunction with an Area Scan and a Spaghetti Diagram. These process activities helped the company identify extra personnel/parts travel to stations, available floor space, and areas of non-value added work. By reorganizing the work area and adding test equipment to the production line, the company achieved a continuous flow of work for the CCAs.

The single piece flow in PCB Area enabled FES to meet its objectives. This approach eliminated many hours of delay caused by processing CCAs in a batch environment. As a result, FES realized an 80 per cent decrease in production cycle time. Table 7.4 shows additional savings with regard to travel, floor space, and non-value added work.

Frontier Electronic Systems - Stillwater, OK:Single Piece Flow in Printed Circuit Board Area

Original Date: 04/14/2003 Revision Date: / /

Table 7.4 Single Piece Flow

	Was	*Is*	*Change*	*Goal*
People/Parts Travel (feet)	1690	430	–75%	– 60%
Increase in Floor Space (sq. ft.)	1559	2229	43%	30%
Non-Value Added Work (minutes)	433	30	–93%	– 50%

One piece flow is the concept of moving one work piece at a time between operations within a work cell. Thus the one piece flow concept can be introduced in a cellular manufacturing environment. At the opposite extreme, we process an entire batch or lot at each operation, before moving it to the next operation. When we use single piece flow, we get Work-In-Progress at the lowest possible level. It encourages work balance, better quality and host of internal improvements.

Ref: http://www.bmpcoe.org/bestpractices/internal/front/front_6.html

ZERO DEFECTS

Performance standard should be zero defect and not Acceptable Quality Level (AQL)

Philip Crosby's third absolute of quality management is:

"The performance standard must be zero defects, not that's close enough."[3]

Acceptable Quality Level (AQL) is a popular term amongst inspectors of manufactured products or materials. In simple terms, assume that the AQL is specified as 1 per cent. In this case then if a lot contains less than 1 per cent defects, the customer will accept the entire lot of items. If the defects are more than 1 per cent, then the entire lot will be rejected and returned to the supplier.

Crosby rightly criticizes this approach. If we adopt AQL, there is no motivation for the supplier to bring the defects down since anyway the customer is going to tolerate 1 per cent defects in the above instance. If the customer is tolerant of supplier's mistake, quality will never improve and continuous improvement is not possible. Philip Crosby is talking about achieving zero defects, real zero defects and not even parts per trillion defects. Therefore, the AQL concept is no longer valid and every product manufactured or service rendered should meet or exceed the requirements of the customer with no defects at all.

Is it Possible to Achieve Zero Defect?

Achieving zero defect is certainly possible. It was applied for the first time on missile production program for the US government. It basically requires managing the organization with clear vision, mission, quality management system, proper system for organizing work operations, perfect customer-supplier relationship – both external and internal – goods arriving just in time from the right vendors and above all a good harmony in the organization. Some of the factors, which will contribute to achieving zero defects in any organization, are discussed in the following paragraphs.

Determination Required

The most important requirement for achieving zero defects is the will power of all the employees in the organization to achieve zero defects. Unless there is a will, it is not possible to achieve even 3 per cent AQL consistently. Therefore, zero defect being difficult, every employee should be committed to achieving zero defects. If 100,000 pages are typed then there should not be an error even in one word. That is zero defects. If one secretary types all the 100,000 pages at one go, then definitely some errors could creep in. Therefore, it is important that the work is divided and properly organized and proper system for checking is in place. That is the reason for establishing customer-supplier relationship and every process is divided into a number of sub-processes, defining owner, supplier and customer and defining requirements for all the three. Even if the system is perfect, unless every person in the organization is determined and has the will, it will not be possible to achieve zero defects.

Right Mindset Required

For zero defect to happen education, training and coaching will not suffice, if the employees do not have or willing to develop the right mind-set for quality. Athreya confirms, "Quality is even more fundamentally dependent on values[4]. Quality therefore depends on the importance the employee attaches for practicing it". Athreya further elaborates on the requirements of various parts of the body for practicing quality. At the micro, individual level, behavioral science is recognizing that it is necessary not only to teach the head with knowledge and skills; and the heart with attitudinal motivation; but also the soul, with values, beliefs and commitments. Thus values, beliefs and commitment are required for zero defects to happen.

We may talk about TQM, ISO 9000 certification and so on, but it is only the employees in the organization who make quality happen in one organization. Therefore, it is important that the values of employees in an organization are aligned, so that the organization is able to produce consistently the products with zero defects at the lowest cost. It is important that the attitude for quality of each person should be right, to make quality happen. We all know that every human being at the outset wants to do a quality job, but allows quality to take a back seat, due to their own justifications. It may arise due to their impression about quality of the rest of the world, which includes other employees, the management, the organization and society at large. Such apprehensions should be eradicated from the minds of the employees. Therefore, it is important that a few guiding principles are followed to enable zero defect. Some of which are discussed below:

Do not Accept Work from Others Which is not up to the Standard

Employees may be tempted to accept work which is not up to the standards, from their colleagues due to reasons such as, time pressure, supervisor's pressure, team pressure, social pressure and lack of knowledge and confidence. Whatever may be the reason, the employee should not accept a work, which is defective, since there is no way to make it all right and to meet the requirements on time. In the interest of the organization, in the interest of the quality of the products or services, employee has to fearlessly say that the work or specifications or instruction received is defective, if it was really so. It does not mean that the employee has to be critical of everything. He has to compare or check or inspect the inputs he receives with reference to the standards of the company or accepted standards of the company. What is most important is the fearlessness to say that the input is not up to the mark. Therefore, after analysis, if an input is not up to the standard, employee should take up the matter with the supplier, whether internal or external supplier, and tell them that the input is not up to the standard. If he is not able to solve the problem himself, he should take the help of the superiors to convince the suppliers.

Do not Pass on the Work to Others Saying that will be Good Enough

This applies, when the employee's role is that of a supplier. Products are made as per supplier's requirement. The employees should have a written specification or known good samples to know the requirements clearly. Before even offering to supply, the employee should be sure that the product or service, which is going to be delivered, is up to the standard. Employees may be tempted to pass on defective work to others essentially due to time pressure. This should be avoided and they should never pass on anything, which is not up to the standard. If they do so, it will put a lot of pressure on them when found by superiors later on. The peers may feel that the employee is not competent, supervisor may feel that the person needs training or are not good enough for the job in hand. Even if the employee is demotivated due to various reasons, the employee should not pass on a defective material to his customer.

Do not Put Off Till Later

Putting off a job till later makes someone else wait for longer than they should have. Imagine, that you are made to wait for no reason or no fault of yours. Feel for yourself about your agonies in such a situation. This should be kept in mind when the employee puts a job off till later, making someone else wait longer than needed. They should take least time possible for doing their part of the job as per standards and pass it on to their customer at the appointed time. This is the best approach every employee should take for enabling TQM.

Do not Put the Blame on Others

When a problem occurs the general human tendency is to put the blame on someone else. However, the management will come to know, who is responsible for the problem, may be at a later date. If a problem has occurred and if immediately the concerned employee owns the same, then the harm will be less severe. When an error has occurred, it is better if the employee himself tries to solve the problem, by taking the help of other knowledgeable persons in the company.

Perfect System Required

Zero defect cannot be achieved by an adhoc system or system which is self-contradictory. Therefore, it is important that efforts are made to put in the right system in the organization and document the system. For instance, if the organizational structure or the quality systems are not documented, there is a likelihood of communication problems within the organization, between the employees. It will not facilitate achieving zero defects. The system should also be continuously improved, even if zero defects have been achieved.

Cultural Change Required

Every organization should aim to achieve the goal of zero defects. But, it cannot be achieved overnight. It requires meticulous planning by the senior management to achieve zero defects. It requires consistent efforts of the management and employees to achieve zero defects. The basic attitude of the organization should change from accepting defects to achieving zero defects. Each employee should be determined to ensure that no defect can pass from his or her end and they will not accept anything, which is defective. Only when all the employees know that it is good to change their culture as above, zero defects are possible to be achieved.

Never Ending Enthusiasm Required

Achieving zero defect will call for extra work at the beginning till the system stabilizes, thereafter, continuous efforts will be needed in maintaining the achievement. This requires enthusiasm among the employees. The employees have to be enthusiastic to put in additional work, so that zero defects are possible in the organization. The management should create enthusiasm by motivating the employees. Each employee should become a catalyst and motivate fellow employees by realizing that it is better to produce no defect than making defects and getting caught in the process. Thus, never ending enthusiasm and the energy of the employees are certainly required for making zero defects possible.

Training Required

If the organization wants to achieve zero defects, it should train its employees for achieving this level. It also includes mentoring by competent persons so that the employees get the right inputs.

Management Commitment Required

The most important factor for any quality improvement program, particularly the zero defects program is commitment by the management. Management commitment involves sparing adequate time for the effort of guiding the employees in achieving zero defects. It includes provision of required resources, i.e. the materials, manpower, machinery and the tools. It requires appropriate communications to the employees that zero defects is the goal of the company. Anyone violating this should be trained and coached endlessly till he or she is able to achieve zero defects. Zero defects cannot be achieved without management commitment. Therefore, the management should not feel happy when the quality is improving or is slightly better than the competitor. This could be due to wrong assessment or some errors in the process of assessment. Even if it is correct, this cannot withstand slightest problem somewhere in the line. The management should be happy only if the product or service is 100 per cent correct i.e. 100 per cent of the work output meets the customers requirements first time and every time. Therefore, at no stage there could be an error.

We are not talking about zero defects at the final stages alone, but we are talking about zero defects at all the stages right from the material receipt till the products or services are delivered. Therefore, the management has to be persistent for achieving the goal of zero defects in the organization.

SUMMARY

Process orientation as against product orientation should be preferred owing to its many advantages. It helps in finding the defects early. Process orientation helps in dividing the total work into manageable number of sub-processes with defined input as well as output with defined value addition in the process. ETX is a popular process model. This helps in easy identification of current status of the process and taking action for further improvement continuously. It also helps in eliminating redundant processes and it brings in clarity and transparency in the organization. However, process orientation will not come easily. It can come only through concerted efforts of the management to educate the employees. Effectiveness of every process should be measured through its various parameters. This will help in improving the processes continuously, which is a goal of TQM.

Subburaj's 6S is a model for modern process improvement in a logical manner. This can be applied for process improvement in every organization. During the study phase the process has to be characterized. During the streamline phase, non-value adding processes should be identified and eliminated. The remaining processes are simplified in the next phase. Simplified processes are then standardized. In an organization, no process is stand-alone. Therefore the improved process has to be synergized with other processes interacting with it. Finally, the revised processes are to be strengthened through educating and motivating the employees. The processes are measured periodically to accumulate the gains made and further motivate the employees.

This process has to be repeated at periodic intervals on the same process and every process in the organization.

Customer-Supplier-Chains need to be established in every organization for building quality into products and services. Traditionally, only external customer and suppliers were treated as such. TQM calls for an employee performing both the roles. He may have an internal or external customer as well as internal or external supplier. The process approach facilitates establishing customer supplier chains. The organization should be organized as a set of processes. Each process owner will have customer(s) and supplier(s). The employees need to be educated to conduct themselves in this manner. They have to treat even an internal customer and supplier as they would treat an external customer and the supplier. The customer supplier chains have many advantages. Primarily, it helps in controlling quality of the process and thereby final product quality. Above all, it helps the management to understand its own organization and operations better.

Supply chain management is all about optimizing all activities throughout the supply chain – series of links and shared processes that exist between the suppliers and customers – so that the products and services are supplied at the right time and at the optimal costs.

JIT concept has evolved by Toyota in Japan many years ago. It is also known as zero inventory program. JIT reduces expenditure of manufacturing, since it eliminates delay at all stages of production. Employee should always feel they should not wait as well as they should not make others wait. Practicing JIT is required in a TQM organization and the organization should facilitate practicing JIT. The organization should plan to get materials JIT, assemble it immediately and deliver it to customers thereafter. In this manner, a lot of money will be saved for the organization. But this calls for fulfilling a number of requirements. However, JIT is practiced by many Japanese companies and hence it is certainly possible to practice JIT.

Lean manufacturing is also an umbrella concept consisting of many good practices like Kaizen, Kanban, Cellular manufacturing, and one piece flow. Lean manufacturing enables JIT. TQM or continuous improvement is needed in JIT as well as lean manufacturing. There is definitely an overlap of these three strategies. However, TQM is the superset encompassing both lean manufacturing and JIT.

Philip Crosby's third absolute means that the performance standard should be zero defects and nothing close to it. The traditional approach of AQL causes loss to the customers. Therefore, one should try to achieve zero defects in every organization. Zero defects will occur only when there is a will to achieve the same in the organization, because it is a difficult task. Employees should also have the right mind-set for this to happen. They should determine not to accept or pass on the defective work or product to others. They should also not put off the work for later as well as do not put the blame on others for their fault. All this will happen, if there is a perfect system in the organization and a cultural change. Management commitment and never ending enthusiasm is required for making this to happen.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. Process definition consists of
   (a) Entry criteria (b) Exit criteria
   (c) Task (d) All the above
2. Defects can be found early in
   (a) Person orientation (b) Product orientation
   (c) Process orientation (d) None of the above
3. Product Quality depends an
   (a) Inspector (b) Inspection
   (c) Process (d) None of the above
4. Subburaj's 6S is meant for
   (a) Rewarding of employees (b) Computing quality costs
   (c) Improving processes (d) None of the above
5. Subburaj's 6S include
   (a) Streamline (b) Simplify
   (c) Standardize (d) All the above
6. Strengthening includes
   (a) Training employees (b) Motivating employees
   (c) Measuring process performance (d) All the above
7. An employee may have
   (a) Internal customer (b) Internal supplier
   (c) External supplier (d) All the above

8. Customer-Supplier-Chains
   (a) Reduce communication gap
   (b) Help in finalizing verification methodology
   (c) Facilitate immediate feedback
   (d) All the above
9. JIT requires
   (a) Materials arriving on time
   (b) No Work-In-Progress
   (c) The items made to order
   (d) All the above
10. Practicing JIT can save
    (a) Space
    (b) Inventories
    (c) Cycle-time
    (d) All the above
11. Performance standard should be
    (a) AQL
    (b) Something closer to zero defects
    (c) Zero defects
    (d) All the above
12. To make zero defect happen
    (a) Right mind-set of the employees are required
    (b) Management commitment required
    (c) Will-power required
    (d) None of the above
13. The tenets of lean manufacturing include
    (a) 5 S system
    (b) Cellular manufacturing
    (c) TPM
    (d) All the above
14. In Kanban process
    (a) Card is attached to parts
    (b) No extra piece produced
    (c) Helpful in case of fluctuations
    (d) All the above
15. Cellular manufacturing reduces
    (a) Lead time
    (b) Inventory
    (c) Scrap and rework
    (d) All the above

II. True or False

1. An organization is a collection of processes
2. Product orientation is healthy
3. Lean manufacturing increases WIP
4. Process adds value
5. ETX is not a process model
6. Process model helps in identifying internal customers and suppliers
7. Process is a repeatable sequence of events
8. Streamline eliminates unnecessary processes
9. Simplifying compromises quality
10. Subburaj's 6S does not include study of processes
11. Each process interacts at least with two other processes
12. Synergize with interacting processes
13. Standardization means formulating procedures for the process
14. Strengthen is demonstrating commitment of the organization in the new process
15. 6S is meant for process improvement
16. 6S can be applied for any business process

17. Customer has to be external
18. Supplier can be internal
19. The organization consists of well connected customer-supplier-chains
20. Training needed for employees for establishing customer supplier chains
21. Quality is controlled throughout the organization with customer supplier chains
22. More inspection adds value
23. Internal customer has to be treated in the same manner as the external customer
24. JIT goes well with TQM
25. JIT requires a lot of planning
26. JIT increases inventories
27. JIT needs skilled employees
28. JIT needs process definition
29. JIT needs Customer-Supplier-Chains
30. Zero defects is possible under TQM environment
31. Zero defect requires competent persons
32. Zero defects will happen on its own
33. Zero defect means 6 Sigma level of quality
34. Zero defect is beneficial to the customers
35. Batch production is same as flow manufacturing
36. Flow manufacturing takes lesser time
37. Cellular manufacturing is at the heart of lean
38. Lean enables JIT
39. JIT enables TQM
40. Kanban means card signal
41. A cart Kanban is used for the withdrawal of large items.
42. SCM minimizes WIP , inventory and cycle time.

III. Explain Briefly

1. ETX model
2. Process orientation
3. What is the primary goal of process approach
4. Activities carried out in each phase of Subburaj's 6S
5. Differentiate between streamlining and simplifying
6. Explain why synergizing is required at all
7. Which is the first phase of 6S and why?
8. Can Subburaj's 6S be applied in a manufacturing organization and if so how?
9. Advantages of customer supplier chain
10. Process approach and customer supplier chains
11. Factors that will contribute to the successful establishment of customer supplier chains
12. Identify customers and suppliers in a training program
13. Do customer supplier chains fit with process approach?
14. Why should we practice JIT?
15. How to practice JIT?

16. Is JIT possible in the modern times? if so explain?
17. Is process orientation necessary for JIT to happen? If so explain
18. Give at least three requirements for JIT
19. Is JIT a new concept?
20. Requirements for zero defects
21. Explain the requirements of mindset for zero defects
22. Explain the ill effects of accepting AQL
23. Supply chain management
24. Lean manufacturing
25. Cellular manufacturing
26. Kanban
27. Single piece flow

IV. Match the Following

A	B
Streamline	educate
Simplify	formulate revised procedures
Study	modify interacting processes
Strengthen	eliminate unnecessary processes
Standardize	make it easy
Synergize	measure current process parameter

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Chapter 8

Continuous Process Improvement

INTRODUCTION

TQM means gradual and continuous improvements of the processes within the organization. TQM consists of finding new opportunities for improvements of processes, improving them, measuring improvement and then repeating the cycle again and again. The improvement strategies were evolved, experimented and published by the quality gurus. A number of new improvement methodologies were evolved in Japan. In this chapter, we will learn the following concepts, techniques and tools that are used for continuous process improvement.

- Juran's Trilogy
- Kaizen
- Kaizen Blitz
- 5S Practice
- Three MUs
- The Seven Deadly Wastes
- Business Process Reengineering

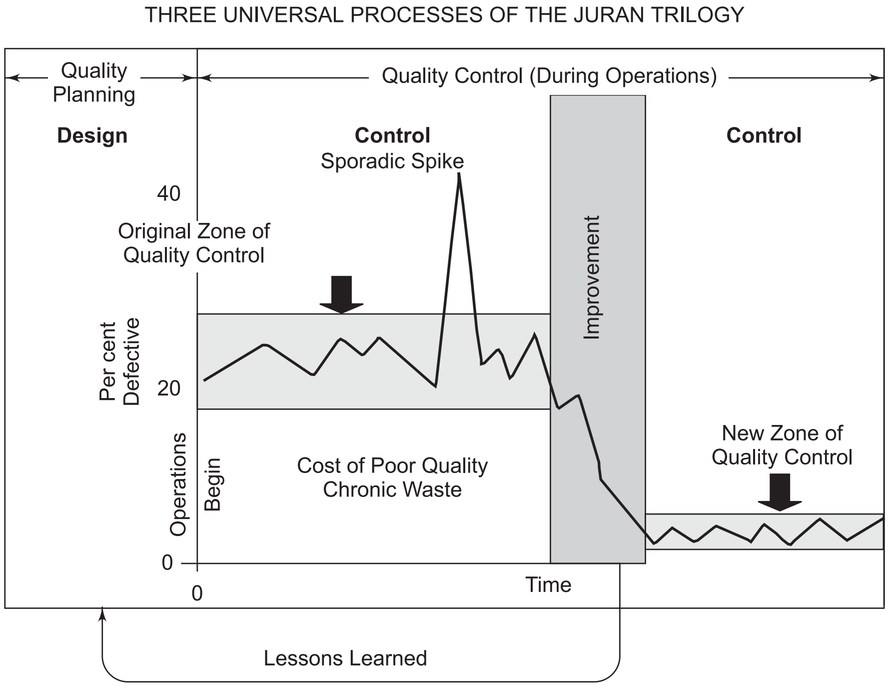
JURAN'S TRILOGY

Juran[1] brings out that good financial results are achieved in an organization through three managerial processes namely, planning, control and improvement.

Juran suggests similar analogy for better quality results. The quality trilogy consists of the same three managerial processes and aimed at improving quality of products and services. They are:

- Quality Planning
- Quality Control
- Quality Improvement

The above three organization wide processes discussed in Chapter 1 are the constituents of Juran's quality trilogy. Juran's trilogy means, "managing for quality is achieved by the use of the three managerial processes of planning, control and improvement". Quality trilogy is given in Fig. 8.1 below:



Juran's Quality Trilogy

Figure 8.1

The above is a plot of time vs. percentage defective. The quality planning activity starts much before the production operations begin. During quality planning the needs of the customers are identified; the product and the processes that will facilitate making the product are developed to meet the needs of the customer. Then the operation starts at time $t = 0$. The operating personnel operate the processes and produce the products. They will find a number of deficiencies in the product thus made; which make the percentage defects higher. It could be as high as 20 per cent. The deficiencies might have occurred due to errors in the planning process. Juran calls this region of high defects as the chronic waste region. During this phase, a large number of defects are found and corrected through quality control. The process operators apply control to prevent things from getting worse. Sometimes, the defects could be very high, 40 per cent as indicated in the Fig. 8.1. This is called Sporadic Spike. If quality control is not strictly followed, such spike could occur frequently causing inconvenience to the customers and the organization. This is the original zone of quality control, as indicated in the figure. In the due course of time, due to quality improvement initiatives, a new zone of quality control is reached. This gain was achieved through the third process namely quality improvement. Now the per cent defectives may reach 5 per cent. This achievement is due to quality improvement action initiated by the organization. Once the performance stabilizes at the new zone of quality control, the quality plan has to be updated.

To summarize, there are three regions, chronic waste, quality improvement and new zone of quality control. Quality planning is completed before the operations begin. Quality control is helpful to keep the fire under control, namely the defects under control. The defects have emanated due to defects in quality planning. To reduce the high level of defects, the organization initiates quality improvement which decreases the defect level. Juran's trilogy should be applied to improve quality at periodic intervals. Thus, it is useful for continuous improvement of quality. Therefore an organization should initiate quality improvement efforts on a continuing basis and update the quality planning. Thus, a quality plan is a living document, revised often.

KAIZEN

Look at the Table 8.1.

Table 8.1 Improvement without capital investment

- Productivity improvement of 40 per cent
- Work In Progress (WIP) reduction of 70 per cent
- Machine set up time reduction of 30 per cent
- Space reduction for manufacturing by 40 per cent and no additional capital investment

This is the result of Kaizen. Kaizen is a Japanese word. It means gradual, orderly and continuous improvement. Kaizen does not need any capital investment, but it requires time and efforts of every employee in the organization, right from the top management. Continuous improvement is achieved through improving the current way of manufacturing and eliminating waste. Kaizen is a Japanese strategy for continuous improvement. Kaizen succeeded because it is a good management practice. These practices can be employed by any organization located anywhere in the world. Kaizen calls for never ending improvements. This means that improvement is not a one-time activity, but a continuous activity. After some time, once the process is stabilized, the employees will be able to find out some more scope for improvement. Then again the improvement is made. That is why the word continual may be more appropriate rather than continuous improvement. Thus Juran trilogy and *Kaizen* aim at continuous improvement.

Two Activities of Kaizen

Kaizen comprises the following two activities, carried out simultaneously:

- Maintenance
- Improvement

An organization functions with a set of processes. Maintenance involves activities directed at maintaining current technological, managerial and operating standards. While efforts are going on for improving the processes, the present activities should continue as per the current standards without any interruption. It should not come to a halt. Kaizen involves small, continuous improvements of the current processes. Thus, an organization will be involved in two distinct activities simultaneously namely, maintenance and *Kaizen*.

The improvement function aims at revising the current standards. Kaizen is different from innovation. Innovation aims at dramatic improvement of the existing processes, whereas, Kaizen aims at small, incremental improvement in the existing processes. Therefore, innovation is beyond the scope of *Kaizen*. However, *Kaizen* has to be carried out along with maintaining continuity in the current operations in the organization.

The Kaizen activities in Japan are given in Table 8.2.

Table 8.2 Kaizen Activities

• Finding new ways or improving the ways in which the tasks are currently carried out
• Improving working environment
• Improving processes
• Improving capability of machinery through periodic as well as preventive maintenance
• Improving usage of tools and fixtures
• Improvement of human resources through training and job rotation
• Improving plant layout

It is the primary responsibility of the factory workers to maintain the existing system. The top management and the middle management make efforts in finding out improvement opportunities. The supervisors will also participate in *Kaizen* efforts but their main responsibility will be to maintain the current system. While the workers and the supervisors concentrate on maintaining the current status and production, middle management and the top management have to take keen interest in the following activities towards *Kaizen*:

- Maximizing efficiency and productivity of employees as well as the plant
- Improving the quality of the process, plant and thereby the product
- Minimizing inventory levels and Work In Progress (WIP) – (WIP means that making the product has started but not finished due to some reasons, beyond the control of the organization)
- Improving ergonomics to facilitate the human resources to maximize their output with more comfort
- Call for suggestions from workers
- Enabling team work
- Improving systems in the organization

Three Basic Principles of Kaizen

There are essentially three basic principles of *Kaizen*.

(i) Work place effectiveness
(ii) Elimination of waste, strain and discrepancy
(iii) Standardization

Work place effectiveness Japanese have developed the 5S tools for addressing the work place effectiveness which will be discussed later in detail in this chapter.

Eliminating waste, strain and discrepancy Kaizen is achieved through application of 5S tools for workplace effectiveness and elimination of three MUs. The three MUs stand for three Japanese words as given below in Table 8.3.

Table 8.3 Three MUs and their meaning

1	Muda	Waste
2	Muri	Strain
3	Mura	Discrepancy

The wastes are not free, but have been paid for by the organization, since those who produce wastes also get paid and the material wasted costs money. Therefore, one has to minimize and ultimately eliminate the waste in an organization. The waste, strain and discrepancy in respect of the following are to be reduced and finally eliminated:

- Human resources
- Production volumes
- Inventory (materials)
- Time
- Working space
- Machinery
- Techniques
- Facilities
- Tools and Jigs
- Thinking

Standardization Kaizen stresses standardization of processes, materials, machinery, etc. with the following objectives:

- Represent the best, easiest and safest way to carry out a job in the form of operating procedures and work instructions
- Represent the best way to preserve know-how and expertise and standardize the procedures for the same
- Evolve effective means to measure performance and standardize the same
- Standardize all the procedures that are used in the organization for maintenance and improvement of process
- Standardize the training programs
- Standardize the audit for diagnosing problems
- Standardize the procedures for preventing occurrence of errors and minimizing variability

Thus, *Kaizen* consists of three basic principles namely the application of 5S for improving workplace effectiveness and simultaneously reducing and eliminating three MUs as well as standardization of methodologies.

PDCA AND 7 QUALITY TOOLS

Kaizen advocates usage of seven quality tools for problem solving. It also calls for using PDCA cycle for improvement of processes. It encourages forming cross-functional teams for improvement. The team should identify improvement opportunities and implement them by following the PDCA cycle for effectiveness. This will facilitate effective implementation for improvement.

GOAL OF KAIZEN

The goal of *Kaizen* should also be clearly understood. They are given in Table 8.4.

Table 8.4 Goal of Kaizen

• Kaizen is implemented not for profit but for quality. Unless an organization improves quality, it cannot prosper.	• Kaizen should be prioritized based on the impact on the customers. Thus, Kaizen is a customer driven strategy for improvement
• The success of *Kaizen* should be measurable through its impact on the customer satisfaction	• Kaizen is a problem-solving tool based on cross-functional team and collaborative approach
• Kaizen will be successful only when it is process oriented	• Kaizen is basically for improving the processes in the organization
• It is important to recognize that any organization will have problems and hence the employees should be encouraged to admit when there is a problem	• Collaboration between the cross-functional team, the process owners (those who carry out the job regularly) and the management is essential for success of *Kaizen*
• A suggestion system is an integral part of *Kaizen*. The management should encourage the employees to give suggestions and their involvement in improvement process	• Quality Circles can become part of *Kaizen* since it is a group oriented suggestion system

Kaizen is a low cost approach to improvement, available to every organization that has the determination to improve its processes for delighting customers. An organization should recognize that improvement is never ending. Kaizen brings out improvements, which results in improved productivity, efficiency, profitability and above all better quality of life of employees and satisfied customers.

Kaizen Implementation

The organizations embrace *Kaizen* in two ways as given below:

(i) Gradual improvement of processes
(ii) Kaizen Blitz

The first methodology is similar to what was discussed in chapter four. The management constitutes an Apex Quality Council which overseas continual and gradual improvement in the processes. For each improvement project, specific teams – PAT are constituted with specific goal. The improvement teams use the seven QC tools for problem solving. They use 5S tools for reorganizing work places of the factory for their effectiveness. They reduce or eliminate three MUs. They will use PDCA cycle to evolve and implement improvement plans. Thus, it is a long-term exercise for every process improvement.

Kaizen Blitz Kaizen Blitz, on the contrary, is a quick improvement methodology. A large number of organizations embark upon Kaizen Blitz (events) to unleash employee creativity and dramatically improve the operations overnight. Usually the Kaizen Blitz is completed in a single week. The solutions are implemented quickly. In the traditional context, Kaizen means making small improvement over an extended period. However, in the recent past, large number of organizations in US and Europe and around the world organize Kaizen Blitz, which lasts for a week. While the Kaizen in the traditional sense is aimed at creating a perfect production line, the goal of Kaizen Blitz is simply to create a better production line. Kaizen Blitz is also known as the Kaizen Workshop which targets a particular work place. A cross-functional team is formed comprising of managers, supervisors, workers and sometimes marketing and finance personnel and even consultants. The team after attending a training program on the subject, studies the process, collects and analyzes the data, discusses improvement options and recommends the changes.

The changes are implemented with the approval of the Q C. The changes may call for modifying equipment lay out, or modifying processes, skipping non-value adding processes, etc.

Everyone understands the lean manufacturing concept of Toyota now. After Toyota achieved Just-In-Time production, they started looking at their vendors. Their autonomous study group was formed under Tahiti Ohno. The group visited Gemba meaning work place of a vendor each month and conducted Gemba Kaizen for three or four days. This proved to be very effective[2].

Toyota began conducting Kaizen Blitz to suppliers in the early seventies, which involved the movement of machinery, modifying equipment, change in electrical connections, etc. However, each Gemba Kaizen requires advance preparations, though, the work will be carried out during the selected time.

Kaizen Blitz teaches the core skills to the cross-functional team. Then the cross-functional teams apply the core skills learnt on the processes. They look particularly at the incoming material, manufacturing set up, processes and house keeping.

While a *Kaizen* event takes place within the span of one week, the advance preparation may take much longer. The first step is to identify target areas where improvements will have a significant competitive impact. It's also important to analyze the physical layout to determine what equipment would be difficult to relocate.

Whether it is a Kaizen Blitz or Kaizen in the traditional sense, it involves the following:

- Application of 5S for improving workplace effectiveness
- Reduction and finally elimination of three MUs
- Standardization of effective methodologies for carrying out the work

A typical improvement process using *Kaizen* is indicated in Fig. 8.2:

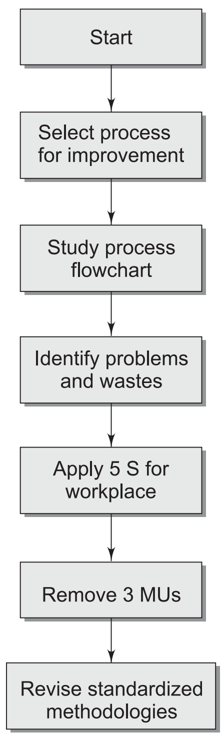


Figure 8.2 Applying Kaizen

The above methodology should be adopted for every improvement action using *Kaizen*.

KAIZEN BLITZ-BENEFITS

The benefits accrued to one organization that implemented Kaizen Blitz, which was published on the Internet, are given in Table 8.5.

Table 8.5 Benefits of Kaizen Blitz

Kaizen Blitz – Benefits				
Criteria		*Before*	*After*	*% Improvement /Reduction*
VA Ratio		0.2%	3.5%	94%
WIP		1044	150	85%
Manufacturing		305 m^2	252 m^2	17%
Set Time		70 mins.	45 mins.	35%
Lead time		13 days	0.6 days	95%
Distance	Turn/Drill	35 m	4.5 m	87%
Travelled	Drill/Weld	186 m	20 m	89%
	Turn/Weld	160 m	5 m	96%
	Weld/Test	10 m	4 m	60%
Transactions		82	0	100%
		Worldwide Business Solutions[3]		

A case study [4] of implementing *Kaizen* in an organization manufacturing acoustic metal ceiling tiles for buildings is given below:

CASE STUDY
BOURTON GROUP*

SAS International Ltd

A series of Kaizen 'Blitz' events throughout all manufacturing areas and in planning – they improved output volume by 30 per cent in a 4-month period without increasing the cost base.

This £40m turn over organization produces and exports acoustic metal ceiling tiles for prestigious building projects such as Hong Kong airport. Kaizen events were held at all three of its South Wales sites. For each 'Blitz' we formed a multi-disciplinary project team, which devoted an entire week of identifying, prioritizing and then implementing improvements. These were followed up with monitoring visits to support internal teams in their efforts to sustain changes and develop further.

Techniques used included data analysis, 5S, visual control, plan-do-check-act improvement cycle and standardization. Some events concentrated on machine throughput – for example, we reduced set up time on the Turret Punches by 48 per cent and by 38 per cent on the Perforating Press. In other areas, we applied line-balancing principles to increase productivity; we doubled Large Ceiling Panel output, and identified potential to triple it in future. Even on automated processes, such as the paint line which delivers a painted tile every 1.4 seconds, by monitoring the line in its entirety, the team was able to identify exactly where losses were occurring and determine remedial actions.

An event that focused on scrap eliminated root causes and improved 'right first time' levels by 61 per cent. Two further activities addressed configuration issues – in the press shop, for example, a re-designed layout:

– Reduced the amount of time spent fetching and carrying by 39 per cent
– Released enough space to create additional process space
– Generated income from the sale of redundant equipment

Finally, over a 12 week period, we improved the planning process – a heavily –, customized, standalone micro system – so that it could generate accurate, reliable information on-line with less effort. This involved mapping the entire process, clearing out all redundant data and introducing new ways of working to maintain the improvements. This work had a very positive impact on all areas of the business: in assembly particularly, problems such as material shortages and duplicated jobs, were dramatically reduced.

In summary, our contribution improved SAS's financial and competitive position significantly. The emphasis we placed on equipping internal teams with *Kaizen* tools and skills will ensure that improvements in the future will not only be sustained but also augmented.

* With permission from Bourton Group, UK.

5S PRACTICES

Kaizen is a carefully evolved strategy by Japanese for improved competitiveness of business. It is more than just a tactical weapon. It is also a collection of tools. The *Kaizen* toolbox includes the 5S for improving workplace effectiveness. 5S is rather a management tool focused on fostering and sustaining high quality housekeeping.

The 5S practices are:

(i) sort
(ii) straighten
(iii) scrub
(iv) systematize
(v) standardize

The Japanese equivalent names for the five practices start with the alphabet 'S'. Thus, these are known as 5S practices.

A perusal of these 5S practices (which are also called 5S tools), may give an impression that they are very simple and mundane, but practicing them meticulously and correctly will definitely add to improvement of quality in the organizations.

The purpose of 5S tools are given in Table 8.6.

Table 8.6 5S Tools

1.	Seiri (sort)	Separate out all unnecessary things and eliminate them.
2.	Seiton (straighten)	Arrange the essential things in order, so that they can be easily accessed.
3.	Seiso (scrub)	Keep machinery and working environments clean.
4.	Seiketsu (systematize)	Make cleaning and checking as a routine practice.
5.	Shitsuke (standardize)	Standardize the previous four steps.

1. Seiri–Sort

The objective of Seiri is to sort and throw away unnecessary items.
Separate tools, machinery, products, inspection, work in progress, and documentation into necessary and unnecessary and discard unnecessary items.

This tool is about organizing things. For instance, every executive receives a lot of paper and email. He is unable to decide which paper he should destroy immediately and which email to delete and which he should preserve and for how long. Some executives are always in a dilemma before destroying even unimportant papers with the worry "in case I need the paper or email later, what will I do"? This forces the executive not to destroy any paper or delete any email. This results in accumulation of a lot of paper and mailbox becoming full, many of them never looked again for years together. This adds only to confusion since the executives will always be searching for things. I know a senior officer in government organization, who used to sit with a waste paper basket in front of him, when he peruses the letters received by him every day. As soon as he looks at a paper, he will instantly decide what action has to be taken without any hesitation, i.e. pass it on to the concerned officer or keep it with him for further action or tear off the paper on the spot. This speaks of his ability to take quick decisions and his organizing ability. Seiri is in fact, aimed at inculcating such a quality in every employee in the shop floor. Seiri means "separating the things which are necessary for the job from those that are not and keeping the number of the necessary ones as low as possible and at convenient locations". Therefore, every employee should decide what to discard, what to store and how to store things, so that they can be accessed easily later. If the place is clean, naturally there will be more motivation to carry out the jobs. If the place is full of unwanted things, then it will be difficult to work. It is very easy to advise, but how to handle? The executive can classify items into the following categories:

- Low usage
- Medium usage
- High usage

Those items that are of low usage can be kept at far off places. The average usage items can be kept in a cupboard nearby. The high usage items, which are frequently referred, could be kept closer to him neatly. Those, which will never be required, are disposed off immediately. If this is followed for every paper or email that is received or item received, it will improve the efficiency of the executive. Similar practice can be practiced in case of tools, equipment and machinery required for manufacturing and providing services. Therefore, an item that is required continuously should be on the table. Items not required frequently can be little away. The item that is required once in a week, can even be in the stores. This will help in carrying out tasks faster. Thus, Seiri advocates proper organization of entities used in the organization so that it does not cause strain in the working and improves productivity.

2. Seiton–Straighten

The purpose of this tool is to arrange necessary items in a neat, proper manner so that they can be easily retrieved for use and to return them to their proper locations after use.

> For easy and fast access when needed, everything has a place and everything in its place.

Deciding to place items at different places depending upon the need is not going to improve the efficiency, unless the things are arranged neatly and properly. Neatness is not only cleanliness and organization but also, systematic working. It is a measure of efficiency. It calls for clarity in the organization. It prevents people from searching for things and wasting their time. For neatness to happen, one has to analyze how people get things done and why it takes so long to get a tool. An organization is supposed to be neat, if no time is wasted in searching and the productivity is the best possible. The executive has to devise a system so that everyone understands easily. The following could be adopted for enabling neatness in the organization:

Step 1: Plan to arrange neatly The management should plan to arrange everything at the appropriate places in appropriate manner. For instance, a person takes out the cash chest from a cupboard after opening its two locks, uses it for sometime and then puts it back again and locks the double lock. If he does this 50 times a day, at the rate of 2 minutes every time, he spends about 100 minutes a day, only on taking the cash chest out and putting it back. Selecting a proper cash chest with unbreakable lock and keeping it permanently near the cashier could eliminate this. In this case, he locks it only when he goes out, may be 10 times a day and at the rate of 10 seconds for locking and opening , he will spend only 100 seconds in a day. See the time saved and thereby improved efficiency. Similarly, in the production floor, where quick turn around time is required, minutes wasted in taking something and putting it back could cause a lot of wastage of man-hours. Always the problem lies in retrieving things. Some of the problems in retrieving things are:

1. Not knowing the correct name of the things
2. Not sure where things are kept
3. Storage site at a far off place
4. Storage sites scattered all around
5. Repeated visits to far off places for taking and putting back
6. Hard to locate the things since the box contains many other things
7. Storage location and items not labeled
8. Thing is not there, but not clear whether the stock is exhausted or somebody is having it
9. No distinction between good parts and defective parts, all look same
10. Too wide to carry
11. Too heavy to carry
12. No trolleys to carry huge items
13. Improper design of path ways with lot of obstructions

In the planning phase, appropriate places should be selected for storage of various items. If there are no written criteria, then each person will have his own criteria and again they will take lot of time in retrieving things. People cannot also remember where the items are kept. There could be so many places where an item could be kept. Therefore, the important point to be noted is that the places where an item will be placed should be decided and documented so that anybody can take the item easily. While doing so the 13 points given above should be avoided.

Step 2: Decide where things should be stored The organization should have a name for every item and a place for each item to be stored. Similarly, each tool, each material, each document or file should have its address known to the users. Such a scheme should be followed for every item in the organization. While assigning the storage place for an item not only the location of the shelf, even the cupboard number should be clearly identified and should be recorded. The diagrams of the tools could be drawn on the storage place. The workmen should be directed to keep the tools on top of the diagram. Tool should be put back at the same place marked for it. In this manner, it is easy to find out whether the tool is stored or in use. It is also easy to find whether the tool is missing at the end of the day's work. Such simple planned actions will reduce the fatigue of the employees. The following procedures should be adhered to:

1. Everything should have a name
2. A place for everything and everything in its place
3. Quick identification and retrieval mechanism
   - Frequent–use items should be retrievable easily

4. Safe storage / transfer
   – Heavy things on the bottom
   – Heavy things to be carried on trolleys
   – Benches and ladders to be used wherever required
5. Height consideration for the storage of items depending on the frequency of their use.

Step 3: Be consistent in following the rules It should be the discipline on the part of the employees to follow the rules, which they made for themselves. Whatever may be the problems, the tools or items should be put back at the places marked for their storage.

3. Seiso-Scrub

> The objective of Seiso tool is to clean and inspect the respective work places thoroughly, so that there is no dust on the floor, machinery and equipment. Keep machinery and work environment clean.

The importance of cleaning need not be over emphasized. Employees in the organization should be responsible for cleaning their own places. Periodic cleaning of their workbenches, cupboards, PCs, switchgears, etc. is essential. Otherwise psychologically the employees will not be able to perform well. The first job every day in the morning for an employee should be to clean the work place. At the end of the day, before leaving the office, they should see that the place is cleaned. They should see that their work place remains clean and tidy throughout the day. They should not make things dirty. If oil or grease is spilled on the table or floor, they should be cleaned immediately. Throwing away rubbish, scattering cables around, leaving the marks after taking tea, throwing food items in the washbasin etc. may all be small things, but creates bad impression.

Some employees don't attend to problems immediately because of lethargy. It should be overcome. They should make every effort to keep things in an orderly manner. In the electrical distribution, the fuses should be checked and loose ends should not be hanging. Every employee should be conscious about fire hazards and safety hazards. It is reported in Japan that there are no sweepers and every family is responsible for cleaning the pavement in front of their house. They only require rubbish collectors. Such a dedication for keeping the place clean should be visible in all the organizations. If cleanliness is not maintained it can be harmful to the personnel working (health hazards), machinery (can fail often due to dust etc.), materials (due to contamination) and can cause problems in both quality of the process and products and productivity of the employees. A fine particle of dust can crash computer hard disks, which are used in every office. Handling an electronic component with a bare hand with human sweat can cause reliability problems of life saving devices. Many people are allergic to dust leading to health problems. Thus, periodic cleaning is very important in work places.

4. Seiketsu-Systematize

> The objective of this tool is to maintain high standards of work place organization by keeping everything clean and orderly at all times. Develop routine practices for cleaning and checking

If the organization can systematize the 5S processes, then it becomes easier for continuously and repeatedly maintaining the organization's neatness and cleanliness. This may call for visual management. Visual management is an effective means for systematic workplace organization. It is useful for production, quality, safety and customer services. Visual management is a technique, by which the visitors as well as the employees understand where to keep things like the marked car parking lots, information about lubrication oil written on the machine, like what type is used, what colour, what grade, when to change and where it is available etc. It also includes signboards. There should also be indications for abnormally hot spot or high voltage in machinery. It includes identification labels for all the machinery parts. Safe walking areas in factories are to be marked so that visitors will not go near dangerous machinery. These are all part of visual management. Thus, visual management is self-contained and understandable instruction, painted neatly at the right places. In high-risk industry, zonal labels like normal zone, danger zone are to be visible clearly to enable people to be careful. This will help them to keep a distance from dangerous places. Another important consideration for Seiketsu is transparency, tools and files should be visible so that it is easy to locate them. This will reduce the time for searching. Even the map of the organization can be displayed at various places. This will help people to go to the place where they want to. Such visual signs should be planned and used at all the places to reduce the searching time. It also reduces the time spent on discussions with people in trying to find where the office is or where the item is. The signboard should be put in such a manner that even an illiterate person can go to the place he wants to without an attendant. Similarly, the items should be easily locatable. Such simple steps will facilitate workplace organization.

5. Shitsuke–Standardize

> The objective of the last 5S tool is to make the previous four steps part of the daily routine and to observe self-discipline through continuous practice. Follow procedures and standardize continuously to improve processes and reestablish standards.

Discipline is the fundamental requirement of success for any organization. Discipline will come only with repeated instructions, coaching and training. The employee should be taught what should be done and what should not be done. There is a need for systematic training and coaching for bringing in discipline. Employees should be coached and tried out before actual deployment. This is same as Deming's PDCA.

Self-discipline is important because it reaches beyond discipline. Self-discipline guarantees the continuity of a daily routine. Japanese are a very self disciplined race and hence they have the lowest crime rates in the world and are well known as 'obedient' tourists. Discipline is also a part of industrial safety. If people are not disciplined, it can cause a lot of serious accidents. If an electrician does not do his job properly and does not care about his fellow employees, it will be the cause of a lot of electrical accidents. Similarly playing with petrol, gasoline etc. is dangerous. Therefore, the employees should have self-discipline to practice 5S and the importance of discipline for TQM need not be over emphasized. Discipline is thus essential to maintain high standards in work place organization. Only this will enable keeping everything clean and orderly at all times. Discipline follows standardization.

5S CERTIFICATION

National Productivity and Competitiveness Council (NPCC) of Mauritius offers 5S Certification. The NPCC Certification was introduced in April 2002. It is aimed at developing and assisting the productivity culture across Mauritius.

NPCC 5S Certification: The Process

1. A team of 5 auditors will audit the Gemba (work place) proposed for certification. Three audits, spread over the period of one year will be conducted.
2. The audited organization shall keep the following relevant information:
   - General background of the organization
   - Sections or departments where 5S is applied
   - Photos of the section or department where 5S is applied
   - Tangible and intangible benefits gained
   - Documented proof : support structure for 5S (like a formal 5S coordinator), training on 5S conducted and attendance sheets, standards (for colour codes, etc) and proof of regular 5S activities
4. Following three random audits and on the basis of the auditors report, eligibility of the 5S certification will be considered.
3. A certificate will be awarded by National Productivity and Competitiveness Council and Kaizen Institute (Africa, Asia and Pacific) to any organization, which has successfully implemented 5S practices.

THE SEVEN DEADLY WASTES

Wastes cannot be totally eliminated but can be reduced to the minimum. Toyota, the Japanese automobile manufacturer, identified the following seven types of wastes as the most common in industries.
- Waste from overproduction
- Waste of waiting time
- Transportation waste
- Processing waste
- Inventory waste
- Waste of motion
- Waste from product defect

We will discuss them briefly:

1. Overproduction Waste

This occurs due to failure of production planning when money is blocked in the unsold products. When the programming language Java was popular before the bursting of dot COM bubble, an ambitious book supplier stocked large volume of Java books. When there was a change in requirement and many copies were not sold, he had to close down the organization. Therefore, overproduction is very harmful. Just-In-Time (JIT) is the right approach. But practicing JIT needs a healthy organization practicing Kaizen.

2. Waste due to Waiting

Work-In-Progress (WIP) is a direct measure of quality of the organization. A product is nearly completed but waiting for a particular part to arrive from another country. Hence the product cannot be shipped. This is WIP and an example of waste due to waiting. This can occur at any stage of manufacturing due to poor planning, organizing as well as lack of dynamism in making alternate arrangements when a particular man, machine or material is not available due to unforeseen circumstances. The process layout and production should be such that the flow is continuous and neither a machine nor an operator is waiting for something.

3. Transportation

Unnecessary transportation is a waste. Therefore, every assembly line should be under one roof preferably. The plant layout should be organized such that there is no back and forth movement anywhere. If there is no conveyor, the goods or semi-finished products should be transported using trolleys or carts. But the distance traveled should be kept at the minimum.

4. Processing Waste

The machinery should be kept in smooth working condition by periodic and preventive maintenance to eliminate processing waste. If a process is held up due to breakdown of the machinery, money is lost. Furthermore, appropriate tools and fixtures should be provided so that the time taken for manufacturing is optimum. The design of the product should be such as to enable easy manufacturability, testability and maintenance.

5. Inventory Waste

Supply chain management should be such that there are no excess materials. Similarly, the organization should produce exact number of every part. Sometimes they produce a little more to take care of eventualities. Even such extra items can become huge in due course of time, necessitating selling them as a scrap. In the stores also reorder levels should be fixed for every item on scientific basis to avoid dead stock. The poor housekeeping can lead to valuable items lying on some cupboards unnoticed. Every part should be accounted to avoid inventory waste.

6. Waste of Motion

As Watts Humphrey [6] says, the purpose of driving is to reach the destination on time and not to spin the wheel. This happens if the person does not have the map. Similarly, if the workers are not trained in their job properly, there will be lot of motion but no work. Searching for things, non-availability of the correct tools, not monitoring the running machine etc. can cause wastage of lot of time. The objective of the organization should be to add value by every motion of the employee and machinery.

7. Product Defects

The defective parts or supplies cause loss of money. Not only that, managing the scrap causes unnecessary work like, safe custody, accounting, disposal as well as cause strain on the space available for good manufacturing. Thus eliminating scrap through zero defects is the only solution to the problem.

BUSINESS PROCESS REENGINEERING (BPR)

What is BPR?

BPR is undertaken essentially to result in a quantum jump in performance of processes. BPR is synonymous with innovation because it is more than just automating or applying Information Technology to the existing processes or operations. It will bring in benefits to all the stakeholders of the organization. Very high achievements are expected out of BPR. For instance, expectations are as high as 50 per cent reduction in design cycle time in case of R&D projects, 60 to 80 per cent reduction in total cost of manufacture, reduction of delivery time from a month to a day! BPR exploits the unexploited potentials of the organization. A test laboratory was committing five working days for the completion of every calibration job, when its peers were committing two weeks to a month's time for the same activity. They learnt from its customers that a competitor was taking a day's time for calibration of such equipment. Then they decided to achieve such a cycle time. They planned and implemented a scheme by which they take only 8 hours for the calibration jobs. This is an example of applying business process reengineering.

BPR is "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvement in critical, contemporary measures of performance, such as cost, quality, service and speed".

A dramatic improvement can take place only when the change in the process is radical and bold. Dramatic improvements will only help the organization to leapfrog in performance or achievements. Rightly, BPR calls for dramatic improvements in critical and contemporary measures of performance such as quality, cost, service and speed. The objective of BPR is to reduce the cost of maintaining quality, improving service features and delivering the products and services fast.

Fundamental Rethinking

Dramatic improvements can take place through elimination of redundant operations, unnecessary operations and operations, which add cost, but, not value to the products and services. BPR is an opportunity for innovative persons to decide, after due considerations, which processes are redundant and make a recommendation accordingly to the management. Then, the management will take a final decision to eliminate the process.

Radical Redesign

Dramatic improvements cannot be achieved only through fundamental rethinking. It calls for design of new processes. Some service organizations take 15 days to respond to an enquiry through fax. This is mainly because of the redundant system established in the organization. Therefore, in order to reply to a query in half an hour time, the redundant processes, processes that inhibit quick action and need unnecessary approvals etc. should be dispensed with. The reengineering team should question fundamentally the necessity to follow the existing procedures or methods or use of machinery and should not care to throw all of them and start afresh. Only then, dramatic improvements can take place.

How to Carry out Reengineering?

The steps involved in BPR are similar to those in TQM. However in reengineering, much bigger results are expected and not incremental improvements.

The five phases of reengineering cycle are given below:

1. Planning
2. Process Study

3. Study of the best practices
4. Redesign
5. Implementation

This cycle repeats itself whenever the management wants dramatic improvements in the performance of the organization. Reengineering does not fit in *Kaizen*. However, reengineering may be called for occasionally to make quick and dramatic improvements in the process.

Information Technology

Some consultants give an impression that BPR means application of Information Technology (IT) only. No doubt, application of IT will help in improvement of productivity, efficiency and quality of the work. However, IT alone cannot result in dramatic improvement. IT has to be integrated into the redesigned process skillfully and logically. Simply buying computers and asking people to make use of it, will not improve the performance. The computer should be used where it is possible. Since, IT can reduce the monotony of people, the reengineering team can try to explore applications where it could be gainfully employed. The most difficult part in reengineering project is the intelligent way of understanding the current practices and finding innovative new methods. IT is only a part of the new method. This should be clearly understood. IT can be applied not only in reengineered processes, but also in the continuing processes. The investment in IT is certainly worth it, provided the managers know where to use and how to make people to learn the techniques of using them for their day-to-day operations. Therefore, the emphasis is in finding out innovative processes and by the way using IT and certainly not the other way round i.e. redesigning the process only to use IT in spite of no visible benefits.

BPR AND TQM

The aim of BPR is to make dramatic improvement in quality. There is a lot of debate as to whether BPR is an alternative to TQM. Some proponents feel that TQM is outdated and BPR will replace TQM altogether. There are a lot of misconceptions about BPR, vis-a-vis TQM. TQM is not only continuous improvement, but, has many other facets as given in the various chapters. BPR is one of the tools to achieve TQM as discussed in this section.

The two approaches namely TQM and BPR neither contradicts nor compliments each other because they are two parts of the same approach. AT&T illustrates this well in its reengineering handbook, which poists business reengineering as a fundamental component of total quality approach. Therefore, total quality is an objective, TQM is a means to achieve it and BPR is an important tool within the TQM technology. This observation makes the relationship between TQM and BPR crystal clear. While BPR is a tool, TQM is an umbrella concept involving many other strategies.

SUMMARY

In this chapter we got some tips for continuous process improvement. Juran's trilogy gives the analogy of financial control to quality control. Juran suggested quality improvement for eliminating chronic waste and reaching new zone of quality control.

Toyota Motor Organization, Japan pioneered the JIT manufacturing. To enable JIT manufacturing an organization needs to apply *Kaizen*. Kaizen is a strategy for gradual, continual improvement. The impact of *Kaizen* is tremendous.

Kaizen can be applied on a long-term basis for gradual improvement. This will result in sustainable improvement. However, to suite the modern times, organizations are organizing the Kaizen Blitz or Kaizen Events. This lasts for a week, although the preparation for this event has to take place much before. A cross-functional team is selected beforehand to take part in the Kaizen Blitz. The team after receiving training on Kaizen Blitz gets into the job of improving the chosen process area. All this happens in a week's time. After achieving JIT manufacturing, Toyota embarked on improving their suppliers. They conducted a number of Kaizen Blitzes in the suppliers' premises. This had a tremendous impact amongst the suppliers for JIT manufacturing and lean manufacturing. The seven deadly wastes identified by Toyota should be eliminated in every organization.

Practicing TQM requires application of simple tools by employees in their day-to-day life in the office. Japanese skillfully employed these tools and attained all round improvement in their organization. 5S tools were also developed and applied by the Japanese formally. These are based on common sense, but at the same time, aimed at improving quality of life in the organizations. If 5S is in practice, then the organization's productivity, efficiency and quality will improve continuously. Kaizen aims at reduction of three MUs and standardization of methodologies.

5S does not say anything, which we do not know already. However, small things which do not consume much of our time to learn and practice such as arranging things depending on the usage, keeping places clean and tidy, evolving proper sign boards, safety precautions, discipline, the persistence to see that the procedure is not deviated even in case of emergency, all have a greater impact in the organization and, are the steps to learn and apply in the journey towards TQM by all the employees. 5S essentially means good housekeeping so that the employees put all their best efforts in the main activity with improved quality, productivity and efficiency. Thus 5S helps in improving workplace effectiveness.

We also discussed about Business Process Reengineering (BPR) that helps in achieving dramatic results through radical redesign of processes.

REVIEW QUESTIONS

I. Choose the Most Appropriate Answer.

1. 5S improves
   (a) Quality of the product and processes (b) Efficiency
   (c) Employee morale (d) All the above
2. Seiri means
   (a) Throwing away all items (b) Throwing away unnecessary items
   (c) Sorting in a database (d) None of the above
3. Seiton is
   (a) Applicable to waste also (b) Not part of 5S
   (c) To arrange necessary items in a neat and proper manner
   (d) None of the above
4. Visual management is a part of
   (a) Seiketsu (b) Seiri
   (c) Seiton (d) None of the above

5. 5S is
   (a) A part of *Kaizen* tools
   (b) Management tool
   (c) Used for inspection
   (d) All the above
6. Kaizen is a technique for
   (a) Gradual improvement
   (b) Continuous improvement
   (c) Does not require capital investment
   (d) All the above
7. Kaizen Blitz involves
   (a) Training of cross-functional teams
   (b) Carry out the job quickly
   (c) Aimed at dramatic improvement
   (d) All the above
8. Kaizen is aimed at
   (a) Application of 5S
   (b) Standardization of processes
   (c) Waste Elimination
   (d) All the above
9. BPR is aimed at
   (a) Continuous improvement
   (b) Gradual improvement
   (c) Radical redesign and dramatic improvement
   (d) All the above
10. Juran's trilogy includes
   (a) Quality Planning
   (b) Quality Control
   (c) Quality Improvement
   (d) All the above

II. True or False

1. Kaizen means dramatic improvement
2. BPR is a Kaizen tool
3. Standardization of methodologies is important to *Kaizen*
4. Kaizen blitz is a quick improvement process
5. Juran trilogy aims at eliminating chronic waste
6. Seven deadly wastes improve processes
7. Lean manufacturing saves space
8. WIP is high in lean manufacturing
9. Visual management improves processes
10. Kaizen reduces costs
11. BPR aims at gradual improvement

III. Write Short Notes on

1. 5S Tools
2. 3MUs
3. Importance of visual management
4. Describe how each tool will improve quality of the product
5. Applicability of the 5S tools in an office
6. Kaizen Blitz
7. Comparison of mass production vs. lean manufacturing.
8. Juran's Trilogy
9. BPR
10. Three basic methodologies of *Kaizen*

IV. Match the Following

A	B
Seiri	standardize
Seiton	systematize
Seiso	sort
Seiketsu	scrub
Shitsuke	straighten

V. Project Work

Study the workplace effectiveness in any organization of your choice and suggest how the present situation can be improved using the 5S tools?

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Chapter 9

Supplier Partnership

Take care of those who work for you and you'll float to greatness on their achievements.

—H.S.M. Burns

INTRODUCTION

Supplier partnership is one of TQM elements. One of the reasons for success of Toyota Motors and such other organizations is developing and nurturing good vendors or suppliers of materials, parts, components and sub-assemblies. Hence, supplier partnership is very essential for every organization. In this chapter, we will learn the following:

- Importance of suppliers
- Supplier selection
- Early involvement of suppliers in product development
- Product audit
- Vendor rating
- Bonus and Penalties

In this chapter, company or organization or vendee refer to the organization receiving their supplies from others. The supplier of materials and supplies are referred as vendor or supplier. It is also assumed that the supplies are not those products available commercially off the shelf (COTS).

IMPORTANCE OF SUPPLIERS

The dynamics of market forces demand every organization to convert itself into a virtual corporation for cost effectiveness and improved quality. In a virtual organization, the main function of the company is to make the core of the system and depend on a large network of suppliers for the rest of the sub-assemblies needed for building the system. Thus, a large portion of the work is outsourced. Outsourcing has become the watchword even in services. It is more critical in manufacturing. Outsourcing enables the manufacturers to focus their attention in managing their brands rather than capital equipment required for manufacturing every part. Modern times demand lean manufacturing. We discussed in Chapter 7 about Chain Management (SCM). This has been developed to focus attention on this important industrial activity. Therefore, every organization has to find the right suppliers for the needed raw materials and supplies. The quality of the end product is also determined by the quality of the raw materials and supplies. If the quality of materials bought is suspect, then the quality of end product will also be suspect. Therefore, the quality of supplier is quite important. Hence, organizations are paying attention to suppliers' quality. The company has to consistently make efforts to see that the vendor's supply is up to the mark. Some of the steps to be taken by an organization for ensuring suppliers' quality are discussed briefly in this chapter.

SUPPLIER SELECTION

An organization should evolve a suitable methodology for selection of right suppliers. Selection of right suppliers is the most important activity with regard to supplier partnership. The organization has to depute a team of executives to assess the quality of proposed suppliers. If the supplier is already certified under ISO 9000 or similar standards, the job becomes a little easier. They should familiarize themselves with the suppliers' quality measures, including the methodology for final inspection before dispatch. Based upon the quality system and the quality of the supplies as evaluated by an independent agency, the suppliers may be selected. The supplier should be selected based on their technological capabilities and their ability to deliver as per schedule.

SUPPLIER STANDARDS

Every organization should stipulate standards to be met by its suppliers. The suppliers standards set by Toyota Motors[1] is given as follows:

Toyota Supplier Standard

"We at Toyota rely on outside suppliers for most of the parts and materials in the vehicles we make. Every step in making Toyotas, from development to production, consists of joint work with suppliers. The suppliers we seek are companies that have the will and the ability to become active partners with us. We are looking for suppliers who possess world-class competitiveness in terms of quality, cost, delivery and technological capabilities."

Quality Quality is essential to customer satisfaction. Defective products lead to complaints and even recalls. Toyota count on suppliers to pursue quality levels well above our minimum standards.

Preventing defects - Our standard practice is to trust the suppliers to provide us with defect-free products. Toyota does not ordinarily inspect the parts and materials that we source.

Built-in quality – The best way to assure quality is to build quality into products systematically. That means designing products and processes to maximize quality.

Delivery Providing customers with the products they want and when they want them is also an important element of customer satisfaction.

Reliable delivery – Suppliers must deliver the products on schedule and in the amounts required.

Flexibility in production and delivery – Customer tastes change constantly. Suppliers need to be able to respond flexibly in production and delivery.

Technological Capabilities

Competitive technology – is something to pursue through continuing advances in product development and in production engineering.

Value-ad and sophistication – A big consideration in evaluating suppliers technological capabilities is the ability to offer products that are a step ahead of the competition.

Speed – The ability to translate concepts into products quickly is another important aspect.

Dramatic cost reductions – Suppliers should foster the ability to broaden the marketability of their products through dramatic reductions in cost.

A demanding standard indeed! Such a standard for suppliers has helped Toyoto motors to move ahead of its competitors. There should be at least two sources for each raw material or supply for taking care of sudden increase in demand of supplies owing to increase in demand for the products as well as to have a check on the price of the supplies and so on. Getting supplies from too many suppliers will increase the variability of the product in addition to increasing the workload in the organization. The selected suppliers should be clearly intimated about the requirements. Some of the essential information is given below:

- Quantity required
- Quality requirements
- Specifications for the materials
    i. Style
    ii. Workmanship
    iii. Acceptable quality level
- Delivery instructions
- Payment terms.

Their agreement for the above should be taken before they are registered as qualified suppliers. Every organization makes consistent efforts to reduce the number of vendors. This enables them to focus attention on small number of vendors. Thus partnership has to be built with vendors.

LONG-TERM CONTRACTS

The commercial off-the-shelf (COTS) items can be purchased from the market as needed. However, the other raw materials and supplies are to be purchased only from selected vendors. It is advantageous to procure the COTS from the same selected vendor to avoid variability in the quality of the end products.

Some companies are tempted to give short-term commitments for purchase of materials such as ordering materials required for three months. While this may appear to be advantageous to the company, it is certainly, not an advantage to the vendor. In the first place, it is also not even advantageous to the company. Unless the company can order in large quantities, the vendor will not be able to supply at competitive prices. Although, the company cannot order the items required for a period of a year as one order, it can give a commitment as to how much the company will require in the normal circumstances over a period of, say, three years and estimated monthly breakup. This will motivate the vendor to plan to invest in machinery, training of employees and to improve the quality system and work on a long-term basis. Due to unforeseen circumstances the company may not be able to buy the products as committed, but the company does not start operations in the hope of unforeseen circumstances. Therefore, they should be confident enough to enter into long-term contract with the vendors. If the vendor does not maintain the committed quality, schedule, price or services, the company should be free to change the vendor. However adequate precautions should be taken on time so that the need for the same does not arise. Therefore, the company and the vendor should work as a team for mutual benefit. Long-term contract with the vendors is one of the TQM strategies.

Long-term contracts are therefore important both to the vendor and the vendee. It is important to the vendor because he can invest in tooling, process machinery, and inspection equipment and even in new plants. He can spend time and money in hiring and educating employees and establishing quality system. All these will be done by the vendor only when he gains confidence that the company's orders is going to last for some time provided he maintains the quality. The long-term contract is also important to the company, because it reduces expenditure on account of selection of new vendor every time. Once the company realizes that the vendor is a partner due to the long-term contract, the vendor can be associated even in design review meetings of the company. This will provide advance intimation to the vendors on what is expected of the materials in the future. Therefore, they will be on the lookout for new technology even at the design stage of the end products. This will provide a long lead-time to the vendors to develop materials and supplies. Generally companies are reluctant to enter into long-term contract anticipating that prices will come down over a course of time, but due to the contract they have to pay a higher price than the market rate. Even this could be taken care of by agreeing and incorporating progressive reduction of prices as the Toyota supplier standard[1] indicates.

Toyota Supplier Standard

Cost – Offering high quality and excellent function at low prices increases product appeal. The conservation of material and energy that stem from cost-saving measures helps safeguard the environment.

Low prices through low costs – We welcome low prices from suppliers only when we can see that they are the result of genuine cost competitiveness.

Unceasing effort on behalf of cost savings – Suppliers need to strive to continuously reduce costs and to translate their reductions into lower prices.

The vendor will also agree for such a reduction because of production in bulk as well as cost savings on account of improved quality day-by-day, lesser marketing expenditure and assured demand.

INVOLVEMENT OF SUPPLIER IN DEVELOPMENT

Long-term relationship has many benefits. For instance, whenever new products are developed, the suppliers can be involved right from the design stage. It will be in the interest of the company, if suppliers are helped in the development of the components along with the development of the product. The supplier can also be involved in design review of the new product so as to understand the requirements of the components to be supplied by him. This will give the necessary lead-time for the supplier. It will help in reduction of design cycle time for the company. Thus suppliers should develop and grow with the organization. Such a partnership is one of the objectives of TQM.

ALIGNMENT OF QUALITY SYSTEM

The quality system of the vendor should be aligned with that of the company. Now that the ISO 9000 standards have been accepted worldwide, it would be better to help the vendor to establish the quality system meeting ISO 9000 standards. Even otherwise, the company should train the vendors employees to establish a system for managing quality. Any assistance by the company in this direction will pay for itself in terms of improved quality of supplies. Once the quality systems in the company and its vendors are aligned, then the effort of the company to check quality of supplies will greatly be reduced. In the modern times, as Toyota standards confirms, every company wants to trust suppliers to provide them with defect free-supplies. They don't want to inspect the supplies. Therefore it is all the more important to ensure alignment of quality systems.

QUALITY AUDIT

At periodic intervals, the company should carry out formal second party quality audit to check the effectiveness of the vendor's quality system. The quality audit will be carried out as per the agreement with the vendor with regard to the elements of quality system covered by the contract. The agreement may stipulate the requirements of the relevant clauses of ISO 9000 standards either partly or fully. The scope of the audit should be documented. During each audit, correction of non-conformities observed during previous audits should be checked, before assessing the quality system and finding new points for improvements. No doubt such quality audit with a large numbers of vendors will cause expenditure to the organization, but it is worth doing in order to align the quality system of the vendors with that of the organization.

PRODUCT AUDIT

A thorough evaluation of vendor's products at periodic intervals is required to assess the quality of their design and manufacturing. For this purpose, the company should pick up samples at random from the vendor's premises and get them evaluated in an independent test laboratory or in their own test laboratory. This testing should be carried out as per the specifications agreed to between both the parties. Generally the materials and products should comply with national or international standards. This may also involve tests to confirm their reliability. The vendor should inform the company whenever design changes are made so as to carry out another evaluation, if needed. The type testing or qualification approval testing or product audit as above should be repeated at periodic intervals, say once in three years to check the continued suitability of the supplies.

INCOMING INSPECTION

Appraisal or incoming inspection of materials on sampling basis may be required although the supplier would have already inspected the items before shipment. The company should gradually make the supplier to take the full responsibility for the quality of the supplies. However, the company should not accept the materials without any checking. Initially the company may be carrying out the inspection on sampling basis, with more detailed measurements on the incoming materials. As confidence is gained, the company can reduce the level of inspection. Nevertheless, they should continue to carry out inspection on sampling basis. The results of inspection should be communicated to the vendors, immediately without loss of time, so that it will alert them for improving quality.

SUPPLIER RATING

The vendors are to be continuously assessed / rated, based upon the performance of the supplies with respect to some or all of the following parameters:

- Quality
- Price

- Delivery
- Services.

There exist national standard specifications on the topic of vendor rating. Vendor rating is an objective oriented method of continuous assessment of the supplier's ability to supply on time, with quality, at the agreed prices and as per the requirements of the company. Each supplier should be rated on the basis of every lot of materials supplied. Such rating should also be communicated to the vendors. The company should take steps to see that the rating of the vendors improve continuously. If the rating is constant or it falls, then the company has to make efforts to improve the quality of the suppliers. Each company should develop a procedure for vendor rating and such procedures should be communicated to all the registered vendors. An example of vendor rating[2] is given in the following section.

VENDOR RATING SYSTEM

Vendors may be rated based on any or all of the following factors:

(a) Quality,
(b) Price
(c) Delivery, and
(e) Service

Quality Rating – Quality Rating (Q_R) for a lot or consignment is given by:

$$Q_R = \frac{Q_1 + X_{1*}\, Q_2 + X_{2*}\, Q_3}{Q}$$

Where

Q_1 = quantity accepted

Q_2 = quantity accepted with deviation,

Q_3 = quantity accepted with rectification,

Q_4 = quantity rejected,

Q = total quantity supplied $= Q_1 + Q_2 + Q_3 + Q_4$

x_1 = demerit factor (less than one) when material is accepted with deviation, and

x_2 = demerit factor (less than one) when material is accepted with rectification.

The values of x_1 and x_2 are to be decided by the management.

Example 9.1

In a lot of 100 components of type X supplied by vendor A, 60 were accepted. Find out quality rating.

$$Q_R = 60/100 = 0.6$$

Price Rating – Price rating (P_R) for a lot or consignment is given by:

$$P_R = P_L/P$$

Where

P_L = Lower of the prices quoted by vendors for the item, and

P = Price quoted by the vendor being rated.

Example 9.2

The lowest price of component type X is \$4. The vendor A has quoted \$5 for the same type. Find out price rating.

$$P_R = P_L/P = 4/5 = 0.8$$

Delivery Rating – Delivery rating (D_R) for a lot or consignment depends upon the quantity supplied within the stipulated delivery time and also on the actual delivery time for the full consignment. The delivery rating may, therefore, be obtained by the following formula:

$$D_R = (Q_1/Q) \times (T/(T*p + 1.5*T_{1\,*}\,q))$$

where

Q = quantity promised to be supplied within the stipulated delivery time

Q_1 = actual quantity supplied within the stipulated delivery

T = promised delivery time for the full consignment,

T_1 = actual delivery time for the full consignment,

$p = Q_1/Q$, and

$q = 1 - p$.

Example 9.3

Vendor A was to supply all 100 components in 10 days. He supplied 50 in 10 days and all 100 in 20 days. Find the delivery rating.

Here $Q = 100$

$Q_1 = 50$

$p = Q_1/Q = 50/100 = 0.5$

$q = 1 - p = 0.5$

$$D_R = (50/100) \times (10/\ (10)\ 0.5 + 1.5 \times 20 \times 0.5) = 50/100 \times 10/20 = 0.25$$

Composite Vendor Rating

We have to assign weightages for each of the ratings to get a composite vendor rating for each lot. For some supplies price may be more important, for some item quality may be the most important and so on. Depending on the relative importance, the management has to assign weightages for each of the ratings. For instance, the company arrives at the following weightages for the component type, X.

Rating	*Weightages*
Q_W - Quality	40
P_W - Price	40
D_W - Delivery	20
	100

Now we can arrive at composite vendor rating for the vendor using the formula for the Vendor *A* discussed in the above examples:

$$V_R = Q_W \times Q_R + P_W \times P_R + D_W \times D_R$$
$$= 40 \text{ x } 0.6 + 40 \text{ x } 0.8 + 20 \text{ x } 0.25 = 61$$

Thus composite vendor rating can be arrived at for each lot supplied by a vendor.

Vendor rating for a product is obtained as weighted average of the ratings for the lots received over a period of time. This may be computed by the following formula:

$$\text{Average rating} = \frac{n_1\ VR_1 + n_2\ VR_2 + n_3\ VR_3 + \ldots.. + n_k\ VR_k}{n_1 + n_2 + \ldots\ldots + n_k}$$

where,

VR_i = vendor rating of i_{th} lot, and

n_i = lot size for i_{th} lot.

Based on the vendor rating calculated above, each vendor may be classified into three classes. An example to illustrate the classification scheme is given below:

Rating obtained	*Class of vendor*
90 and above	A
80 to 90	B
Below 80	C

Example 9.4

The composite vendor rating and the lot size of supplies of vendor A in the month of January 2004 is given below:

S.No	*Lot size*	*CVR*
1	100	60
2	100	58
3	100	72
4	100	74
5	100	76

Find out the rating of the vendor

$$\text{Average rating} = \frac{100 \times 60 + 100 \times 58 + 100 \times 72 + 100 \times 74 + 100 \times 76}{100 + 100 + 100 + 100 + 100} = 68$$

Thus, vendor A has been rated based on supplies made by him in January 2004. Similarly other vendors can be rated.

PROPER COMMUNICATIONS

Although the intentions are good, the relationship between the vendor and the vendee may deteriorate due to inadequate or improper communications. The company should formulate a clear specifications for each raw material that is bought. A copy of the specifications and its latest amendments if any, should be made available to the vendor. In fact, the specifications for the raw materials should be a controlled copy, with the vendor being given a controlled copy of the specifications. Whenever changes are made to the controlled documents, copies of the amendments should be automatically given to the holders of the controlled documents. In case of controlled documents, holders of the documents are recorded and they are given copies of every amendment. The purchase order should contain the requirements in clear terms. The quantity required, the style or applicable specifications, inspection requirements, delivery instructions, etc. should all be communicated clearly. Faster communication modes such as fax and email could be utilized to improve the communication between the vendor and the vendee. The supplier's seminars, the visit of executives from the company to the vendor and vice versa should be utilized to improve the communications and bridge gaps, if any. No doubt, it costs money and time for proper communication with the vendors. But there is no escape from this. If vendor's quality is poor, then the quality of the end product will also be poor. Therefore, in order to practice TQM, communications with the vendor should be good.

SUPPLIER SEMINARS

At regular intervals, the executives of the company should visit the vendors. During the visit, they should also conduct seminar for the employees of the vendors. During the seminar, they should educate them about the latest trends in manufacturing, quality assurance and other related matters. They should also make use of this opportunity to bring out the defects noticed in the materials supplied by the vendor. LG Electronics in India[3] has gone one step further. They take their vendors in India to Korea to expose them to international standards. They help them achieve the rejection rate of 500 parts per million.

SUPPORT FOR IMPROVING INFRASTRUCTURE

The company can help the vendors in improving their infrastructure. They could give short-term loans to help them buy necessary instruments or machinery. They could also allow them to use some of the spare facilities available in the company. Of course, all these should be given on charge basis to avoid any bitterness later on. They can educate the executives of the suppliers about the applicable standards. They could permit the vendors to refer to the standards available in the company. The company should give all possible assistance so that the vendor is able to supply the materials as per requirements, as otherwise the Company has to take additional responsibility for making them in-house or in identifying and developing another vendor. Companies like Maruti Udyog[3] in India have given seed capital to its suppliers to improve their manufacturing facilities.

BONUS AND PENALTIES

The vendors should also be treated carefully and tactfully. They should be motivated to perform better. The measures of motivation can be as simple as timely payment or early payment or even advance payment depending upon the quality of the product supplied. The award-winning suppliers will further improve by conforming to quality and delivery schedules. If the vendor is not up to the mark, minor punishments such as delayed payments may be good enough to correct the performance of the vendors. It is important for the vendor to know that the company monitors his performance. For this purpose, a database on the vendor's history should be maintained by the organizations and regular feedback given to improve their performance continuously.

SUMMARY

Vendor development is of strategic importance because expenditure saved by improving the efficiency and productivity of vendors improves the competitiveness of the company. The vendors should be treated as an extended arm of every organization. They should be involved in development of new products so as to save cost and time. A healthy relationship should be established between the company and its vendors. It will be wise to select the right vendors at the first instance. For this purpose, the quality system of the vendors and the quality of their products have to be thoroughly assessed. Vendor rating is quite useful in evaluating objectively the quality, price and delivery of the vendors in an ongoing manner. The company should make the vendor take the responsibility for the quality of the supplies. However, incoming inspection may be required to assess the continued quality of the raw materials and supplies, which will also give data for vendor rating. In the context of virtual corporation, vendor development and supplier's quality are very crucial. Therefore, one of the important requirements for TQM is the supplier's quality, which requires constant monitoring, systematic and sustained efforts by every organization.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. The parameters for vendor rating include
   (a) Price (b) Service
   (c) Delivery (d) All the above
2. Supplier should be treated as
   (a) adversary (b) friend
   (c) partner (d) None of the above
3. Communications with the vendor should be
   (a) Often (b) Rarely
   (c) As needed (d) None of the above
4. Supplier performance should be monitored
   (a) Once a year (b) Lot to lot
   (c) Never (d) None of the above
5. Incoming inspection of supplier should be
   (a) Carried out on 100% basis (b) Eliminated
   (c) Carried out on sampling basis (d) None of the above

II. True or False

1. Supplier seminar shall is essential for vendor development
2. Support for infrastructure can be given
3. Product audit is not necessary
4. Supplier should be selected on price basis alone
5. Quality system should be aligned
6. ISO 9000 certified vendors should be preferred
7. Long-term contracts shall not be entered
8. Irregular supplier should be rewarded
9. Vendee refers to vendor
10. Average vendor rating is the average of composite vendor ratings
11. Prefer large number of vendors for each item

III. Explain Briefly

1. Supplier seminars
2. Vendor rating
3. Supplier selection
4. Product audit
5. Vendor relationship
6. Toyota's supplier partnership program

IV. Solve the Following.

1. Find out composite vendor rating for the following given that $Q_W = 50$, $D_W = 30$ $P_W = 20$, Lot size = 500
   Quantity delivered within the committed date of 5 days = 300
   Balance supplied in 15 days
   Quantity accepted: 350
   Price rating =1.
2. Find out composite vendor rating for the following given that $Q_W = 80$, $D_W = 10$, $P_W=10$
   Lot ordered : 1000
   Quantity accepted = 700
   Quantity accepted with deviation = 200
   Quantity accepted with rectification =100
   Demerit factor for deviation = 0.7
   Demerit factor for rectification = 0.5
   Supply schedule = 45 days
   Quantity supplied within schedule = 400
   Balanced supplied in 60 days
   Price quoted by lowest supplier = \$1
   Price quote by the supplier = \$1.25

3. Find out average rating for a vendor with the following track record:

Lot size	*Composite Vendor Rating*
2000	85
1000	95
500	98
5000	75
10000	65
1500	90

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Chapter 10

Performance Measures

Statistics: The only science that enables different experts using the same figures to draw different conclusions.

—Evan Esar (1899-1995), *Esar's Comic Dictionary*

INTRODUCTION

A world-class organization, whether it is in the public sector or private sector doesn't do different things, but do things differently. They apply performance measurements to gain insight into and come to conclusions about their organization, effectiveness and efficiency of its business processes and people. Such leading organizations do not stop at collecting the performance data, but use them. They use the performance measurement data to drive improvements and successfully translate strategy into action.

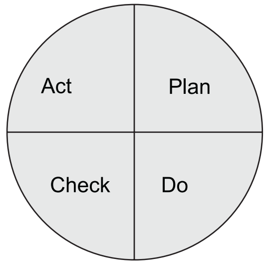
One of the important principles of TQM is to measure for success. Therefore performance should be measured to know clearly whether an organization is achieving its objectives and goals. The objectives of an organization are manifold as illustrated below:

- Achieving business objectives
- Improving response to customers need
- Increasing functionality and improving quality and reliability of the product
- Customer satisfaction
- Reduction of cost of products
- Improving competitive position
- Achieving the required growth rate for survival
- Return on investment
- Making more and more profits!

TQM should enable achieving business results as outlined above. To achieve the above results the organization should device suitable measures. In this chapter, we will also discuss about it and Balanced Scorecard, a new and futuristic approach to performance measurements and management.

PDCA FOR MEASUREMENT

PDCA cycles may be used for determining performance measures as explained below:



PDCA for measurement

Figure 10.1

Plan Phase

During this phase, the possible measures are identified. The right measure is the one that can help the organization to prove a point. For instance, we may want to prove or disprove that customers are satisfied. The performance measures that will clearly lead to such a conclusion should be selected. Carrying out measurement being expensive and important, due care should be given for the same. Approval of senior management may be required for the planned measures.

Do (Measure) Phase

The organization collects data in this phase as per approved procedures on a pilot basis. The procedure will address the following:

- What will be measured?
- Who will measure?
- When it will be measured?
- How? The detailed instructions for measuring.

For instance, we decide to measure customer satisfaction based on feedback forms given to the customers. Therefore we give feedback forms to select customers and ask them to evaluate our product or service based on their experience.

Check Phase

During this phase the results are counter checked through other means. The feedback obtained from customers through feedback form is compared with feedback obtained orally through telephone. An analysis has to be made to validate the methodology adopted.

Act Phase

If the results confirm the reality then the measures can be confirmed during the Act phase. If the feedback obtained through forms more or less indicated the perceived quality by customers, then we confirm the procedure and adopt it for organization-wide application.

Examples of Measures

Let us now look at some examples of measures.

Customer Satisfaction

- Customer Satisfaction Index (CSI)
- Total number of customers
- Number of repeat customers
- Number of new customers
- Cycle time achieved
- Percentage on time deliveries
- Time taken to accommodate design changes
- Number of change request accepted
- Warranty cost
- Mean time to repair
- Mean time between failures
- No. of customer complaints as a percentage of orders
- Failure cost as a percentage of turnover
- Total quality cost as a percentage of turnover

Quality Measures in Production

- Actual production time as a percentage of planned time
- Cost of scrap / rework
- Machine idle time as a percentage of total production time
- Value of Work In Progress
- Cost of miscellaneous materials such as lubricants as a percentage of production value
- Percentage of billable hours to total time available
- Number of accidents

Quality Measures in R& D

- No. of requirement change requests
- No. of design changes
- Failure costs due to R&D as a percentage of sales value
- Average percentage deviation from project schedule
- Ratio of R&D expenditure to turn over

Quality Measures in Human Resource Management

- Employee satisfaction index (ESI)
- No. of employees suggestions received and implemented
- Training cost per employee
- Number of mentors
- Number of complaints from employees
- Employee attrition rate
- Percentage of employees involved in process improvement
- Training days per employee per year
- Training expenditure as a percentage of turnover

Quality Measures in Purchasing

- Number of deliveries rejected as a percentage of total
- Cost of failures of incoming material
- Cost of incoming inspection
- Number of purchase orders that contain defects
- Production hours lost due to non-availability of materials
- Reorder level.

Quality Measures in Administration and Sales

- Number of invoices with errors
- Number of credit notes with errors

Measures for Financial Performance

- Number of credit notes as a percentage of total invoice
- Average number of debtor days
- Market capitalization growth
- Total turn over
- Total profits
- Growth of turnover and profits per year
- Total outstanding revenue
- Revenue vs expenditure ratio
- Revenue as a ratio of capital investments
- Revenue as a ratio of depreciation
- Quality costs as a percentage of turnover
- Revenue per employees
- Ratio of overhead expenditure to total expenditure

CRITERIA FOR SELECTION OF MEASURES

Adequate attention is required to be given by the management for selection of performance measures. Some criteria for selection are given below:

1. The selected measure should relate closely to the issues, which will require examination. The issues are quality, resource utilization, cycle time, profit, etc.
2. The measures should have high information content.
3. The measures should be sensitive to variations. The measures should quickly bring out variations in product, process or system.
4. The measure should really reflect the degree to which the processes achieve goals of the organization.
5. The measures should permit easy and economical collection of data.
6. The measures should facilitate consistent collection of well-defined data.
7. The measures should help the organization to identify occurrence of special cause variations.
8. The measures should be easily understandable and implementable.
9. A few vital measures than many trivial measures should be selected.
10. The measures should be identified by or acceptable to the process owners.
11. The measures should reflect the needs of internal customers namely employees and external customers.
12. The measures should facilitate improvement actions.
13. The measures should be obtainable on time for taking corrective and preventive actions.

14. The measures should be aligned to the organization's vision, mission and objectives, i.e. they must be able to bring out how close the organization is to achieving the goals of the organization.
15. The measures should be able to satisfy all the five stakeholders. Therefore, there has to be a proper balance of measures to satisfy the varying interests of the stakeholders.
16. There should be measures for each process, each section and organization as a whole.

MEASUREMENT STRATEGY

The Quality Council is responsible for formulating strategy for measuring. The measures should be planned after thorough analysis. For each measure the following questions should be answered.

- What is the purpose of measuring?
- How will the measurement result be used?
- Is it important in determining the acceptance of the process or product?

Three Activities of Measurements Planning

The three activities of measurement planning is elucidated in Fig. 10.2 below:

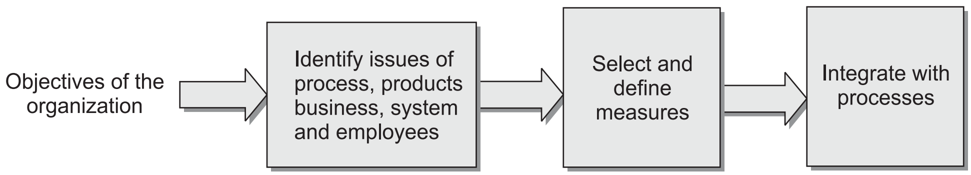


Figure 10.2 Measurement Planning

The relevant issues should be identified from the goals and objectives of the organization. They pertain to process, product, system, employees and business. Then the appropriate measures should be selected to address issues. The selected measures should be defined clearly and unambiguously. Then the measurement process should be planned and integrated with the ongoing processes. The measures should be collected as part of normal work in the organization.

Steps for identifying issues The following steps will help in identifying issues

- Classifying business goals or objectives
- Identifying critical processes
- Listing the objectives for each critical process
- Listing potential problem areas associated with the processes.

Questions for identifying measures

- What determines customers satisfaction?
- What determines quality?
- What determines success?
- What could go wrong?
- What is not working well?
- Where are the delays?

- What can be controlled and what cannot be?
- What is our real capacity?
- How much are we working?
- Are the processes improving?
- Are the products improving?
- Is customer satisfaction improving?

Selecting measures The above will bring out the measures for performance. Some measures will address more than one issue and one question. Some measures, which will address multiple issues and multiple questions are given as follows:

- Product quality
- Process cycle time
- Product delivery quality
- Process cost
- Customer satisfaction
- Employee satisfaction

The measures that will address the six common measures are given below.

Product quality

- Internal failure cost
- External failure cost
- Materials rejected
- Vendor rating
- Cost per piece
- Product quality characteristics
- Percent on time delivery
- Mean time between failures
- Mean time to repair

Process cycle time

- Set up time
- Total cycle time

Product delivery quality

- Wrong shipments
- Delayed delivery
- Product delivery with defects
- Products returned to supplier

Process cost

- Cost of work in progress
- Down time of machinery
- Material cost
- Per cent reduction in floor space

Customer satisfaction

- Sales growth

- Profit growth
- CSI
- New customers
- Customer attritions

Employee satisfaction

- Employee productivity
- Employee absenteeism

PERFORMANCE MEASURE DESIGN

The performance measure should be designed to answer the following questions:

1. What is the measure?
2. What is the objective of the measure?
3. What is the expected output of the measure?
4. What is the required input?
5. How the measure is arrived at?
6. Who is the owner of the measure?
7. What is the information required for data collection?
   When?
   How?
   Where?
   From whom?
8. Reporting information-report to be given
   To whom?
   Where?
   How?
   When?
9. What records are to be maintained?

Define Measures This is a very detailed activity. Each measure should be clearly defined. The following should be defined for each measure.

- Who will measure?
- What will be measured?
- How it will be measured?
- Training required for measuring
- Data format and organization of results
- Quality checks on data
- Data analysis

Integrating with Process

The success lies in integrating the measures with the existing processes. Every employee should be given responsibility to measure in addition to executing the process. Thus, the measures should become internal part of the processes.

Use of 7 QC Tools for Performance Measurement and Analysis

The seven QC tools discussed in the next chapter should be used for presentation of process measures. The process flow chart can be used for selecting and defining measures, cause and effect diagram can be used for carrying out brainstorming to

(1) Select measures
(2) To discuss cause of poor performance as revealed by the measures.

The Pareto Diagram can be used to identify a few vital causes, which contribute either to success or failure. Capability studies should be carried out for all critical process and control charts will be useful for this purpose. Data collection can be carried out using Tally sheets.

Objectives of Performance Measurements

The following are some of the objectives of measuring performance:

- Assess performance against goals. If there are gaps, take action to improve.
- Achieving the goals to:
  - (i) Meet the competition
  - (ii) Enhance customer satisfaction
- Communicate goals
- Improve process by stimulating improvement and innovation
  - (i) Identifying opportunities for improvement
  - (ii) Motivating employees
  - (iii) Locating problem areas
- Feedback
  - (i) Enabling comparison with world's best practices
  - (ii) Recording achievements and fixing new goals
  - (iii) Giving a feedback about improvements needed
  - (iv) Transferring responsibility for improvement to employees

Tasks Involved in Measuring Performance

Establishing commitment The performance measures should have the backing of the middle and senior management. Therefore, the idea should be sold to them to get their commitment.

Setting strategic objectives The strategic objectives should be set taking into account the following:

- Vision, mission statements and objectives of the organization
- Benchmarking findings
- Undertaking survey about competitor's capabilities
- Undertaking survey about customer requirements
- Defining critical success factors
- Defining strategy to improve performance

Defining measures

- Defining measures for each key business process area

Ownership

- Defining the boundaries of the processes assigned to the owner for the measurement

Checklist for Performing Measures

The performance measurements should fulfill some of the criteria given below:

1. Performance measurements should be consistent.
2. The measure should lead to getting a balanced view leading to financial performance, customer satisfaction, internal quality, efficiency, productivity improvement.
3. They should be relevant to the activity.
4. They should be simple to understand.
5. It should be easy to collect data and arrive at conclusions.
6. They should be implementable by lowest level employees in the organization.
7. They should be measure with appropriate scale such as per cent defects, or per cent deviation, etc.
8. They sould be based on strategic objectives and making general goals more specific.
9. They should be a reflection of short and long-term objectives.
10. They should be oriented towards objectives of business process.
11. They should only be a few and vital.
12. They should be useful for stimulating improvement.
13. They should be dynamic, i.e. the measures should reflect the dynamic nature of the business.
14. They can be integrated into a management process and reward management systems.
15. They should be agreed to by employees and not imposed by management.
16. They should be fit for public display at prominent places in the organization.

Measures to be Avoided

Followings are the kind of measures that are best avoided.

- Expensive
- Difficult to implement
- Trivial or viewed as trivial
- Conflicting with other measures
- Producing misleading information
- Short-term in nature

We will now look at an effective tool for performance measures and management, namely the Balanced Scorecard.

BALANCED SCORECARD (BSC)

According to Stephen Covey[1], "People and their managers are working so hard to be sure things are done right, that they hardly have time to decide if they are doing the right things". For doing right things, an organization needs the right business strategies. Right strategies will result in continuously improving operations to deliver the products and services right the first time and every time. However, in many organizations, there is a gap between strategic planning and execution of strategies. That is the reason, why they fail to achieve their vision. According to 1998 Fortune Magazine article, an estimated 70 per cent failures of initiatives of senior executives are not caused by a poor strategy, rather by poor execution of the strategy. Many organizations look at the bottom line of balance sheets to determine success. No doubt, good financial results are the success of the strategies in the past. They are lagging indicators or delayed snapshots to know whether they were successful in the past. Therefore, an organization needs leading indicators for ensuring success in the future. The leading indicators provide an early indication of whether an organization will achieve its business goals or will it be able to sustain these achievements in the future. That should be the right business strategy.

History of the Balanced Scorecard

Robert S. Kaplan and David P. Norton published an article in the Harvard Business Review Jan-Feb. 1992, called "The Balanced Scorecard - Measures that Drive Performance"[2]. The article stressed the importance of not relying solely on financial measures to measure organizational success. It stressed the need for balance between short-term and long-term objectives, between financial and non-financial measures and between internal and external performance measures. Balance is necessary for efficient and effective movement of the organization and reaching the fullest potential. The performance measurement systems must achieve a balance, which supports progress of the organization vis-à-vis its objectives. This is essential because the financial results are enabled by a number of factors as follows:

- Customer satisfaction
- Supplier satisfaction
- Employee satisfaction
- Efficient processes
- Modern technology
- Good organizational culture

Balanced Scorecard Perspectives

Balanced Scorecard (BSC) is a conceptual framework for translating the organization's vision into a set of performance indicators distributed among four perspectives. The four perspectives are:

- Learning and Growth Perspective
- Business Process Perspective
- Customer Perspective
- Financial Perspective

Performance indicators are used to measure an organization's progress towards achieving its vision. An organization monitors both its current performance (financial, customer satisfaction and business process results) and its efforts to improve processes, motivate and educate employees and enhance information systems - its ability to learn and improve.

The balanced scorecard developed by Kaplan and Norton provides a strategic framework for identifying and linking the enablers with the desired results by defining the relationships between performance levels in four distinct perspectives. BSC can be applied both in commercial organizations as well as in the public sector.

Customer Perspective This perspective captures the ability of the organization to provide quality products and services, the effectiveness of their delivery systems and overall customer service and satisfaction. Customers include both internal as well as external. It must provide answer "To the question "To achieve our vision, how must we look our customers?"

Financial Perspective The financial perspective is different for public and private sector. Private sector's financial objective generally represents clear long-range targets for profits for the organizations. Success of public organizations should be measured by how effectively and efficiently they meet the needs of the target sector. Therefore, for the government, the financial perspective captures cost, efficiency, delivering maximum value to the customer, etc.

Internal Business Process Internal business processes are the mechanisms through which performance expectations are achieved. It should provide answer to "To satisfy our customers' value proposition as well as to satisfy our other stakeholders, what process must we excel at?" This perspective provides data regarding the internal business results against measures that lead to financial success and satisfied customers. To meet the organizational objectives and customer's expectations, organizations must identify the key business processes at which they must excel. Key processes are monitored to ensure that the outcomes are satisfactory.

For instance, a software organization must excel at the 18 key process areas (KPAs) of Software Capability Maturity Mode (SW-CMM) of Software Engineering Institute. Those organizations that excel at all KPAs are considered to be at level five. Level five software companies satisfy all stakeholders and achieve success in all the four perspectives. Thus, internal business process perspective is quite important.

Learning and Growth This perspective captures the ability of the employees, the quality of the information system and organizational alignment to manage the business and adaptability to change, in supporting accomplishment of organizational goals. Processes will be successful, only if adequately skilled and motivated employees are used and they are provided with accurate and timely information. In order to meet customer requirement and customer expectations, employees may be required to take on new responsibilities, which require skills, capabilities, technologies that were not available before. The employees should ask the question "If we are to succeed, what must we do to learn and improve?" To quote[2] Kaplan and Nortan, to satisfy this perspective of BSC, the organizations must ask "To achieve our vision, how will we sustain our ability to change and improve?".

Thus, Kaplan et. al. described the balanced scorecard as a framework for translating an organization's vision into a strategy by focusing on shareholders, customers, and internal and external processes and learning requirements, which collectively describe the strategy of an organization and how the strategy can be achieved.

Balanced Scorecard—a Management System

The balanced scorecard is a new approach to strategic management. The balanced scorecard is not only a measurement system, but also a management system. It enables organizations to clarify their vision and strategy and translate them into action. It provides feedback around both the internal business processes and external outcomes in order to continuously improve strategic performance results.

Kaplan and Norton describe the innovation of the balanced scorecard as follows:

> "The balanced scorecard retains traditional financial measures. But financial measures tell the story of past events, an adequate story for industrial age companies for which investments in long-term capabilities and customer relationships were not critical for success. These financial measures are inadequate, however, for guiding and evaluating the journey that information age companies, must make to create further value through investment in customers, suppliers, employees, processes, technology, and innovation".

The balanced scorecard suggests that we view the organization from four perspectives as given in Fig. 10.3 and to develop metrics, collect data and analyze it in relation to each of the four perspectives.

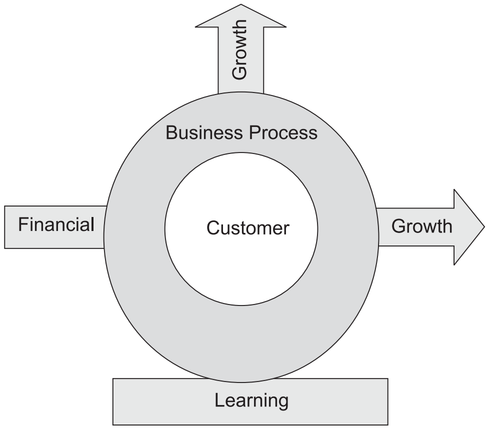


Figure 10.3 Perspectives of Balanced Scorecard

The customer is the nucleus of the whole business. Business processes are aimed at delighting the customers. This needs continuous learning of the employees, which is the foundation of the organization. All these lead to financial growth, which will be visible.

Metrics

Essentially we have to collect the metrics from all the four perspectives to get a balanced view of the current status and make realistic plans for improvement in the future, so as to consistently be in business and be growing.

The metrics must be developed based on the priorities of the strategic plan. Processes are then designed to collect information relevant to these metrics and reduce it to numerical form. This will enable the management to examine the outcome of various plans and strategies and track the results to guide the company and provide feedback to employees and suppliers. The metrics of balanced scorecard enables the following:

- Strategic feedback to show the present status of the organization from many perspectives for senior management as well as employees.
- Feedback on various processes to guide improvements on a continuous basis.
- Trends in performance over time.
- Quantitative inputs for forecasting and use in models for decision support systems.

Let us look at the metrics for the four perspectives briefly:

Metrics for Learning and Growth Perspective One of the important contributions of balanced scorecard is to reiterate that the employees are very important assets to an organization. The training and learning of the employees will keep the organization growing. The central idea of this perspective is that the senior management take steps to convert their business into a learning organization, in which knowledge of employees is the key resource. Therefore, the management consistently ponders over as to how to enhance the skills of the employees through training, continuing education and appropriate mentoring. Such knowledge acquired should be preserved through appropriate means. The knowledge should be shareable. The Intranet is a promising tool for sharing and storing the learning in the organization. Some of the metrics that will indicate whether the organization is investing in this area are the funds provided for training, effective implementation of training programs, growth of employees and in turn improvement of quality.

Metrics for Business Process Perspective The metric should be designed to indicate how well the business processes are being carried out. Measures for this perspective can be designed only through intimate knowledge of the processes. The metrics collected should address this perspective and help the management in understanding the current status of processes, product and services. This will in turn facilitate identifying the goals and targets for the future.

Metrics for Customer Perspective It has been proved beyond doubt that customer delight and customer focus are the key to sustain business. The metrics derived from customer perspective should help the organization to understand the level of customer orientation of the organization and the customer satisfaction achieved. A good score on this front would ensure success in the future. Even if the current bottom line is good and if the scorecard of customer perspective is poor, then the organization will collapse may be in a few months or years. But, if the current bottom line is bad and if the scorecard in customer perspective is good, the organization will surely perform well and reap the benefits in the near future.

Metrics for Financial Perspective This is the only perspective on which the traditional organizations measure success. Kaplan, et. al. give equal weightage to the financial performance, the traditional measure. The organization should build a corporate database for collecting and analyzing financial data. There is a need to include additional financial related data, such as risk assessment and cost benefit data, in this category. Currently, in a traditional organization, the financial perspective is unbalanced. What is needed is to balance the financial perspective with the other three perspectives just discussed above.

An example of metrics of a typical manufacturing organization is given below:

CUSTOMER	
Objective	Measure
Customer Satisfaction	1. Per cent of customers satisfied with timeliness 2. Per cent of customers satisfied with quality
Effective service Partnership	% of customers satisfied with the responsiveness, cooperation and communication skills of the Customer Service Team

Finance	
Objective	Measure
Reduce Quality Cost	Quality Cost

Internal Business Processes	
Objective	Measure
Reduce WIP	Cost of WIP as a per cent of turnover
Reduce Defects	No. of defects found: ☐ Internal ☐ External

Learning & Growth	
Objective	Measure
Information Availability for Strategic Decision Making	1. Extent of reliable management information
Quality Workforce	1. Per cent of employees meeting mandatory Qualification standards
Employee Satisfaction 1. Quality Work Environment 2. Executive Leadership	1. Per cent of employees satisfied with The work environment 2. Per cent of employees satisfied with the professionalism, culture, values and Empowerment

Figure 10.4 Example of Metrics

Six Steps for Building Balanced Scorecard

The articles and books by Kaplan and Norton have helped the management fraternity rediscover the basic concepts such as employee empowerment, customer satisfaction, and continuous process improvement. Vice President of the Balanced Scorecard Institute Institute, Howard Rohm, has given a six-step process to build an organization's balanced scorecard. These steps to build a balanced scorecard are discussed as follows.

Step 1 The organization should assess its foundations, vision, its core plans, market opportunities, competition, financial position, short-and long-term goals and an understanding of what satisfies the customers?

Step 2 The organization should develop an overall business strategy. Some of the common themes are:

1. Build the business
2. Improve operational efficiency
3. Develop new products
4. In case of a public sector organization
   - Build a strong community
   - Improve education
   - Meet citizens requirements better

Step 3 When an organization has understood its own business and derived the overall business strategy, based on that, it has to now decompose the business strategies into small components called objectives. Objectives are the basic building blocks of strategy - the components or activities that make up complete business strategies. For instance, an organization may like to diversify its products range, which is an example of an objective.

Step 4 A strategic mapping of the organization's of overall business strategy is created. This may be achieved through the cause and effect diagram.
An example strategic mapping to improve customer satisfaction is given in fig. 10.5.

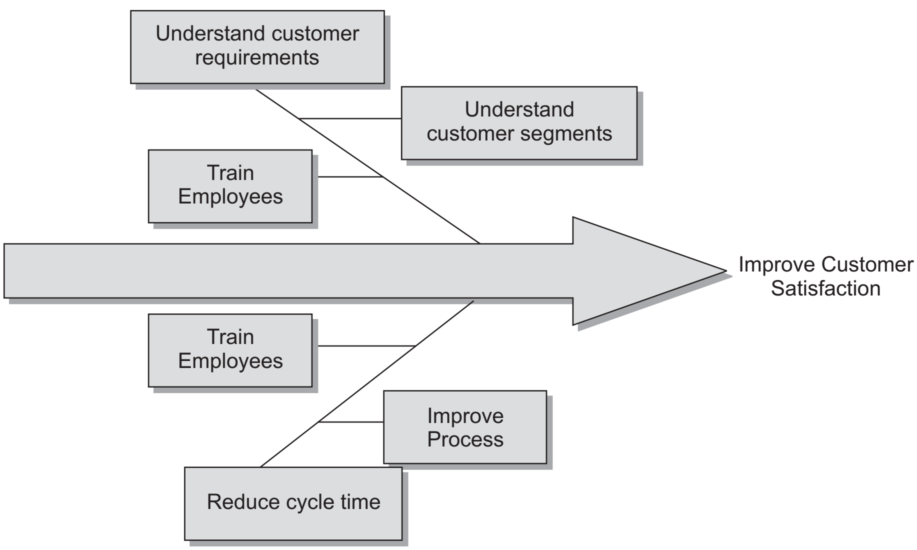


Figure 10.5 Strategic mapping to improve Customer satisfaction

Step 5 The strategic map will give the metrics to be collected straightaway. During this phase, the performance measures are developed to track both strategic and operational progress. To develop meaningful performance measures, one has to understand the desired outcomes and the processes that are used to produce the outcomes. Desired outcomes are measured from the perspective of internal and external customers, and processes are measured from the perspective of the process owners and the activities needed to meet customer requirements. We use the strategic map developed in the previous step and specifically the objectives to develop meaningful performance measures for each objective. We should evolve a few vital performance measures, which will be the key performance drivers, the critical to overall success. The performance measures will certainly provide a continuous learning framework for measuring and managing both strategic and operational performance. Therefore, at this stage the organization identifies and develops meaningful metrics and the expected level of performance is common to targets.

Process flow-charting will help in identifying the measures. The casual analysis helps the organization in identifying the causes and effects of good performance. The organization should start with the result (the effect we want to achieve) and then identify all the causes that contribute to the desired result. The causal model is most useful for identifying input and process measures, which are the leading indicators of future results.

Step 6 New initiatives that need to be funded and implemented to ensure that the organization's strategies are successful are identified. At this stage, the organization knows what should be the initiative that will help the organization to meet its objectives.

Planning for BSC

Deming emphasizes that all business processes should be apart of the a measurement system with feedback loops. The managers should examine the feedback data to determine the causes of variation at each step in a process, should identify the processes with significant problems, and then focus their attention on improving that subset of processes. Deming’s PDCA cycle can be used to implement a philosophy of continuous product and process improvement.

BSC can be used for performance improvement in a systematic manner. The organization should plan for the following from each perspective.

- Objectives
- Measures
- Targets
- Initiatives

A blank data sheet for planning purposes is given in Fig. 10.6.

The above data sheet provides a template for planning for process improvement. It summarizes each perspective for ready reference. Then the BSC team can formulate objectives of the organization from each perspective. This will lead to identifying corresponding measures, targets and initiatives required for achieving the target.

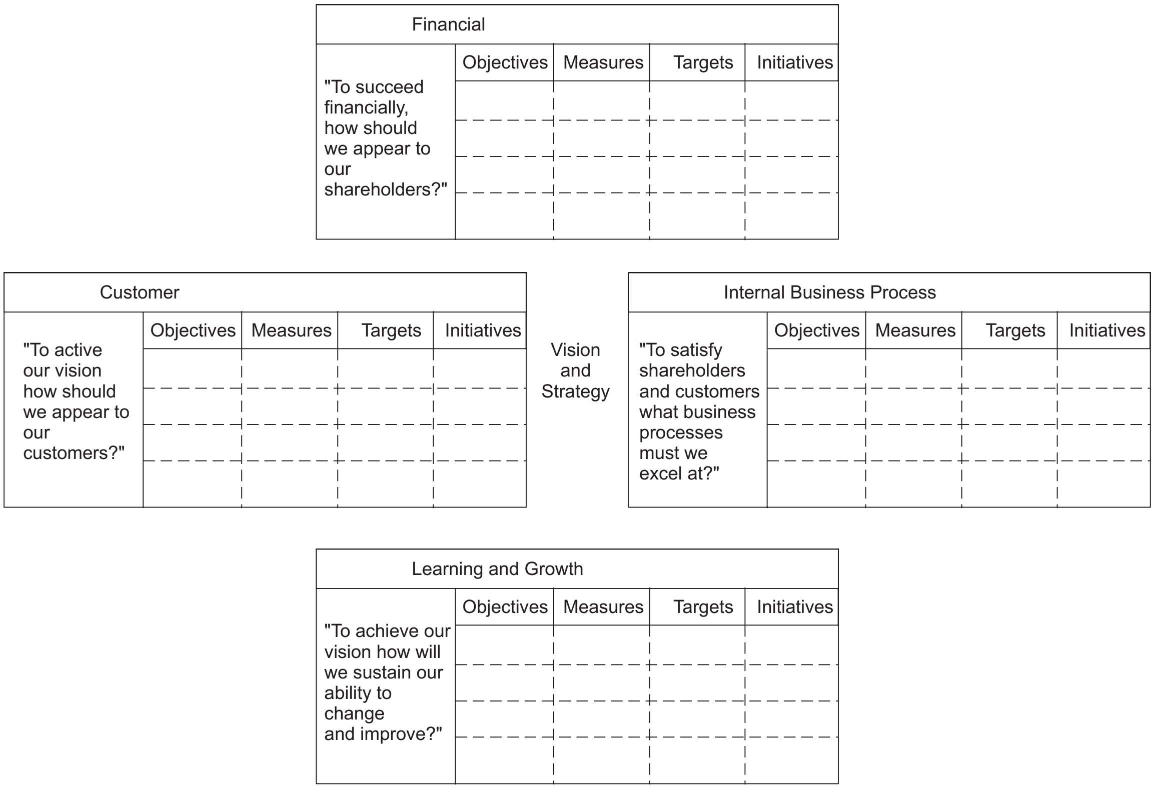
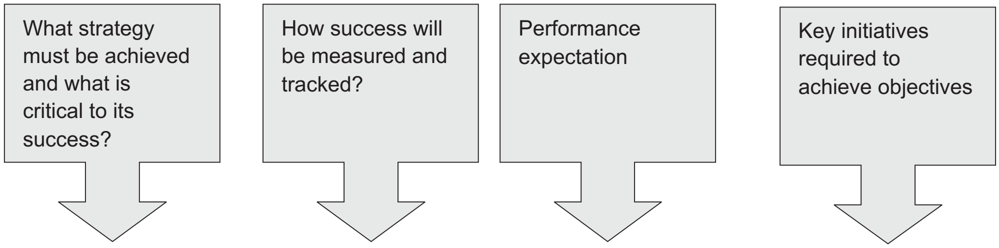


Figure 10.6 Data sheet for planning of BSC

Presentation of Balance Scorecard

Once the scorecard of actual measures is available, they can be presented in different forms to meet the needs of the organization: One of the examples of presentation of the balanced scorecard[1] is given in Fig.10.7

The balanced scorecard system provides a basis for executing a lasting strategy for managing organization successfully. The balanced scorecard provides a basis for executing good strategy well and managing change successfully.



	Objective	Measure	Target	Initiatives
Financial	Broaden revenue mix	Revenue mix	10% Product A 40% Product B 50% Product C	➢ Sales Promotions ➢ New Channels of Marketing
Customer	Increase customer satisfaction	Customer retention	95%	➢ Frequent Buyers' Club
Internal	Develop new products	Per cent revenue from new products	1999 – 15% 2000 – 50% 2001 – 60%	➢ R&D Program ➢ Customer Mailing
Learning & growth	Develop strategic skills	Cross-train	90%	➢ Custom Training ➢ Knowledge Library

Figure 10.7 Linking Scorecard Components

PERFORMANCE BASED MANAGEMENT SYSTEM

The key steps in performance-based management are given below:

- Define mission and goals
- Measure performance
- Use performance information
- Sustain performance based management

The various steps involved in performance-based management are[3] given below.

Key steps in performance based management

1. Define Mission & Goals (including Outcome-Related Goals)
   (a) Involve key stakeholders in defining missions and goals
   (b) Identify key factors that could significantly affect the achievement of the goals
   (c) Align activities, core processes and resources to help achieve the goals
2. Measure Performance
   (a) Develop a set of performance measures at each organizational level, which are limited to the vital few, respond to multiple priorities, link to responsible programs and are not too expensive.
   (b) Collect sufficiently complete, accurate and consistent data to document performance and support decision-making at various levels.
   (c) Report performance information in a way that is useful.
3. Use Performance Information
   (a) Use performance information to improve performance
   (b) Communicate performance information to key stakeholders and the public
   (c) Demonstrate effective or improved program performance
   (d) Support policy decision making
4. Sustaining Performance-Based Management
   (a) Devolve decision making with accountability for results.
   (b) Create incentives for improved management and performance
   c) Build expertise in strategic planning, performance measurement and use of performance information in decision making
   (d) Integrate performance-based management into the culture and day-to-day activities of the organization.

To summarize, the balanced scorecard helps an organization to look at multiple strategies for balanced growth of the organization. The aim of this exercise is to put the organization at a sound footing and give a futuristic orientation, which will not only enable better financial performance at the present, but also in the future. This can be achieved only if there is a balanced growth comprising the employees, processes, customer satisfaction index as well as financial indices.

CASE STUDY

AT&T, Canada[4]

With losses totaling more than one million a day and with rapidly degrading company morale, the focus was stuck on survival for the telecommunications firm known as Unitel.

Shareholders from diverse industries were in conflict over what strategic direction to pursue, except for one CEO. The need for executive leadership was great. Bill Catucci, the third CEO in a five-year period, was determined to succeed.

His direction was radical and he managed the business as an integrated enterprise, not as individual functions within business units. He saw the balanced scorecard and supporting governance and management processes as a vehicle for achieving his vision: A company that would be perceived as a leader with customers, employees, shareholders, and community.

During the three years of Catucci's leadership, the new company called AT&T Canada accelerated its annual growth rate to 32 per cent, compared to the industry average of just four percent. Overall service revenues increased by 15 per cent, with an 11 per cent rise in revenue per employee.

ATTRIBUTES OF SUCCESSFUL PERFORMANCE MANAGEMENT SYSTEM

A performance management system will be successful if properly formulated and implemented. The key attributes of a performance management system are as follows:

- A documented conceptual framework is needed for the performance measurement and management system.
- Effective internal and external communication are the keys to successful performance measurement.
- Accountability for results must be clearly assigned and well understood.
- Performance measurement systems must provide intelligence to decision makers, not just compile data. Performance measures should be limited to those that relate to strategic organizational goals and objectives, and that provide timely, relevant, and concise information for use by decision makers—at all levels—to assess progress toward achieving predetermined goals.
- Rewards, and recognition should be linked to performance measurements.
  Financial and non-financial incentives linked directly to performance. Such a linkage sends a clear and unambiguous message to the organization as to what's important.
- Performance measurement systems should be positive, not punitive. The most successful performance measurement systems are not "gotcha" systems, but learning systems that help the organization identify what works—and what does not—so as to continue with and improve on what is working and repair or replace what is not working.
- Results and progress toward program commitments should be openly shared with employees, customers, and stakeholders. Performance measurement system information should be openly and widely shared with an organization's employees, customers, stakeholders, vendors, and suppliers.

SUMMARY

One of the important principles of TQM is to measure for success. Therefore, the organization should evolve performance measures to carry out analysis and plan for improvement. In this chapter, we discussed about some measures pertaining to various activities of the organization. We also discussed about the criteria for selection of measures and measurement strategy. Recently, Kaplan and Norton published an article in the Harvard Business Review called “The Balanced Scorecard—Measures that Drive Performance”, which gave a new thrust to performance based management. The balanced scorecard is a mechanism to identify measures that will enable the balanced growth of the organization.

Financial measures are lagging indicators, they show what happened in the past. What we would like to have are some leading indicators to get an idea of what may be ahead. The balanced scorecard offers an alternative to the traditional financial indicators and explains what has to be measured in order to assess the effectiveness of strategies. The balanced scorecard is a leading indicator.

The balanced scorecard has to be evolved from the following perspectives: learning and growth, business processes, customer, financial. It appears that the balanced scorecard is a promising performance measure. The balanced scorecard provides leading indicators meaning that these measures indicate the future performance of the organization. On the contrary, in a traditional organization, measure of financial indicators, is a lagging indicator meaning that it is an indicator of what was achieved in the past. The balanced scorecard is one of the methodologies for evolving performance measures for successful future. It is applicable to all organizations both in the public and private sector, which implement TQM.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. The objectives of the organization include
   (a) Customer satisfaction (b) Return on Investment
   (c) Reduction of cost of products (d) All the above
2. TQM facilitates
   (a) Achieving business results (b) Achieving the required growth rate
   (c) Improving response to customer needs (d) All the above
3. Quality of measures for business include
   (a) Failure cost (b) Employee absenteeism
   (c) Number of employees involved in process improvement
   (d) All the above
4. Measures in financial performance include
   (a) Total profits (b) Total turnover
   (c) Growth rate achieved (d) All the above
5. The Balanced Scorecard is a
   (a) Measurement system (b) Management system
   (c) Strategy for growth (d) All the above

II. True or False

1. Kaplan and Norton evolved the balanced scorecard.
2. The balanced scorecard enables doing right things.
3. The balanced scorecard does not advocate doing things right.
4. The balanced scorecard is an organizational strategy.
5. The balanced scorecard helps us to translate vision into strategies.
6. The balanced scorecard is not related to performance measures.
7. Quality cost is not relevant to performance measures.
8. Financial performance is not relevant to performance measures.
9. Failure is due to poor strategies by and large.
10. Failure is due to poor implementation of strategies.
11. The balanced scorecard can be used in organization of any size.
12. The balanced scorecard finally results in a set of measures.

III. Explain Briefly

1. Measures in the financial perspective
2. Measures in learning perspective
3. Measures in customer perspective
4. Measures in the internal business process perspective
5. Relevance of performing measurement to TQM
6. How the balanced scorecard helps in doing right things?
7. The linkage between objective, measure, target and initiative with an example
8. The myth that financial performance is the most important measure.

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Section **III**

Statistical Process Control

In the last chapter, we discussed about performance measures. One definition of TQM is application of quantitative techniques for improvement of processes in organizations. Statistical process control facilitates application of quantitative techniques whereby we can express the performance of processes in hard numbers. Thus, this section is devoted to learning statistics based process control techniques. For the sake of convenience this section is presented in four chapters as follows:

Chapter **11**

The Seven Quality Control Tools and Introduction to Statistics

An adequate science of control for management should take into account the fact that measurements of phenomena in both social and natural science for the most part obey neither deterministic nor statistical laws, until assignable causes of variability have been found and removed.

—Walter A. Shewhart, 1943

INTRODUCTION

The quality of a product or service depends on the quality of process employed. Therefore, every organization needs to establish a set of well-defined processes for manufacturing of products or design of services. The quality of a process has to be designed and controlled. Processes should produce the products truly as per design. The objective of process control is to control the quality of the processes and ensure that the deliverables are produced as planned. The process characteristics can be measured, analyzed using statistical tools and controlled. The aim of statistics based process control is to produce products and services with quality consistently. The application of statistics to quality control has enabled quick analysis and control of quality in all types of businesses. Application of the tools in the process helped in arriving at solutions to the problems, as well as taking preventive actions. Application of statistical process control and quality control tools, which are known as SPC tools or 7QC tools, are therefore very important for continuous improvement in the TQM journey.

The Statistical Process Control (SPC) has been born out of understanding that variations are inherent in any manufacturing or services. SPC is a tool to control variations and thereafter reduce them continuously. The goals of SPC are:

- Collection of data of performance of products and service deliverables

- Finding out variations
- Analyzing through brain storming and determining the causes and eliminating the causes
- Improving performance of processes continuously

In this chapter we will learn the following:

- Process flow charts
- Cause and effect diagram
- Tally sheet
- Pareto diagram
- Scatter diagram
- Histogram
- Control chart
- Fundamentals of statistics
- Causes of process variability
- Accuracy and precision
- Characteristics of normal distribution
- Standard normal distribution
- Acceptable quality level

PROCESS CONTROL

Usually, the quality of the product or service is planned and expressed in the form of specifications or company standards. The objective of process control is thus to produce the deliverables meeting the specifications by closely monitoring the processes. Each process will have specifications so as to meet the end product quality standards. This requires measurements or examinations during the execution of tasks in the processes. Therefore, the intermediate products should be examined to see the actual performance against the expected performance. If the process is not under control, i.e. the process is not performing as per the specifications; the processes are to be adjusted. After adjustment of the process, performances are to be measured. This process goes on.

The process control should therefore be planned. The intermediate checks or examination or measurements should be planned. The planning involves the type of measurements, inspection measure and test equipment (IMTE) required for the same, collection of data and the associated format, analysis and Interpretation of results and actions to be taken based on the analysis, etc. Therefore, each process owner will require the following:

1. Process flow chart
2. Specifications for the processes
3. Documented procedures for carrying out the tasks and for measurements of process parameters
4. Criteria for acceptance or rejection of the products made
5. Data collection sheets
6. Instructions for recording data, use of the required tools for analysis and carrying out analysis
7. Methodology for adjusting the process based on actual results
8. Training for the process owners in all the above points.

The importance of process control will be evident from the following news item.

The Economic Times
Chennai, February 11, 2004
GM recalls 636,000 SUVs
Michael Ellis, Detroit 10 February

General Motors said on Monday it will recall about 636,000 mid-size utility vehicles, its second major recall in four days.

GM, the world's largest automaker, said there had been two reports of crashes related to electronics that could short-circuit when water leaks into a wiper module. No injuries or fatalities were reported from those two crashes, GM said.

The recall includes certain model year 2002 and 2003 Chevrolet TrailBlazer and TrailBlazer EXT, GMC Envoy and Envoy XL, and Oldsmobile Bravada SUV models, as well as some Isuzu Motors Ascenders, which GM builds, GM said in a statement. Of the total, about 580,000 are in the US and 31,000 are in Canada. GM said dealers will patch a vent hole in the windshield wiper module. —Reuters.

The seven Quality Control (QC) tools are very useful for ensuring process quality and thereby end product quality. We will now learn the first QC tool namely flow-charting which is essential for process control.

TOOL 1: PROCESS FLOW CHART

A process flow chart is a diagrammatic view of the various steps in sequential order that form an overall process in an organization.

Flow charts are used in the quality management for depicting the processes in an easily understandable form. This is used to understand how any job or process is carried out. Every organization has a number of processes; each process with a number of sub-processes with clearly defined inputs and outputs. The processes involve, men, machine, material, methods and specifications, all used for providing a service or manufacturing a product. Although, an organization consists of many processes, all inter-linked together, employees may be aware of the previous and next processes only, particularly in bigger organizations. Very rarely the entire process flow is documented and made available to employees. But, it must be carried out for improved planning, communications and analysis of problems.

Process flow chart should indicate the various steps in the process which means, all the sub-processes and their inputs and outputs are documented in one diagram. Process flow chart is a diagrammatic view of the various steps in the organization. This helps not only the employees, but also the quality system auditors in understanding how the processes are functioning in the organization. As a prerequisite for ISO 9000 certification, process flow charts are insisted and the organizations are asked to document the processes. Although, before starting the operations, the organizations would have had process flow charts, they remain only with the seniors and never get passed on to the employees. Whenever changes are made to the process flow, they are also not documented. The process flow chart should be updated whenever changes are made in the organization and should be available in the shop floor. Some companies display them on the shop floor, which is a good practice.

Steps Involved for Making a Process Flow Chart

The various steps involved in formulating a process flow chart are given below:

- Define the process
- List the steps involved
- Draw the diagram placing the process steps in boxes in the order of their sequence and link each other by arrows
- Analyze the flow chart

The symbols used for drawing the process flow chart are given in Fig. 11.1.

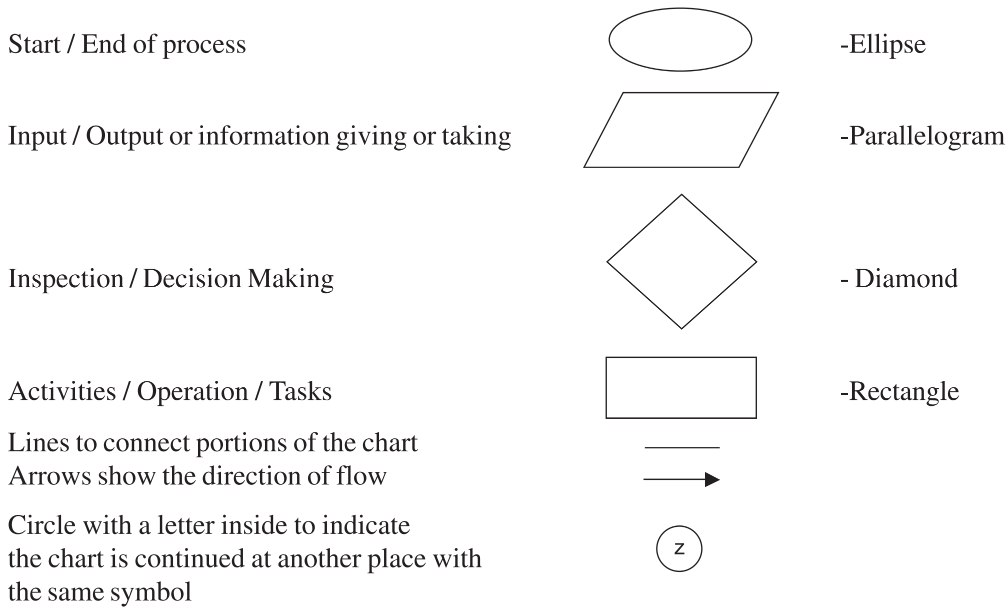


Figure 11.1

The processes should be linked through straight lines with arrow marks indicating direction of the flow. The process flow chart should depict the real process and not what is supposed to be done. An example of the process flow diagram is given in Fig. 11.2.

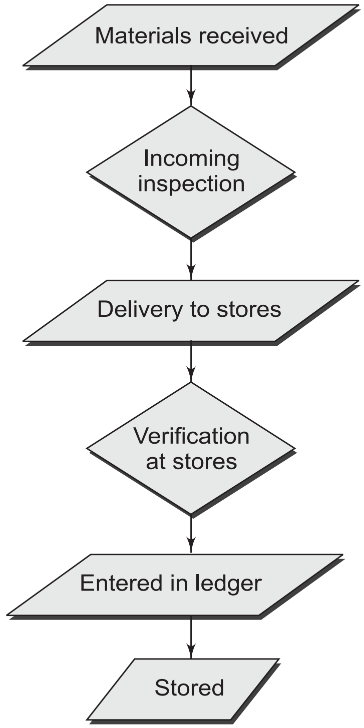
Analysis After the process flow chart is made, it should be analyzed with the following questions:

Points to be checked at the macro level

(a) Are all the steps ecessary?
(b) Is any step missing?
(c) Which are the points of delay?
(d) Can the process be simplified?

Points to be checked for every input

- Are there specified, clear and agreed standards?
- Is there adequate feedback?



Example of a process flow chart for material receipt

Figure 11.2

Points to be checked for every process step

- Is the step necessary?
- Are facilities/equipment adequate?
- Do the operators have necessary skills?
- Is it possible to measure performance?
- What impact a defect in the process will have?

Points to be checked for every output

- Are there specified, clear and agreed standards?
- Is there adequate feedback?

Answer to these questions will throw light about where improvements are needed in the process.

Such a question should be asked not only immediately after process flow chart is made, but also at regular intervals.

Advantages of Process Flow Chart

Although, documenting process flow chart may be difficult and time consuming in larger organizations, there are many benefits which would motivate the organizations to document the process flow chart. Some of them are:

The employees who work in the process understand all the processes in the organization. This illustrates to them the importance of their process in the organization and act as a check against poor quality. This will motivate every process owner to improve quality of his own process.

Since seeing is believing, once the process flow chart is made, it will help the management to analyze and eliminate unnecessary processes and improve the processes for further improving quality.

This improves the communication between the departments. Process flow chart is also very helpful in training the new employees and employees who are promoted from one category to another.

Above all, process flow charts help employees to realize how they fit in the overall process and establishing and understanding internal customer-supplier relationships. Process flow charts are not only to be made, but also to be used. It could be used while discussing about improvements to be made to the process, in the QC meetings, in the presentations about the company as well as in training of the new employees. The process flow chart should be reviewed at regular intervals and efforts made to simplify the processes wherever feasible. Thus, process flow chart is quite useful for every organization.

Once the flow chart for the process is made, the other seven steps given in the previous section on process control can be carried out.

TOOL 2: CAUSE AND EFFECT DIAGRAM

Before looking at the features of the tool, Newton's law of motion may be recalled. According to Newton's law, there can be no effect without a cause. If the quality (effect) is bad, it is due to many causes both known and unknown. Cause and effect diagram helps the user to understand and list out all possible causes and effect or a desired effect.

Prof. Ishikawa at the University of Tokyo developed this tool in the year 1943. Hence, it is known as Ishikawa diagram. Since the diagram is drawn in the shape of skeleton of a fish, it is also called fish bone diagram. The tip of the fish is the effect to be achieved, like improving customer satisfaction or problem to be resolved, reducing schedules or bringing down the cost of production or reducing defects and so on. The effect can be achieved through a number of causes. The causes are written in the bone portion of the diagram. The Ishikawa diagram helps a group of employees to organize the discussions and arrive at all possible causes, which will help in achieving the effect. The causes can be grouped under a number of main causes. Each main cause can have a number of level one causes related to the main cause. Each level one cause, can have a number of level two causes and so on. Ishikawa diagram for reduction of cycle time is given in Fig. 11.3, along with indication of various levels of causes.

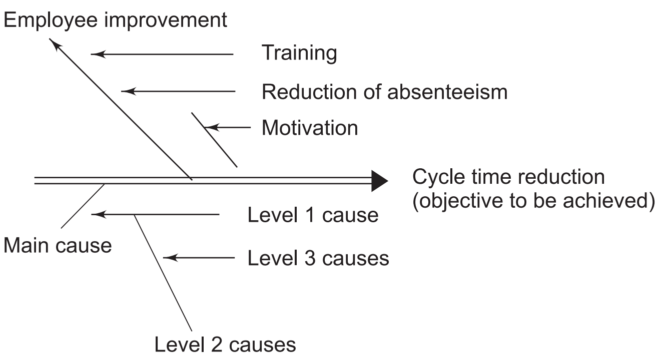


Figure 11.3 Cause and Effect Diagram

The objective of the diagram is to find out ways to reduce the cycle time. While there are many main causes, one of the main causes is of employee improvement as shown in Fig. 11.3. The employee improvement has to be achieved through training and reducing absenteeism, which are the level one causes under the main cause employee improvement. Level one cause of reduction of absenteeism calls for a number of steps, which are to be listed as level two causes. One of the level two causes for the above is improving motivation. Thus, a group of people can sit together and do brainstorming about steps to take the reduce of cycle time. Each person can be asked to give his opinion as to how to improve the process or achieve an objective. The ideas given by each employee have to be put under the appropriate headings/ groups by the facilitator. In fact, it is better that the employees sit around a round table and a white board is used to list out the causes in the diagram. The facilitator should be a trained person who can conduct brainstorming session to come out with the causes for the chosen improvement. The various steps involved in formulating the cause and effect diagram are summarized below:

The first step is to determine the quality characteristics to be improved. It is always easier for people to comment on the negative side. In order to be positive, the same problem can be posed in another manner, i.e. how to improve customer satisfaction. In this case, the points will be focused on the various steps to be taken for improving customer satisfaction. Unnecessary problems may not get projected if the attention is diverted in the positive direction.

The second step is that the teams are allowed to generate many ideas without interruption. Initially, all the ideas can be written down against appropriate main causes. Later on, the team can analyze each idea and remove the over-lapping or irrelevant ideas after a thorough brainstorming.

It may also be essential to review the recommendations. Hence, the team can review what they have written on the next day. Thus, the cause and effect diagram helps the organization in organizing their thoughts for improvement. It provides a structure for brainstorming. It is also a lot of fun, since it is a new method of analyzing one's own work area. This also helps the team members to understand the process better. As time goes, one problem might have been solved, but a new problem could have arisen. Whenever a problem has to be solved, it is better to call the persons who are working in the process and ask them to carry out brainstorming and come out with recommendations. Such recommendations should be implemented by the management. In fact, it would be a good idea if the process owners sit together at least once in three months and find out how they can improve their processes further. For this purpose, the cause and effect diagram provides the framework for channelizing and coming out with recommendations quickly and effectively.

The steps involved in constructing a cause and effect diagram are:

- Identify the end objective
- Construct a skeleton diagram
- Identify the main causes first
- For each main cause, identify next level causes
- Incubate (reassemble after a day or 2)
- Analyze the causes and make recommendations
- Take action

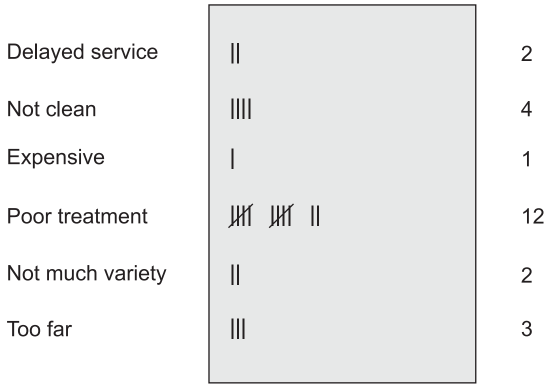
The results are to be measured. This requires data collection. A tool that can be used for data collection is discussed next.

TOOL 3: CHECK SHEET

Quality improvement is an information intensive activity. It is necessary to have correct information about the problems and their causes for enabling quality improvement. In order to make improvements in the process, the following steps are undertaken:

- Formulate precisely the questions we are trying to answer- for instance, Have in-process defects decreased?
- Collect the data and facts relating to that question
- Analyze the data and facts relating to that question
- Present the data in a way that clearly communicates the answer to the question.

Check sheets are a systematic way of recording data. It is also called a tally sheet. Check sheets can be used by even a shop floor level operator very easily. It is quite suitable for on-line data collection and getting a quick review of the process. For instance, if a restaurant decides to find out the dissatisfaction of its customers, a check sheet can be devised as given in Fig. 11.4.



Check sheet to study customer dissatisfaction in a restaurant

Figure 11.4

It can have various causes for customer dissatisfaction as given in Fig. 11.4 like delayed service, not clean, expensive, poor treatment, not much variety, too far, etc. As soon as the client comes to pay the bill at the cash counter, an employee can check what he didn't like. When the customer says what he did not like, a mark can be made against the corresponding category. The fifth tally is in a row is indicated by a slanted line crossing the four vertical tallies as indicated Fig. 11.4. In this manner, the customers' feedback can be taken continuously. At any time, it can be found which category of defect is more. This can give rise to on-line correction of the defects. In this manner, at a given point of time if few customers are not happy with the treatment meted out to them by the waiters, the supervisor can rush immediately and see for himself what is the problem and correct the situation. Thus, time taken for taking a decision based upon data collected is very quick while using the check sheet or tally sheet as a tool.

If an organization wants to compute service delivery time, i.e. the number of days taken from the time of acceptance of the order, it can proceed as given in a sample data as plotted in Fig. 11.5. Here instead of putting a mark, a cross is put in the box.

When a service is delivered, a cross is put at the lowest available box, corresponding to the number of days taken for that job. As and when a service is completed, a cross can be marked at the appropriate

Number of days taken

1	2	3	4	5	6	7	8	9
	X							
	X	X						
	X	X						
	X	X						
	X	X						
X	X	X	X					
X	X	X	X		X			

Service delivery time

Figure 11.5

column as indicated. For instance, if time taken for a job is three days, a cross is put at the next available box from the bottom against three days. One can easily conclude after this chart is made. In this case, generally it takes two to three days for delivery. Thus, this check sheet is very useful to enter data as and when it comes. The time taken for analysis is NIL and immediate conclusions can be arrived at. This method has been used in olden days to count, for instance, the number of bags of paddy brought home from the field or number of goats available in the flock, etc. Similar method can be used for finding out the most probable defects that occur in equipment or utilities. It can also be used to analyze the trends of events such as coming to office, leaving office, etc. This method gives visible results without much of mathematics. Thus, it is useful for getting immediate inference and taking corrective actions.

TOOL 4: SCATTER DIAGRAM

Scatter diagram helps in analyzing the relationship between two variables. For instance, the relationship between absenteeism and errors committed in a manufacturing or service or administrative organization can be plotted in a scatter diagram. In the x-axis, we plot the variable and in the y-axis, the effect of the variable. In the case discussed above, we plot the absenteeism, i.e. the number of persons absent in a day is marked and in the y-axis, the errors committed.

Figure 11.6

Such charts can be used for any real life situations. If a study is conducted about the demand for a particular item at various prices, we may get the data as given in Fig. 11.6. This relationship can be summarized easily as a straight line.

In another situation, the relationship between the number of defects and number of men employed in a service organization is depicted in Fig. 11.7. Here again, this can be approximated to a straight line with the relation $y = mx + C$, where m is the slope and a positive number.

Figure 11.7

The advantage of establishing such a relationship is that once an exercise is carried out in this manner, it is easy to extrapolate the results mathematically for any given situation. For instance, if an equation has been found for the demand for biscuits based on price, then the demand at any given price can be extrapolated.

In practice, there may be some data, which may not lie in a straight line or a curve of known shapes while fitting the curve to get a relationship. An instance is given in Fig. 11.8. In such cases, no definite relationships can be established. At least, we can conclude that there is no relationship between the two entities considered.

Although scatter diagram is a very powerful tool, it can easily be misrepresented. Therefore those who know most about the process or product should evaluate the diagram.

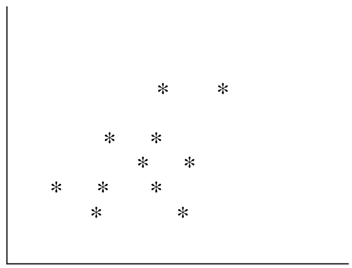


Figure 11.8

TOOL 5: PARETO CHART

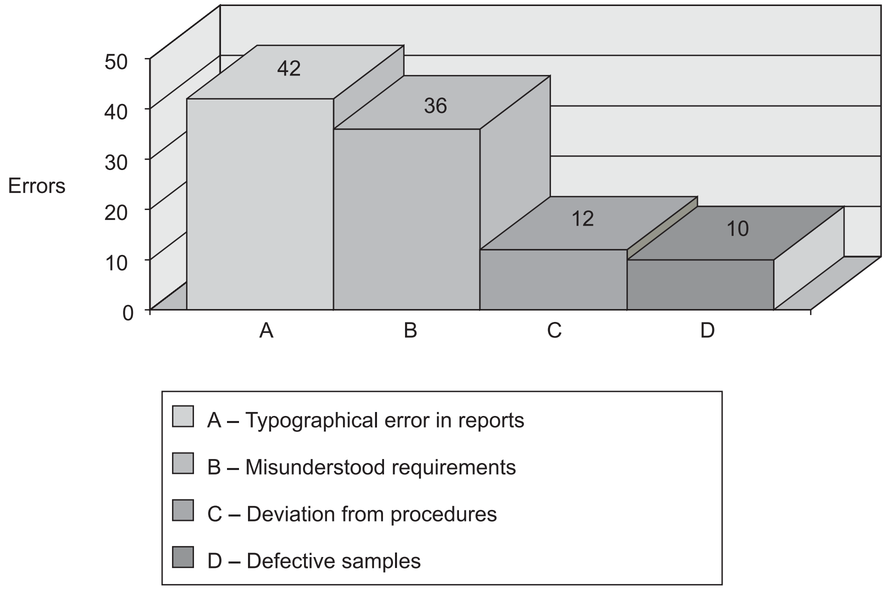
Vilfredo Pareto, a nineteenth century Italian economist, observed that a large share of wealth was owned by relatively few people, a mal-distribution of wealth. Juran defined Pareto principle in the year 1950 in a similar manner. He found that this was true in many areas of life including manufacturing. The Pareto principle essentially suggests that 80 per cent of the problems are due to 20 per cent of the causes, i.e. machines, raw materials or operators. Similarly 80 per cent of the scrap or rework costs come from 20 per cent of the causes. Pareto charts help identify the problems in the organization that cause the greatest loss of profit. Therefore, it is important that the organization finds out the few vital problems and eliminates them so that success can be achieved.

The Pareto chart is also a two-dimensional picture and has two axes X and Y. In the 'X' axis, we plot different categories of defects and in the 'Y' axis their percentage of the total. The data pertaining to the quality problems in a service industry are given in Table 11.1.

Table 11.1 Distribution of In-Process Errors Detected

Misunderstood requirements	36%
Deviation from procedures	12%
Defective samples	10%
Typographical errors in reports	42%

A Pareto diagram is constructed using the data as given below:



Distribution of In-Process Errors Detected

Figure 11.9

The causes are to be arranged in decreasing order of their rank. Each cause is given equal width. Then bar graphs are to be made for each cause equal to the measured value.

A look at the figure clearly brings out the few vital problems. In this case, the major problem is typographical errors, which constitute 42 per cent of the defects. Therefore, if this is solved, the quality problem will be solved to a large extent. Such exercises are to be carried out and the Pareto chart has to be plotted whenever prioritization has to be carried out. Pareto analysis can be used by the management to prioritize the action plan. Obviously, the first and if necessary, the second cause in the Pareto chart are the ones to be tackled first. Thus, Pareto chart is a good management tool.

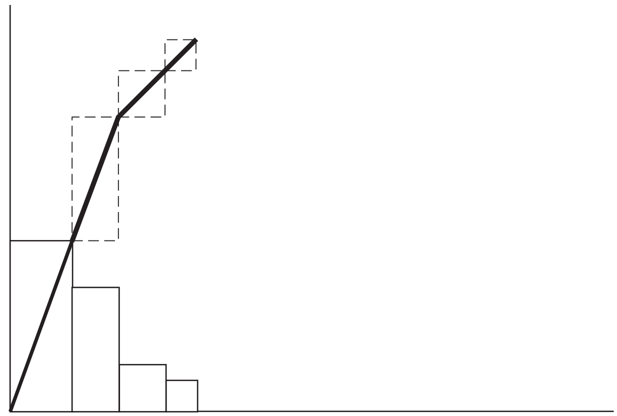
Steps Involved in Pareto Diagram

1. Calculate the share of each cause as a percentage of total.
2. Then arrange the causes in descending order.
3. If there are too many small causes contributing too little to the total, group them as miscellaneous.
4. Draw column graphs for each cause equal to their contribution.

The job is not complete. We have to plot the cumulative Pareto chart. This is carried out for the same example in Fig. 11.10.

The way to plot the cumulative Pareto chart is explained below:

- Arrange the data (frequency) in descending order
- Calculate the percentage of the total, of each datum
- Calculate the cumulative percentage
- Draw the column graphs in solid line pertaining to each of the causes, in descending order.



Cumulative Pareto Chart for In-Process Errors

Figure 11.10

- Place each of the subsequent column graphs at the right edge of the previous column graph.
- The second column graph has to be redrawn with dotted lines just above the first one at the same place (in the X- axis) as indicated in figure. The second and subsequent column graphs are redrawn in dotted line at their original place in X-axis. They start at the level where the previous one ends. The height will be equal to the original height. For instance, the second column will start at 42 and end at 78, but placed at the end of the first column graph as indicated in Fig. 11.9.
- Join the diagonals of each column graph with solid lines to get the cumulative Pareto chart.
- Give a title to the diagram.

Pareto analysis can be used in identifying significant quality costs. It can be used in diverse applications such as formulating specifications. In this case, the potential users can be surveyed to find out their requirements. The percentage of each requirement to the total is plotted against the requirements. Then the first few choices give the most important features to be designed in the product or service in question.

TOOL 6: HISTOGRAM

Histograms are powerful tools for elementary analysis of data that contain variation. Statistics is concerned with information about phenomena that vary. No two items will be identical. Machined parts, whatever may be the superiority of the machinery, operator, materials etc. will have variations. There will always be variations. In a resistor manufacturing company, nine samples of 100 ohms resistors were picked up at random from the assembly line and the measured values are listed:

100.0, 100.1, 99.9, 100.0, 99.8, 99.9, 100.1, 100.0, 100.2

The result can be represented in the form of a histogram. Histogram was developed by AM Gurrey, a French statistician in the year 1833. Histogram is nothing but a bar graph. In the bar graph, the range of resistance values measured have to be plotted in the X-axis and the frequency of occurrence of the range of values in the Y-axis. The frequency of occurrence is the number of times the values falling in the range, was measured. We have to divide the range of values in to number of groups, called class intervals.

One criterion is to divide the range in to number of class intervals equal to the square root of the number of readings or data or measurement results. Since nine data points are available, square root of 9, i.e. 3 groups may even be sufficient. Each group is a class interval. We may keep the class interval as a convenient number. In the above example, the lowest point is 99.75 (just below the lowest value) and highest point is 100.25 (just above the highest value). In the above case we can divide the data into five groups. When we divide the range by five we get a class interval for each group or class as 0.1. Thus, the lowest class interval is 99.75 to 99.85. The highest-class interval is 100.15 to 100.25. The numbers of cells or class intervals are to be decided by the user. Note that the width of all cells should be equal.

A frequency table for the resistance value measured above is indicated in Table 11.2.

Table 11.2

Class Interval	*Frequency (No. of occurrence)*
99.75 –99.85	1
99.85 –99.95	2
99.95 –100.05	3
100.05 –100.15	2
100.15 –100.25	1

With this table, a histogram is constructed as shown in Fig. 11.11.

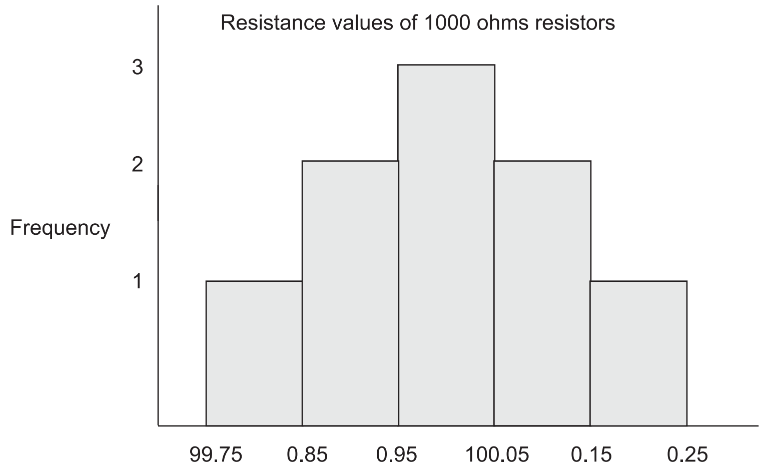


Figure 11.11

A histogram exhibits the number of data points that fall within a given cell or bar or class interval. Let us recapitulate the steps involved in formulating histograms.

Step 1: Measure and record data pertaining to a process
Step 2: Arrange values in ascending order
Step 3: Note the range, i.e. maximum and minimum of the values
Step 4: Divide the range into number of groups called class intervals
Step 5: Now divide the X-axis as per class intervals.

Step 6: Choose a proper scale for Y-axis. In our case the maximum frequency is 3.

Step 7: Count the number of occurrences of the data in each class interval. This is called frequency of occurrence in each interval.

Step 8: Plot the frequency or count of number of occurrences corresponding to each interval in the form of bars. It is essentially a column graph.

Step 9: Give a suitable title for the histogram. Here we call it "Resistance Value".

Since histograms are drawn to depict distribution of frequency of occurrence, it is also called a frequency distribution diagram.

If the middle points are joined through a smooth curve it will result in a bell shaped curve as shown Fig. 11.12.

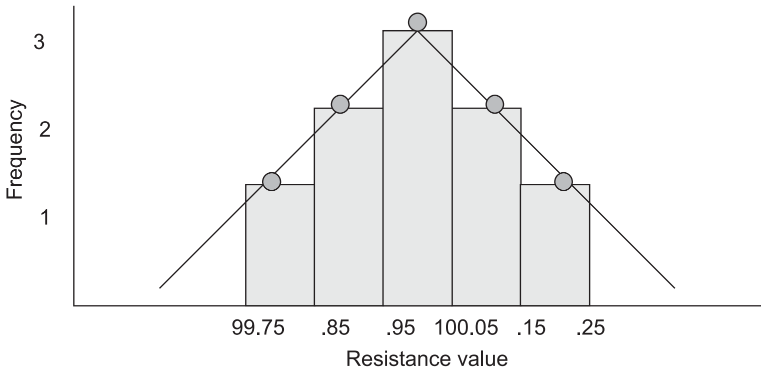


Figure 11.12

The above is called a normal histogram. Histograms were shown as column graphs of frequency and then as a normal histogram - bell shaped curve. Histograms can also be displayed as bar graphs as shown below in Fig. 11.13.

To carry out a proper analysis, histograms require 50 to 100 data points. Many stable processes exhibit a bell shaped curve.

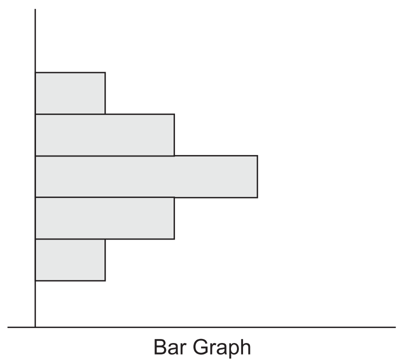


Figure 11.13

FUNDAMENTALS OF STATISTICS

Two of the seven QC tools require understanding of basic statistics to apply them.

Statistics has been defined as the collection, organization, analysis, interpretation and presentation of data. It is a tool to analyze complex problems and arrive at a conclusion with a high probability of accuracy. It is a special discipline of mathematics to provide logical analysis and decision-making ability with sample data. The degree of confidence varies depending on many factors; but it has been accepted as an effective tool when used correctly. For instance, to find out the average consumptions of milk in a country, it is impossible to survey all the people for collecting this data because it will be time consuming and expensive. Therefore a few people of various spectrum of living can be contacted to find out what is their daily need. Then the average consumption can be calculated.

A factory may be producing one million pieces of a product per shift. It would not be viable to inspect all the one million pieces. On the contrary, fewer samples can be drawn at regular intervals say once in an hour of production and these pieces can be thoroughly inspected and based on the result an interpretation about the quality of the one million pieces can be made statistically. Thus, statistics is a useful technique in quality control and process control.

Let us look at the definition of two basic terms.

Statistic *A numerical data measurement taken from a sample that may be used to make interference about a population* Let us understand the words in the above definition correctly. Numerical data measurement is measuring an entity and expressing the result as a number. Measuring daily consumption of milk of a person or family is numerical data measurement. The result of measurement is numerical data, for instance, one litre or five litres. If we want to find out the milk consumption in a city, say, Chennai, the measurements of milk consumption in all the households in Chennai are called population. This can be estimated or inferred by measuring consumption in say, 1000 households. This is numerical data measurement taken from a sample of 1000 households. This is used to make an inference about a population, i.e. milk consumption in the city of Chennai. Thus, statistic (note there is no "s" at the end) is used to make an inference about a population.

Parameter *The true population value, often unknown, estimated by a statistic* The daily consumption of milk in Chennai is unknown. That is the true population value. It may be difficult and expensive to measure it directly. Hence, we don't collect data from every household. Collect data from a sample of households and estimate the population value. Therefore, parameter refers to true population value, not measured directly, but estimated through statistic.

Population and sample Population is thus a large collection of items of the same type. For instance, the bottle manufactured in a shift is called population. It has been found that inspecting the population does not give more confidence owing to the following reasons:

- Fatigue or boredom of the employees
- Handling them and causing damages some times
- Mixing up of good and bad ones due to time pressure owing to large quantity to be inspected
- Too expensive due to man hours spent

Thus, inspection by sampling has become widely acceptable. The whole theory of SPC has been developed to adopt inspecting samples and deriving valid conclusions. The samples should be picked up at random.

This is the fundamental principle of statistics. The three quality gurus Shewahrt, Deming and Juran helped Japanese to use statistics to control and improve the destiny of the nation.

Measure of Central Tendency

The type of frequency distribution as shown in the histogram examples is called a normal distribution. Such distributions occur when there is a concentration of observations about the average, and it is equally likely that observations will occur above and below the average. While there are other distributions to depict characteristics of industrial products such as exponential, Weibull, Poisson and rectangular, the normal distribution is good enough to start with. It is good enough for most industrial applications. The frequency distribution may be defined as "tabulation or tally, of the number of times a given quality characteristic measurement occurs within the sample product being checked".

We have a set of data as given in the above example. We would like to know the central tendency of the values, i.e. the central value of the collection of data. The measures of central tendency are:

- Mean
- Mode
- Median

(a) Arithmetic mean The average of a sample is obtained by dividing the sum of values by the number of readings.

$$\bar{x} = \frac{x_1 + x_2 \cdots x_n}{n}$$

$$\bar{x} \text{ (}x\text{ bar)} = \text{average} = \Sigma x/n$$

where, $x_1, x_2 \ldots x_n$ = value of successive readings.
n = number of readings

A sample average is the best estimator of arithmetic mean (μ) of a population. Therefore $\mu = \bar{x}$. The arithmetic mean is the most widely used measure of central tendency.

Example 11.1

Calculate the average and arithmetic mean of the values given below.

100.0, 100.1, 99.9, 100.0, 99.8, 99.9, 100.1, 100.0, 100.2

$$\bar{x} = \frac{3 \times 100 + 2 \times 99.9 + 2 \times 100.1 + 99.8 + 100.2}{9} = 100$$

$$\therefore \qquad \mu = 100$$

(b) Median (Mid Point) It is the value, which divides a series of readings arranged in order of magnitude of their values so that an equal number of values are on either side of the centre or median value. For instance, if the readings are 3, 4, 5, 6, 7 then the median is 5. In the above example, the median is 100. To find median, the values should be arranged in ascending order. If the number of readings n is odd, then the median is the value at position $(n + 1)/2$. If n is even then the median is the value at $(n/2 + 1)$.

Example 11.2

Find out median for the following two sets of data

(a) 67, 76, 78, 79, 85
(b) 12, 12, 13, 14, 15, 16

Solution:

The data is already arranged in ascending order in both cases.

(a) The number of data $n = 5$, n is odd
Therefore median will be value at $(n + 1)/2$, i.e. $(5 + 1)/2 = 3$
Median is the value at third place
Median = 78

(b) The number of data $n = 6$, n is even
Therefore median will be value at $(n/2 + 1)$, i.e. $(6/2 + 1) = 4$
Median is the value at the fourth place
Median = 14

(c) Mode The mode is the most frequently occurring data in the collection. In Example 11.1 it is also 100. Since it occurs 3 times.

Notice that in Example 11.1, all the three parameters namely mean, median and mode are same. This is one of the characteristics of normal distribution.

Example 11.3
Find out mode for the following 2 sets of data

(a) 67, 76, 78, 78, 78, 79, 85
(b) 12, 12, 13, 14, 15, 16
(a) In the data set the value 78 occurs more times than any other value. Hence mode = 78
(b) In the data set the value 12 occurs more times than any other value. Hence, mode = 12

Measures of Dispersion

Another parameter to characterize a set of data is spread or dispersion. The measures of dispersion are:

- Range
- Variance
- Standard deviation

(a) Range Range is the simplest measure of dispersion, but used in many applications such as control charts. Range is the difference between the largest value and smallest value in the given data set.

Example 11.4
Find out range for values given in Example 11.1
Maximum = 100.2
Minimum = 99.8
∴ Range = 100.2 – 99.8
= 0.4

(b) Standard deviation The standard deviation of a population (σ) is a measure of the spread of the values of a lot. Suppose 10,000 pieces of bolts are turned out in a lathe, the diameters can be measured and depending upon the standard deviation, the workmanship/performance of the lathe can be estimated. If it is computed for samples drawn from a lot, then standard deviation for the sample is called sample standard deviation, usually denoted by s.

$$s = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \cdots (x_n - \bar{x})^2}{n-1}}$$

s = Sample standard deviation
$x_1, x_2, \ldots x_n$ = Value of each reading
$\bar{x}$ = Mean of the readings
n = Number of readings

Example 11.5
The values given in Example 11.1 are taken to explain the concept of standard deviation.

The mean was found to be 100 and the number of readings = 9

$$s = \sqrt{\frac{3 \times (100-100)^2 + 2\,(99.9-100)^2 + 2\,(100.1-100)^2 + (99.8-100)^2 + (100.2-100)^2}{8}}$$

$$= \sqrt{\frac{0 + 0.02 + 0.02 + 0.04 + 0.04}{8}}$$

$$= \sqrt{\frac{0.12}{8}}$$

$$= \sqrt{0.015}$$
$$= 0.122$$

Example 11.6

Four Samples were drawn from a production lot and their weight (in grams) were
4, 5, 5, 6.

Find the standard deviation.

Mean = (4 + 5 + 5 + 6)/4 = 5

$$s = \sqrt{\frac{(5-4)^2 + (5-5)^2 + (5-5)^2 + (5-6)^2}{3}}$$

$$= \sqrt{\frac{2}{3}}$$
$$= 0.812$$

Population standard deviation When the population mean is assumed to be equal to sample average, then there will be no error. If we treat values of the sample as a population and calculate mean (μ) there will be no error. But that is not the case with standard deviation. If we do the same with standard deviation there will be a bias. To eliminate the bias the following formula may be used to calculate σ, the population standard deviation

$$\sigma = \sqrt{\frac{\Sigma(x-\mu)^2}{N}}$$

where x = The individual values
μ = Population mean
N = No . of values.

Example 11.7

For the values given in Example 11.6, calculate σ.

$$\sigma = \sqrt{\frac{2}{4}}$$

Note: Change only denominator

$$\sigma = 0.71$$

Note the difference.

(c) Variance of Population Variance of a population is σ^2. Similarly sample variance is s^2.

CHARACTERISTICS OF NORMAL DISTRIBUTION CURVE

When we measure characteristics of a sample and plot frequency distribution, we get histogram. When we plot the measured values of the population we get a smooth curve. The population mean is μ and the population standard deviation is σ.

The normal distribution curve shown in Fig. 11.14 depicts the results of most manufacturing operations.

The characteristics of the normal distribution curve are:

1. The frequency of the mean value of the population μ is the highest.
2. 68.26% of all values in the distribution will occur between plus or minus 1 σ over the mean value.
3. 95.45% of all values occur between $\mu \pm 2\sigma$.
4. 99.73% of all values lie between $\mu \pm 3\sigma$.
5. The curve never touches the x-axis. The curve extends between $-\alpha$ to $+\alpha$.

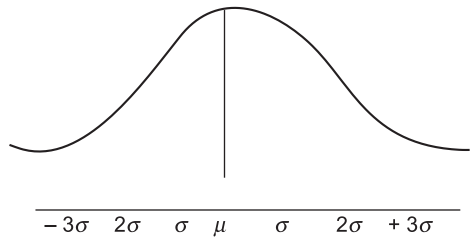


Figure 11.14

This makes the job of prediction of quality of a manufactured product a lot easier. If mean and standard deviation are computed then the percentage of values between any two values can be easily calculated.

Variations in Distribution

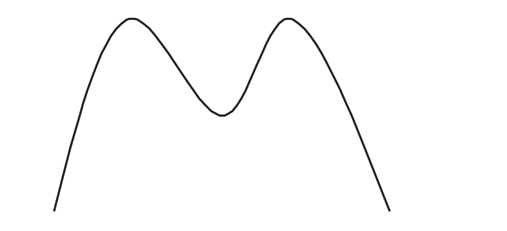
Distribution may be skewed to the left or right as shown in Figs 11.15 (a) or (b).

(a) Left skewed (b) Right skewed

Figure 11.15

This can happen due to some malfunctioning in the equipment or poor judgment of the operator.

If put together samples fabricated on two machines or by two operators in one machine as one lot, it can depict bi-modal distribution as given in Fig. 11.16.



Bi-modal distribution

Figure 11.16

Table 11.3 indicates the percentage areas under normal and skewed Frequency Distribution Curves.

Table 11.3

	Percentage of Area ---		
	$\mu \pm \sigma$	$\mu \pm 2\ \sigma$	$\mu \pm 3\ \sigma$
Normal Distribution	68.26	95.45	99.73
Skewed Distribution	≥ 55	89	95

Thus, assuming the outcome of a manufacturing process, even though it might be left skewed or right skewed or bi-modal, as normal distribution for all practical purposes will not alter the results significantly. Hence, it will be assumed in the rest of the chapter that measurement process follows normal distribution.

Example 11.8

Table 11.4 gives the length of bolts, picked up at random from a manufacturing plant.

Table 11.4 Length of bolts manufactred in mm

7	13	10	11	9	12	8	10
8	12	7	8	11	11	10	9
10	11	8	9	10	13	9	7
13	10	11	10	9	12	13	11
11	9	12	9	11	8	10	7
12	8	9	10	12	12		

By looking at the table, different people will give different conclusions. Some may say the process is very much under control and some may say, generally, the spread is more. Some may say the process is not under control. It is just a table containing 46 data. We are not able to come to any definite conclusion by looking at the table of numbers. This can be analyzed using histograms. Let us now calculate the frequency of occurrence of each data. The frequency of occurrence is given in Table 11.5 (Length in mm and Frequency). We have decided to have a class interval of 1mm. The class interval is nothing but the width of each cell.

Table 11.5 Length of bolts manufactured in mm

Length in mm	*Frequency*
9.5 –10.5	10
10.5 –11.5	8
11.5 –12.5	6
12.5 –13.5	4
8.5 –9.5	8
7.5 –8.5	6
6.5 –7.5	4

Even this does not give a clear picture immediately. The frequency distribution can be plotted in the form of a histogram as given in Fig. 11.17.

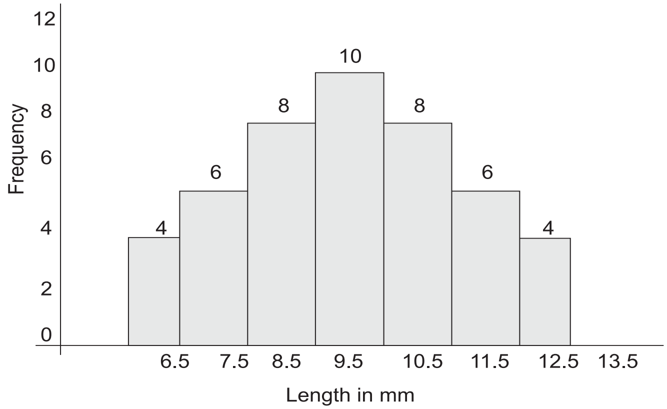


Figure 11.17

This clearly brings out that the central value is 10 and the variation on either side is 3 mm. This data can be further used to calculate the central tendency and dispersion. The central tendency, average or the mean works out to be 10 mm. If the dispersion or standard deviation is also calculated, it is possible to find out clearly, say what percentage is lying between mean ± 1σ, mean ± 2σ and mean ± 3σ. Thus, the data has been converted into useful information by analysis and plotting a histogram. Histogram is thus useful for summarizing, analyzing and displaying data. Once a histogram is drawn, it helps the employees to come to definite conclusions rather than each giving his opinions. This will also bring out the status of the process clearly. It also helps the organizations to improve and again plot histogram and see whether there is improvement or not. Histogram is quite useful for any statistical analysis ranging from census to calculating consumption of petrol, milk, etc. finding the trends of income, savings, expenditure and so on. It is definitely very valuable in commercial organizations. Since, variation is expected in every area, histograms will help in calculating whether the variations are within the limits or not. From such analysis, the statements can be made more emphatically as given below:

All values fall within the specified limits or most of the values fall between mean and the specified lower limits or most values fall between mean and specified upper limits or the values tend to be bunched near the specified lower limits. If the values of machined parts fall near the lower limit, then the lathe needs to be adjusted so that the values can be brought near the mean. The objective of any operation is that the values are around the mean. If by chance, due to machine error or operator error, all the values are near the upper limit, again the process can be adjusted to bring it down. However, formulating a histogram will give the management about the states of the process. Thus, histogram is a useful tool in the problem solving process.

TOOL 7: CONTROL CHART

Walter A Shewhart proposed this tool in 1924 to identify common cause and special cause variations. Deming developed this concept further. Control chart is aimed at monitoring the quality of the process continuously. A simple example of the control chart is given in Fig. 11.18. Assume that we are manufacturing peanut packets.

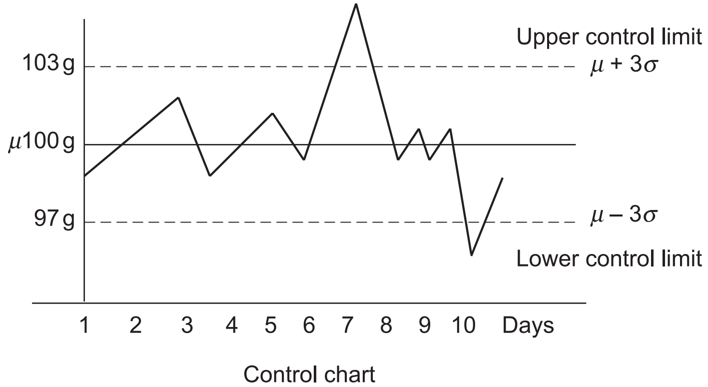


Figure 11.18

The marked weight of peanut packets shipped is 100 gram and we pick up few samples of the packets and weigh them and record the result. The central horizontal line indicates the mean weight of the packets, which is 100 gram. The days (time) are in the X-axis and the average values measured in the Y-axis. We have two more horizontal line one above the mean and the other below the mean. They are called upper control limit (UCL) and lower control limits (LCL) respectively. They are called statistical limits. In this case 103 gm and 97 gram respectively. If the process is under control, it means that the variation is only due to common causes. In such a case the measured value will lie between UCL and LCL. Any point lying outside the limit is due to a special cause variation. In such cases, the organization should make effort to find the root cause of the problem and eliminate it. This control charts are very helpful for keeping track of the production and know the variation in the process instantly. We will learn more about control charts in the next chapter.

Specifications Limits

Use of control chart needs understanding of specification limits and statistical limits. While the specification limits are set by the customer, the process performance decides statistical limits.

Every product should have specifications. The organization that produces will have a target value (T) for a parameter for a model of product manufactured. For instance, the peanuts are packed as 100 grams packets. Here the target value T is 100. The company cannot pack exactly 100 grams every time. Therefore, it will specify the tolerance. It may specify that the packets will contain peanuts weighing between 95 grams to 103 grams. Such a statement on the packet is also essential to avoid liability. Here, lower specification limit (LSL) is 95 grams and upper specification limit (USL) is 103 grams. Some people will give equal variation on either side. Then they specify that the weight is 99 ± 4 grams. This limit is fixed after studying the capability of the process. Once set, the process should be maintained to perform within the control limit. If the process performs within the limits, then the process is good. Otherwise, it is out of control.

Statistical Limits

In the previous section, we discussed about the parameters for the population and a representative sample in a normal distribution. They are summarized in Table 11.6:

Table 11.6 Comparison between sample and population

	Population	*Sample*
Size	N	n
Mean	μ	$\bar{x}$
Standard Deviation	σ	s
Variance	σ^2	s^2
Distribution	Continuous curve	Histogram

Formula for

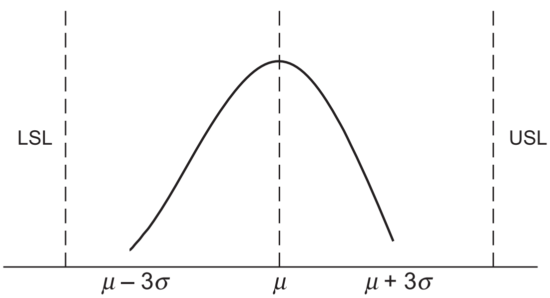
$$\sigma = \sqrt{\Sigma(x_i - \mu)^2 / N}$$

$$s = \sqrt{\Sigma(x_i - \bar{x})^2 / n-1}$$

The bell shaped normal distribution curve represents the frequency of occurrence of each value in a population whose size is very large or infinite. It is basically a continuous distribution arrived at statistically. The statistical limits are $\mu \pm 3\sigma$.

Process Capability

The upper specification limit (USL) and lower specification limit (LSL) are specification limits or tolerance range. The statistical or control limits are UCL and LCL. If the process is capable or under control, the process spread (control limits) and tolerance range (specification limit) will be as shown in Fig. 11.19.



Comparison of process spread to specification limits

Figure 11.19

A capable process is one in which the spread of bell shaped curve is narrower than specification limits as shown in the Fig. 11.19.

Process capability analysis involves comparing the process variations with the specification tolerances. This is carried out to confirm the suitability of the process. Process capability analysis is carried out for one or more of the following purposes.

- Evaluation of a newly established process
- Evaluating the performance of a new machinery such as a lathe
- Reviewing specification based on the inherent variability of the process
- Process audits
- Studying the effect of adjustments made to the process

The process capability analysis may reveal different patterns in addition to that shown in Fig. 11.19, which is a capable process. Some of the commonly observed patterns of process performance are given in Fig. 11.20:

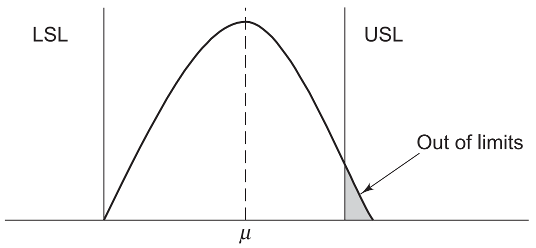


Figure 11.20(a)

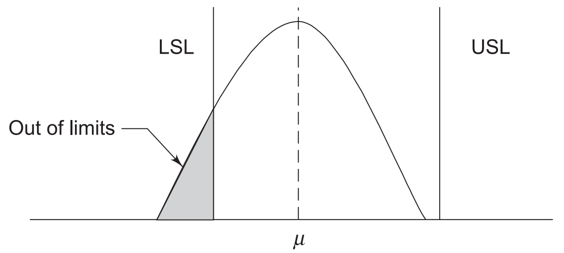


Figure 11.20(b)

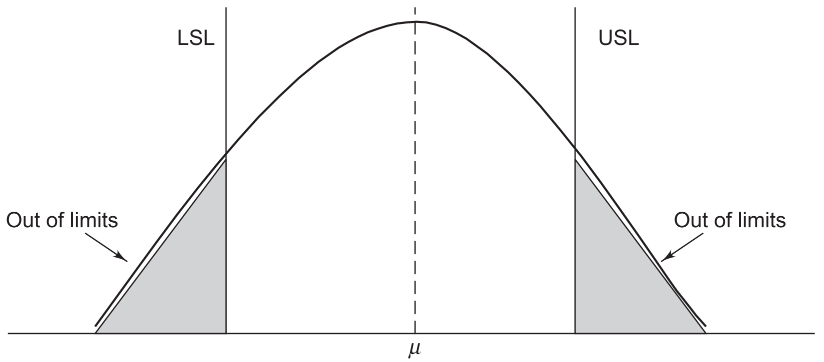


Figure 11.20(c)

In all the above three cases the processes are out of limits.

Variations

Although, we make every effort to produce and deliver products meeting standards, there will still be variations. The causes of variations in industrial processes are given in Table 11.7:

Table 11.7 Causes of variations

Men	Knowledge, skill, experience, motivation
Machinery	Wear and tear, ambient conditions, etc.
Materials	Process variations during manufacturing, storage, handling, ageing
Methods	Process specifications, procedures
Environment	Temperature, humidity, dust, air pressure, etc.

Statistical Process Control (SPC)

A process is stable when it performs within the tolerance for the process parameters. When process performs outside tolerance, it means that there is an assignable cause for such variations. In such cases, root cause of variation can be found using statistical tools.

SPC provides a set of tools for building process capability in any organization. A successful organization is the one, which has built processes that are capable. Capability is the ability to carry out a job correctly. It is manufacturing a product or delivering a service that meets the requirements of the customer first time and every time. For this to happen, one has to ensure that the entire process is carried out correctly. Product manufacturing consists of a number of processes. A process flow chart will clearly identify the processes that are used for building the product or service. The inputs, tasks and outputs of the processes have specifications. At every point in the chain, the performance has to be within the tolerance limits. Only then the final product or service will be within the tolerance limit. Therefore for a product to function correctly, measurements at all points in all the processes involved should be within the tolerance limits. Thus, the process flowchart is the most useful tool for capturing the entire process and identifying check pints for quality. We build process capability by identifying the processes involved and the process measurements as well as making sure that the process performs within limits at all points. Once we achieve this all the time, then it is time for improving the processes as indicated in Juran's Triology. Subburaj's 6S can be used to improve each process. The synergizing phase of the 6S will ensure that compatibility between processes is ensured. Now, we get improved process with tighter tolerance than ever before. Thus, quality improvement has been achieved. Now, we have established a more capable process. This action is repeated continually to enable TQM. Thus, improvement of processes leads to improvement of quality of the products and services. When an organization is able to visualize itself as a set of processes, cause of defects can be attributed to the deviations or variation in the process performance.

CAUSES OF PROCESS VARIABILITY

Process can be expressed as an ETX model and a process flow chart with clear inputs and outputs. At the same time, process results arise due to complex interactions of varying factors. This includes the men, machine, material, methods as well as environmental conditions such as temperature, pressure, humidity, dust, vibration, noise, radio frequency interference, etc. Any variation in any of these can cause variation in processes. If the process variation is not noted and corrected in time, it could lead to variations in the performance of the end product. The cause of process variations can be grouped into two major categories:

- Random causes
- Special causes

Random Causes

Random causes are also known as common causes. As the name suggests random causes cannot be traced out or attributed to any particular cause. This can be due to random variations in inputs to the process such as temperature changes, voltage changes, sudden emotional change of the operator, etc. Thus, they are due to common causes, which cannot be separated out. When only random variations are present in a process, then the process is said to be under control or under statistical control. Variation in test equipment or change of characteristics of raw materials, etc. lead to common cause variations. The variations in the normal distribution where the values lie up to $\mu \pm 3\ \sigma$ are due to random cause.

Special Causes

The variations due to assignable causes are called special cause or assignable cause variations. This may be due to a particular vendor supplied product or a particular machine or operator, etc. These causes are identifiable with analysis. They have to be prevented. When there are special cause variations, the process is said to be out of control or not stable. The process is stable only when there are variations due to common causes. The variability of the process when there are only random variations is called process variability. This is the natural capability of the process. For instance, in an oil bath if the temperature varies between 99°C to 101°C, then the natural process capability is 100 ± 1°C. We have to find out the extent of natural variability when the process is stable or when there is no special cause variation. This will enable us to arrive at the following:

- Process capability
- Extent of variability
- Identify common cause variations whenever they occur

ACCURACY AND PRECISION

These are terms used to describe the quality of measuring instruments. They can also be used to describe the process capability. We have set the tolerance limit of a process, for instance 100 ± 1°C. When the process is operating continuously, the results may be in the range of 103 ± 0.5°C as illustrated in Fig. 11.19(a). This process is precise, but not accurate. There may be another instance the process results are within 100.25 ± 2.5°C or 99.75 ± 2.4°C as illustrated in Fig. (b). In this case, the process is closer to accurate, but not precise. We have to have a process, which is precise and accurate as illustrated in Fig. (c).

Accuracy refers to the ability of a process whose performance is within the tolerance. Precision refers to the degree of variation in the measured values. We thus derive both accuracy and precision in the process performance.

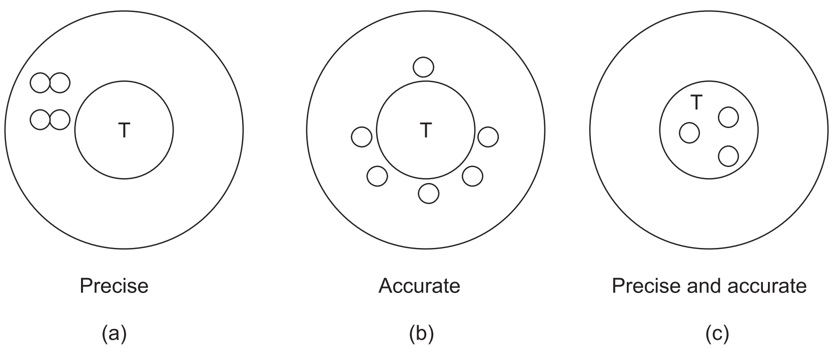


Figure 11.21 T-Target or Boundary of Tolerance limits

Measures of Accuracy

In a normal production, we pick up few samples from each lot and measure their characteristics. We do this at periodic intervals. Each time we can find the sample mean as x_1 bar, x_2 bar, … Suppose we pick up samples 25 times in a day we get 25 averages. We can never find out the true mean, i.e. μ since it will require measuring each and every product produced. However, we can find out the process mean or grand average of the process namely $\bar{\bar{x}}$ as given below:

$$\bar{\bar{x}} = (x_{1\ \text{bar}} + x_{2\ \text{bar}} + \ldots\ x_{25}\ \text{bar})/25$$

Example 11.9

4 samples each were drawn 3 times and results are given below:

Diameter

	I time	II time	III time
	10	11	9
	10	11	8
	11	11	10
	9	11	9
$\bar{x}$:	10	11	9

$\bar{\bar{x}} = (10 + 11 + 9)/3 = 10$

Thus, $\bar{\bar{x}}$ is a measure of accuracy. It gives the location of the central value (μ) of the normal distribution.

Precision–Measure of Spread of Values

The following are the measure of spread of values:

- Range
- Standard Deviation

Range In normal production, few samples say four or five are drawn at random 25 times in a day or a shift. We find out range R for each collection of four samples. In the above example, the range, i.e. the difference between the highest and lowest value, for each collection is given below:

I : $11 - 9 = 2$
II : $= 0$
III : $10 - 8 = 2$

The mean range $\bar{R}$ is the average of samples means, i.e.

$$\bar{R} = (2 + 0 + 2)/3 = 1.33$$

It has been observed that range measure for precision has the following disadvantages:

The range increases when the sample size increases.

Since range looks at only two of the values in the sample namely highest and lowest, change in other values will not affect the range. Hence, this is not a good indicator for precision.

Standard deviation Standard deviation should be used to find the precision when the sample size is more than 10. This takes into account all the values and hence will be more representative of the precision. The true standard deviation of the entire population σ will never be known in an industry. Hence, we calculate the standard deviation of the sample and treat it as σ. The denominator will have n and not n–1 as indicated below:

$$\sigma = \sqrt{\ } (\Sigma\ (xi - \bar{x})^2)/n$$

where xi = sample values
$\bar{x}$ = sample average
n = no. of samples

Example 11.10

Let us calculate the standard deviation for each of the three cases in the previous example.

I $\sigma = \sqrt{2x}\,(10-10)^2 + (11-10)^2 + (9-10)^2/3$

$= \sqrt{2/3}$

II $\sigma = 0$

III $\sigma = \sqrt{2x}\,(9-9)^2 + (8-9)^2 + (10-9)^2/3$

$= \sqrt{2/3}$

Although in case I, the central value is 10 and in the III case it is 9, their precision remain the same.

STANDARD NORMAL DISTRIBUTION

We can transform or convert the unit in the *x* axis in the normal distribution. So far, we were using the actual values in the x axis. Instead we can use a variable *z* in the *x* axis where

$$z = (x - \mu)/\sigma$$

Therefore, when $x = \mu$, z will be zero.

When $x = (\mu + 1\sigma)$, z will be

$$z = (\mu - \sigma) - \mu/\sigma = 1$$

When $x = \mu - 3\sigma$,

z will be $\mu - 3\sigma - \mu/\sigma = -3$

Thus, we derive a standard normal distribution (Fig. (b)) from normal distribution Fig. (a).

x : actual values of the parameter

μ = mean

σ = standard deviation

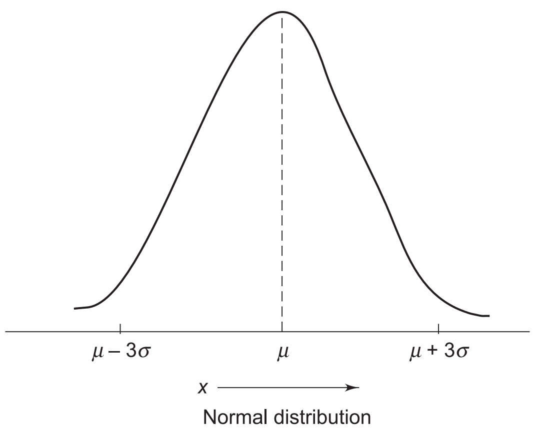


Figure 11.22

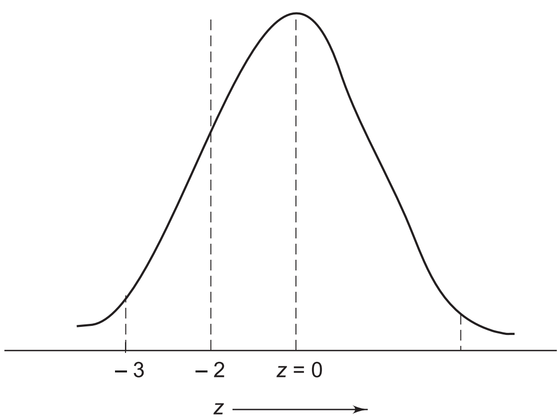


Figure 11.23

$z = (x - \mu)/\sigma$

The Table A (Annexure 1) gives the proportions under the tail of normal distribution. It can be used to estimate the proportion of defectives manufactured. Let us see some examples.

Example 11.11

A company is producing packets of peanuts whose weight is normally distributed with mean of 300 grams. The standard deviation was found to be 5 grams.

(a) What percentage of packets will weigh more than 310 grams?

$$z = x - \mu/\sigma = 310–300/5$$
$$= 2$$

Look at the table at Annexure 1. For finding the area under the standard normal distribution to the right of $z = 2$, we have to look up at $z = 2$.
We get 0.0228.
This means 2.28% of the packets will weigh more than 310 grams.

(b) Find out what percentage will weigh less than 290 grams?
Now $z = 290 - 300/5 = –$ve 2
We are looking at the area to the left of –ve 2. Since there is symmetry; the area to the left of –ve 2 will be equal to the area to the right of $z = 2$. Hence, again when $z = –2$, 2.28% of the packets will weigh less than 290 grams.

Example 11.12

In the above example, find out the packet that will weigh more than 315 and less than 285.

$$z = 315 - 300/5 = 3$$

When $x = 285$

$$z = 285 - 300/5 = –3$$

Due to symmetry, the area to the left of $z = –3$ will be equal to the area to the right of $z = 3$. Therefore, 0.13% will lie outside $z = –3$. The total area outside the limits will be $0.13 + 0.13 = 0.26\%$.

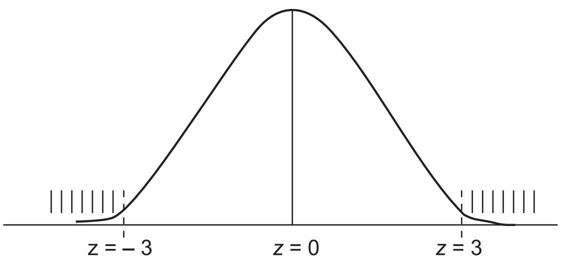


Figure 11.24

Thus, 0.26% of the packets will weigh less than 285 grams or more than 300 grams.

Example 11.13

The life of a dry battery cell is a random variable following normal distribution. The mean life is 1000 hours and standard deviation is 100 hours. Find the expected number of cells from a random sample of 10,000 cells having life more than 1250 hours and between 1250 and 1300.

(a) $Z_1 = (X_1 - X \text{ bar})/\sigma = (1250 - 1000)/100 = 2.5$
From Table A (in Chapter 12), we can find the proportional area under the tail corresponding to $Z =$ 2.5 can be found to be 0.0062 .
The number of cells having life more than 1250 hours lie in the tail with $Z = 2.5$ in the standard normal distribution. It will be equal to $10{,}000 \times 0.0062 = 62$ cells

(b) We know that z at 1250 hours = 2.5
Z at 1300 hours = (1300 – 1000)/100 = 3
From Table A we can find the proportional area of the curve under the tail when $Z = 3$ is 0.0013
Therefore, the proportional area of the curve between $Z = 2.5$ and $Z = 3 = 0.0062 - 0.0013 = 0.0049$
Number of cells having life above 1250 hours, but below 1300 hours = $10{,}000 \times 0.0049 = 49$ cells.

ACCEPTABLE QUALITY LEVEL (AQL)

This is the percentage of products that the customer is prepared to accept outside the tolerance. We can use the standard normal distribution to find out the maximum standard deviation that is acceptable to meet the customer's requirements.

Example 11.14

The customer is prepared to accept an AQL of 1.5%. Assume that the mean value is 300 grams and upper specification limit is 315 grams. Find out the maximum permissible standard deviation.

We know that

$$z = (x - \mu)/\sigma$$

Here x can be upper specification limit (USL) or lower specification limit (LSL).

$$\therefore \quad \sigma = (x - \mu)/z$$

Allowable % deviation = 1.5%. This is in both sides, left and right tails.

$\therefore$ right side tail = left side tail = 1.5 / 2 = 0.75%
or 0.0075 (proportion)
Let us find out z corresponding to 0.0075
It is 2.43 from Table 1

$$\therefore \quad \sigma \max = 315 - 300/2.43$$
$$= 15/2.43 = 6.17$$

Therefore standard deviation of 6.17 grams has to be achieved for an AQL of 1.5%.

(c) Assume that we want to quote an AQL of 0.5%. What is the maximum the σ.
Area of tails on both sides = 0.5% or 0.005
Area under one tail = 0.0025
Corresponding z = 2.8
$\therefore \quad \sigma \max = 315 - 300/2.8$
$= 5.35$
Therefore, we can quote an AQL of 0.5% provided if we are able to control the σ within 5.35 grams.

SUMMARY

Statistics means that measurement taken from a sample can be used to make an inference about a population. Statistic helps us to estimate the parameters of the population. This has led to improved control over the industrial processes and accurate predictions. TQM has abundant application of statistics for continuous process improvement. Statistics is used for continuous control of processes. It helps in identifying common causes and special causes. The seven QC tools are also called the magnificent QC tools. Since initially the tools were used for quality control, they were called QC tools. They are now used in processes also and hence this discipline is called SPC. In this chapter, we discussed about the fundamentals of statistics. We understood what data is. The frequency is the number of times a value occurs. Histograms plot the frequency of occurrence against the class intervals. When the central points of the column graphs in a histogram are joined we get a smooth bell shaped curve. It is also known as a normal distribution. We discussed about the measures of central tendency and dispersion. These parameters can be used to judge the quality of the processes. Histograms should normally be plotted with 50 to 100 data points.

Flow charts are useful to understand, control and improve processes. It is required for ISO 9000 certification. It provides visual representation of the processes. Cause and effect diagram developed by Ishikawa is useful for organizing brainstorming to improve processes. It is drawn in the form of a fish bone. It helps to identify all the causes for getting an improvement of a process. Check sheets or tally sheet is used for data collection and to understand the steps of processes readily.

Juran popularized the Pareto diagram. The Pareto principle is that a few vital improvements will lead to large process improvement. Thus, it is a tool for prioritization of process improvement actions and the like. Scatter diagrams can be used to find relationship between causes and effects such as price and demand.

The 7^{th} QC tool control chart was introduced in this chapter, but will be discussed in detail in the next chapter.

Every process will have variations due to many factors. There are two types of variations namely:

- Common cause
- Special cause

The special causes should be found out and eliminated so that process variations are only on account of common causes. Precision denotes the variations and accuracy denotes the deviation from central value. The process should be accurate and precise. Mean indicates accuracy and range and standard deviation are indicators of precision. Customers dictate the specification limits and process performance decides the statistical limits. The performance should be well within specification limits in a capable process. Normal and standard normal distribution are suitable for process capability studies.

We will continue the discussions on SPC tools in the next chapter.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. Measures of dispersion include
   (a) Mean (b) Mode
   (c) Variance (d) All the above
2. Measures of central tendency include
   (a) Mean (b) Mode
   (c) Median (d) All the above
3. Histogram is depicted as a
   (a) Column graph (b) Bar graph
   (c) Bell shaped curve (d) All the above
4. Tool that helps prioritization include
   (a) Histogram (b) Pareto analysis
   (c) Tally chart (d) None of the above

5. Tally cart can be used for
   (a) Counting (b) Take immediate action
   (c) Know the trends of defects (d) All the above
6. Process specification limit is
   (a) 3 σ (b) -3 σ
   (c) USL (d) None of the above
7. In standard normal distribution, μ is located at z value equal to
   (a) 0 (b) 1
   (c) -1 (d) None of the above
8. Random variations are due to
   (a) special causes (b) common causes
   (c) internal causes (d) All the above
9. The tool suitable to capturing variations in processes is a
   (a) Cause and effect diagram (b) Flow chart
   (c) Control chart (d) None of the above
10. The mean of data : 2, 0, 4, 5, –1 is
    (a) 2.5 (b) 2.8
    (c) 2 (d) None of the above
11. The range of the data in above question is
    (a) 6 (b) 4
    (c) 3 (d) None of the above
12. The standard deviation of the above data is
    (a) 2.7 (b) 2.5
    (c) -2.5 (d) None of the above
13. The mode of the following data,
    5, 6, 7, 6, 5, 7, 8, 4, 5, 5, 7 is:
    (a) 6 (b) 7
    (c) 5 (d) None of the above

II. True or False

1. Normal histogram is obtained by joining the corners of column graph.
2. Mean is the central value.
3. Median indicates maximum frequency.
4. Population standard deviation is indicated by Greek letter μ.
5. Variance is the square of standard deviation.
6. Mean is a measure of dispersion.
7. Histogram is useful to know the dispersion of data.
8. 99.73% of values lie between 2 s limits.
9. Skewed distributions indicate process problems.
10. Flow chart is used for brainstorming.
11. Cause and effect diagram is also known as fish bone diagram.

12. Pareto chart is used to prioritize.
13. Tally chart can be used only by managers.
14. Scatter diagram is useless.
15. Seven tools cannot be used for process control.
16. Flow charts are used only for computer programming.
17. The number of class intervals should be at least equal to the number of data points.
18. Tolerance limits are fixed by customer.
19. Random cause is same as common cause.
20. Accuracy refers to precision
21. R indicates spread.
22. Process is stable when there are special cause variations.

III. Match the Following

1.

A	B
Population Mean	$\bar{x}$
Population Variance	s
Population standard deviation	μ
Sample mean	σ^2
Sample Standard deviation	σ

2.

A	B
Prioritizing	Scatter diagram
Measure central tendency	Flow chart
Brainstorming	Fish bone diagram
Process study	Histogram
Find relationship	Pareto diagram

IV. Explain Briefly

1. Flow chart
2. Pareto diagram
3. Fish bone chart
4. Histogram
5. Scatter diagram
6. Check sheet
7. Define statistic and parameter
8. Measures of central tendency
9. Measures of Dispersion
10. Normal distribution
11. Differences between statistical and tolerance limits
12. Accuracy and Precision
13. Standard normal distribution
14. Variations

V. Solve the Following Problems

1. Employees Arrival Time in an Office (Hours & minutes)

9.05	9.06	9.07	9.11	9.15	9.15	9.15	
9.20	9.20	9.21	9.22	9.22	9.23	9.24	9.24
9.25	9.25	9.25	9.25	9.25	9.26	9.26	9.26
9.27	9.27	9.27	9.28	9.28	9.28	9.28	9.29
9.29	9.29	9.30	9.30	9.30	9.30	9.30	9.30
9.31	9.31	9.31	9.31	9.31	9.32	9.32	9.32
9.32	9.32	9.32	9.32	9.32	9.33	9.33	9.33
9.33	9.33	9.34	9.34	9.34	9.34	9.35	9.35
9.35	9.35	9.35	9.40	9.42	9.43	9.44	9.50

   For the data shown above, do the following:

   (i) Draw check sheet by selecting five minutes intervals of arrival time

   (ii) Draw the histogram

2. Draw an Ishikawa diagram for analysing the cause of employees arriving late to the office.
3. Draw a flow chart of the process of brushing your teeth.
4. Draw a flow chart of admission of a child in a school.
5. Rainfall during the month of December during the last 50 years starting from 1964 is given below. (All figures are in mm.)

15.4	27.8	35.6	10.6	28.6	31.2	16.5	25.1	33.1	34.5
5.4	7.5	12.5	25.4	38.4	41.2	18.1	25.1	33.1	34.5
27.1	31.1	35.1	28.1	33.1	40.1	5.7	6.7	8.7	25.1
45.0	49.0	7.1	15.1	25.1	40.1	15.7	18.7	25.7	40.1
30.1	30.1	27.8	25.1	28.1	23.6	17.1	25.1	25.8	35.8

   Draw the following charts for the above data.

   (a) Tally sheet by taking class interval of 3 mm of rain

   (b) Histogram

6. In the above problem, find out the following:

   (a) $\bar{x}$

   (b) s

   (c) mode

   (d) median

   (e) variance

   (f) μ

   (g) σ

7. The data given in problem 5 gives the yearly rainfall starting from 1954 to 2003. The top left most corners refer to rainfall during 1954, the first column in the next row refers to 1964 and so on and the bottom right most corner refers to rainfall in the year 2003. Draw the control chart and indicate the upper control limit and the lower control limit.

8. A normal distribution has an average of 1000°C. Its standard deviation is 5°C, what percentage of curve will lie between:
   (i) 995°C to 1005°C
   (ii) 985°C to 1015°C
9. Table below indicates the process parameter in degree celsius.

°C	132	137	140	143	145	146	147
Frequency	4	1	22	14	19	3	6

   (a) Calculate $\bar{x}$ and s
   (b) What percentage (approximate) of this distribution will fall between the specification limits of 135 and 145.
10. In a bolt manufacturing organization, 100 samples were drawn at random at periodic intervals. The number of defective samples in each subgroup is given below. Plot a tally sheet for finding out the frequency of the number of defectives. Based on this, plot a histogram. Find average, mean, mode and standard deviation.

   1 1 1 3 4 2 3 2 1 3 3 1 2 1 2 1 2 2 1 1
11. In a biscuit manufacturing company, 200 samples were drawn at random. The number of defectives is given below. Plot a check sheet, based on it a histogram.

   Defectives 11 1 10 11 4 8 3 9 1 10 3 7 2 6 2 5 7 2 9 1
12. A glassware production gave the following defectives on sample size indicated therein. Draw a scatter diagram.

No of defectives	2	1	5	1	4	5	2	3	1	0	0	2	5	4	1	3	2	1	5	0
Sample size	17	21	31	11	25	35	17	34	45	25	22	23	33	34	34	25	21	21	45	10

13. A TV receiver manufacturer measured the number of defects in each TV receiver on final inspection. Plot a check sheet and based on the same a histogram.

   No. of defects 12 11 7 6 5 4 3 2 1 5 4 6 7 8 9 5 7 8 6 7
14. A carpet manufacturer inspected and counted the number of defectives in each carpet that was manufactured. The number of defectives and the sample size are listed below. Plot a scatter diagram.

No. of defectives	2	1	5	1	4	5	2	3	1	1	1	2	5	4	1	3	2	1	5	2
Sample size	25	25	25	18	18	18	18	14	14	14	12	12	20	20	20	20	18	18	18	18

15. The specification for the width of table was 100 cms. The actual width measured on the samples is given below. Plot a tally chart and using that a histogram and a cumulative Pareto Chart.

   99 101 100 102 98 101 100 99 101 100 103 102 99 100 101 98 102 98 101 99 98 100 101 99

Chapter **12**

Control Charts for Improving Process Capability

The control chart is the process talking to us.

—Irving Burr

INTRODUCTION

Technology is advancing at a rapid pace. Simultaneously, the customers demand products with more features, better quality and higher reliability. The organizations are confronted with more competitive markets, ever growing competition, growing business and new employees. The measurements of the processes and products alone cannot solve these problems, but can clarify and focus our understanding of the performance of the processes. Sequential measurements of quality attributes of products and processes can provide a sound foundation for initiating and managing process improvement efforts. The success of any organization depends on its ability to make predictions and commitment about the performance of its products and services. Effective measurement process aids an organization to understand its capabilities. It enables them to deliver products and services as per the stated capabilities. Measurements also enables an organization to detect trends and to anticipate problems. This will help the organization to control its costs, reduce risks, improve quality and achieve customer delight. Control charts help in achieving this objective and hence are important tools to any organization.

In this chapter we will learn the following:

- Central Limit theorem
- Control Chart
    - By Variable
    - By Attribute

- X Bar & R Control Chart
- X & MR Chart
- np chart
- p chart
- c chart
- u chart
- Guidance for selection of charts
- Process capability indices
    - Cp
    - Cpk

PROCESS STABILITY

The aim of statistical process control is to stabilize the processes and then improve it. According to Deming, "A process has no measurable capability unless it is in statistical control". Thus, stability of a process has to be achieved before measuring process capability and prediction of future outcomes. Stability indicates an organization's ability to produce as planned, consistently. Hence, stability is a pre-requisite for process improvement. The characteristics of every process and product will show variations. A process is said to be stable, if variations are only due to common causes and are within limits.

The variations due to common causes are predictable as shown in Fig. 12.1.

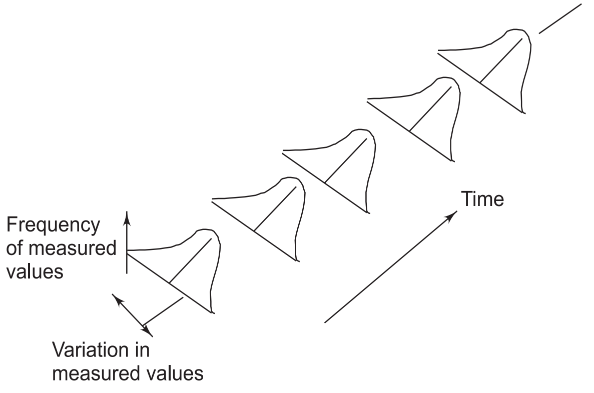


Figure 12.1 The Concept of Controlled Variation

The variations due to special causes can be easily identified as shown in Fig.12.2.

The examples of special causes of variations include the deviations in the incoming material, new operator, sudden change in working environment, too much workload, failure of machinery, etc.

Stability of a process against a chosen parameter is determined by measuring the parameter over a period of time. If the measurement results fall outside the range of common cause variation or if the center line shifts on either directions then it is the indication of instability of the processes due to special causes. Control charts are the important tools to check process stability, measure capability and then improve processes.

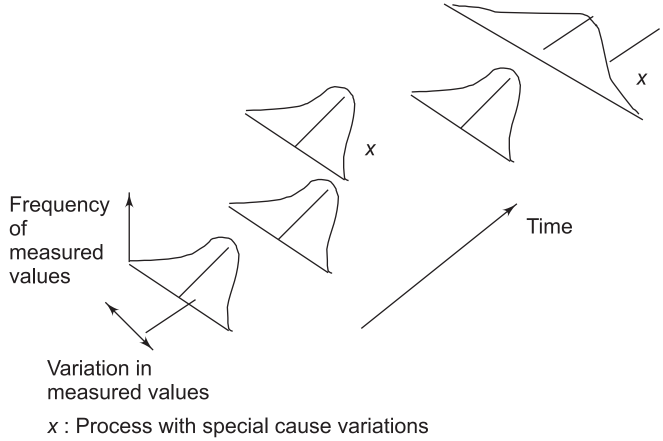


Figure 12.2 Variations Due to Special Causes

The central limit theorem is the basis for control charts.

CENTRAL LIMIT THEOREM

When we plot the variable or characteristics of individual values in a population, we get a bell shaped curve, called a normal distribution. We can pick up four or more samples at random and find their average. We can repeat this exercise of picking up samples and finding their averages, a number of times then and plot the values of sample averages. Again, we will get a normal distribution. Both will be centered over μ or in other words both will have the centre value as μ. The plots are indicated in Fig. 12.3.

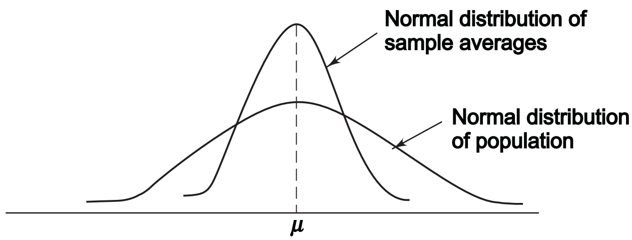


Figure 12.3 Plot of Population and Sample Averages

The central limit theorem states the following:

The sample averages ($\bar{x}$ s) will be more normally distributed around μ than the individual values (x s). The distribution of sample average approaches normal distribution regardless of the shape of the parent population.

Standard Error of the Means (SE)

The standard deviation of individual values = σ

Sample size = n

Then, $S(\bar{x}) = \sigma/\sqrt{n}$, where S_{xbar} is the standard deviation of $\bar{x}$

The spread of sample averages ($\bar{x}$) is less than the spread of population, with the standard deviation of $\bar{x}$s is equal to standard deviation of the population (individual) divided by the square root of the sample size. $S(\bar{x})$ is called the standard error of the means (SE).

The central limit theorem is the basis for control charts. This states that even if the individual values are not normally distributed, the distribution of the averages will tend to have a normal distribution. The individual values may follow a uniform distribution or triangular distribution as given in Fig. 12.4.

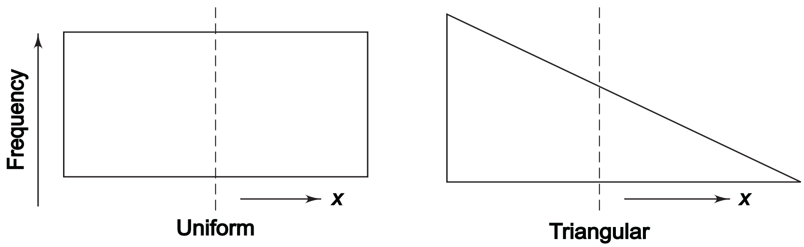


Figure 12.4

But, if four or more samples are drawn at random, then the sample averages is normally distributed. If sample averages are plotted on a control chart, the central limit theorem permits use of properties of normal distribution for such a plot, even when the form of the underlying distribution (population) is unknown. This is the basis of control charts described in the next section.

CONTROL CHARTS

According to Walter A. Shewhart "A phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in future." This is the theme of control charts. He has advised that the process stability and thereafter control should be based on measurements taken on large number of samples. It should not be based on single samples. The number of samples over a period of time will help us to characterize the nature of the process. A stable process is one that is in statistical control. In such a process, the results are predictable. The performance should lie between the upper and lower control limits, which are known as statistical limits. The process is stable so long as the frequency distribution of the measured values lies within the control limits.

SPC and Control charts were developed by Walter A Shewhart in the 1920s to control quality and thereby control the costs. Deming and others used these techniques during World War II and later for improving quality in Japan and other countries. These techniques are now used in every organization including software industries.

As we know, the control chart is a plot of process performance with time. This can be used to analyze two types of data namely:

- Variables
- Attributes

By Variables

When we measure the mass of the peanut packet, we get results on a continuous scale like 300.3, 311.2, 314.6, etc. The values we get from a measurement usually occur on a continuous scale and are called variable data. For instance, length of a bolt, performance of computer, room temperature, mains voltage, etc. are variables.

The variables data are also called measurement data. The measurement data will vary continuously. For instance, a furnace temperature can vary from 900^{o} to 950^{o} in a continuous scale. Some of the measurements that can be classified as measurement data are:

- Voltage
- Current
- Ohms
- Mass
- Length
- Torque
- Efficiency
- Speed
- Light intensity
- Elapsed time

By Attributes

Any counting can occur in whole numbers. Number of defects in a software, the number of parts/product rejected, the number of days the bus did not turn up, the number of days an employee was absent, etc. are called attributes. Thus, the attributes are whole numbers or discrete variable.

On many occasions, we want to know whether a product is functional or not, or a person is late to office or not, or a person took a flight or not. Such binary decisions are also data. Such data are called attributes data. If a person counts the number of times he is late to office in a month that is also an attribute data. On the contrary, variables are continuous and the data occurs on a continuous scale.

A control chart can be plotted for studying the performance of an item either by attributes or variables. In the former case, it is called control chart by attribute and in the latter it is a control chart by variables. In a control chart there are three zones as indicated in Fig. 12.5.

Zone I is called a stable zone. It is up to 2 σ limits on both sides. If the performance is in this zone, the production may be continued without any modifications.

Zone II is between 2 σ to 3 σ. If on some days the production slips to Zone II, then more information about the cause may be obtained. This is called the warning zone. If the performance is consistently falling in this zone, the process may require adjustment to bring the performance to Zone I.

Zone III, beyond Zone II in both the directions, is called action zone. If performance is in this zone, it calls for immediate action to adjust the process. However, all these variations should be due to random causes.

Spikes are indicators of special cause variations. Any special cause calls for immediate action. Thus, depending on the performance of the process as indicated by the data, the status of the process could be deduced accurately.

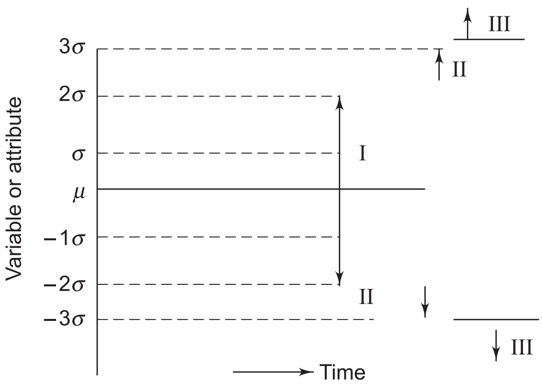


Figure 12.5 Three Zones in Control Charts

CONTROL CHART FOR VARIABLE DATA

We will look at the following types of control charts using variable data.

- x bar and range chart (we can also plot standard deviation instead of range)
- x and moving range chart

X Bar and Range Chart

We plot this chart in the following manner. Samples from regular production are picked up at random. The minimum number of samples or sample size should be greater than or equal to four to get consistent results. Usually the samples are picked up at regular intervals in a shift or in a day or more. Usually 25 such samples are picked up. Measurements are to be carried out on a selected parameter and then listed sub-group wise. For each sub-group, the average and range are to be calculated.

Example 12.1

A jewellery shop was making 10 grams gold coins for sale. At regular intervals, four coins each were selected at random. The weights of the gold coins were measured. The table below indicates the measured values of 25 sub-groups of gold coins (called *x*). Against each column, the *x* bar values were calculated, which are nothing but the average of the four values. Just following that is the range of each sub-group, which is nothing but the difference between the largest value and the lowest value.

Values of gold coin — *x*

Sub group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	10.1	9.9	10.2	10	10.6	10	10	10.1	10.3	10.1	9.8	10.1	10
	9.9	10	10.1	9.8	9.9	9.9	9.8	9.9	10	10	10.1	10.2	9.6
	9.9	9.9	9.9	10.2	10.2	10.1	10.1	9.9	9.9	10	10	10	10.2
	10	10.1	10	10	10	9.9	9.9	9.9	10	10.1	10.1	10	10.1

Calculated *x* bar

9.975	9.975	10.05	10	10.175	9.975	9.95	9.95	10.05	10.05	10	10.075	9.975

Calculated range

0.2	0.2	0.3	0.4	0.7	0.2	0.3	0.2	0.4	0.1	0.3	0.2	0.6

Values of gold coin — *x*

Sub group	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
	10.2	9.9	10.3	9.9	10.6	10.2	9.8	10.1	10.3	10.1	9.8	10.1
	9.8	10	10.1	9.8	9	9.9	9.8	9.9	10.1	9.9	10.1	10.2
	9.7	10	9.2	10.2	10.2	10.1	10.1	9.9	9.9	10	9.7	9.6
	10	10.1	10	10.1	9.8	9.9	9.9	10.1	10	10.1	10.1	10

Calculated *x* bar

9.925	10	9.9	10	9.9	10.025	9.9	10	10.075	10.025	9.925	9.975

Calculated range

0.5	0.2	1.1	0.4	1.6	0.3	0.3	0.2	0.4	0.2	0.4	0.6

Now, we have to calculate the average range —R bar. This is nothing but the average of the ranges of the 25 sub-groups.

$$R \text{ bar} = 0.412$$

Now, we have the calculate the Upper Control Limit (UCL) for the R chart.

$$\text{UCL} = \text{D4} \times R \text{ bar}$$

The Lower Control Limit (LCL) is calculated using the following formula:

$$\text{LCL} = \text{D3} \times R \text{ bar}$$

We have to get the values of D3 and D4 from Table C. Since D3 is zero for a sample size of 4, LCL will also be equal to zero.

UCL = D4 × *R*bar = 0.9394, LCL=0

Now, we plot the *R* chart, which is given in Fig.12.6:

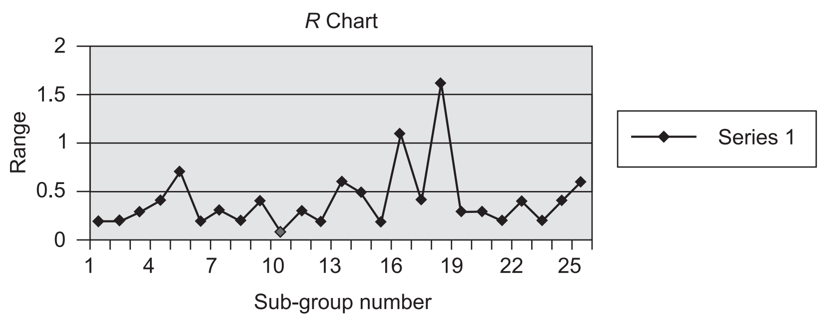


Figure 12.6

We now find that the range *R* in the chart exceeds the control limits in respect of two samples namely sub-group number 16 and 18. This could be due to assignable causes or in some cases measurement errors. Therefore, these two sub-groups are to be eliminated. Data after removing outliers are given below:

First revision after eliminating outliers

	10.1	9.9	10.2	10	10.6	10	10	10.1	10.3	10.1	9.8	10.1
	9.9	10	10.1	9.8	9.9	9.9	9.8	9.9	10	10	10.1	10.2
	9.9	9.9	9.9	10.2	10.2	10.1	10.1	9.9	9.9	10	10	10
	10	10.1	10	10	10	9.9	9.9	9.9	10	10.1	10.1	10
$\bar{x}$:	9.975	9.975	10.05	10	10.175	9.975	9.95	9.95	10.05	10.05	10	10.075
R :	0.2	0.2	0.3	0.4	0.7	0.2	0.3	0.2	0.4	0.1	0.3	0.2

	10	10.2	9.9	9.9	10.2	9.8	10.1	10.3	10.1	9.8	10.1
	9.6	9.8	10	9.8	9.9	9.8	9.9	10.1	9.9	10.1	10.2
	10.2	9.7	10	10.2	10.1	10.1	9.9	9.9	10	9.7	9.6
	10.1	10	10.1	10.1	9.9	9.9	10.1	10	10.1	10.1	10
$\bar{x}$:	9.975	9.925	10	10	10.025	9.9	10	10.075	10.025	9.925	9.975
R :	0.6	0.5	0.2	0.4	0.3	0.3	0.2	0.4	0.2	0.4	0.6

We will now calculate R bar and UCL and LCL.

R bar = 0.3304

UCL = D4 × Rbar = 0.7534, LCL = 0

The R chart is plotted again and given in Fig.12.7:

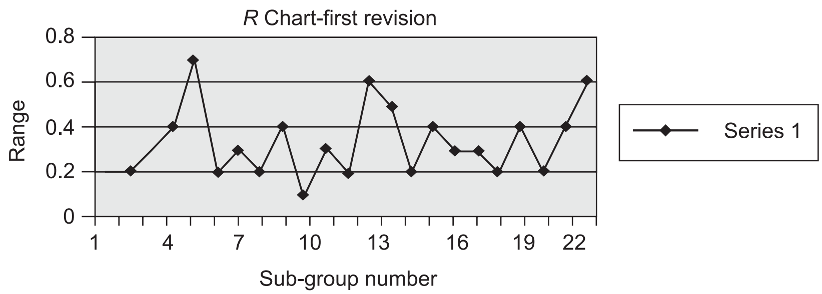


Figure 12.7

Now, there are no outliers. Therefore, the R bar (central value) and UCL and LCL are noted and frozen. It is now time to plot x bar chart. The x bar chart is nothing but a graph of x bar on the y-axis and sub-group numbers in the x-axis. The calculation of x bar bar (grand average) and UCL and LCL for the x bar chart are given below:

Grand average (x bar bar) = 10.002

UCL for x bar = x bar bar + A2 × R bar = 10.243

LCL for x bar = x bar bar – A2 × R bar = 9.761

The grand average is the average of the 23 sub-groups (since we have removed two outliers in the range chart). The values for A2 is to be obtained from Table B.

The x bar chart is given in Fig.12.8.

Let us now summarize the steps involved for arriving at $\bar{x}$ and R charts.

1. Decide on the parameter to be controlled.

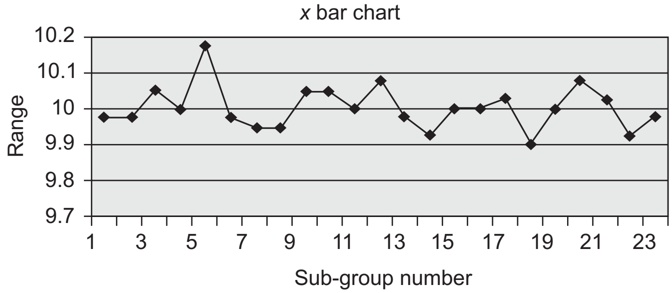


Figure 12.8

2. Pick up at least 4 samples at a time and measure the performance on the selected parameter as per step 1; pick up the samples 25 times.
3. Find $\bar{x}$ and R for each subgroup.
4. Find $\bar{R}$ as an average of R of the 25 subgroups.
5. Calculate UCL and LCL for R chart, taking D4 and D3 from Table C.
   UCL R = D4 *R* bar
   LCL R = D3 *R* bar
6. Plot the *R*-values.
7. Check whether any *R*-values lie outside UCL or LCL.
8. If all *R*-values are within limits, go to step 11.
9. If upto two *R*-values are outside the limits, eliminate the respective subgroups and repeat steps 4 to 8.
10. If more than two *R*-values lie outside limits initially or if some values go out of limits after recalculation in step 9 stop. Find out special causes and take action to improve the process. Start all over again after the process is stable.
11. The grand average *x* bar bar is the average of the remaining sub-groups. Calculate $\bar{\bar{x}}$ excluding the subgroups, if any whose *R* were out of limits.
12. Calculate LCL, UCL, action limits as well as warning limits for $\bar{\bar{x}}$ and *R* Charts.
    UCL *x* bar = *x* bar bar + A2 *R* bar.
    LCL *x* bar = *x* bar bar – A2 *R* bar.

    Now, plot the *x* bar chart. Check that sample averages ($\bar{x}$) of all the sub-groups lie within the control limits.

Now, let us take one more example of *x* bar and *R* control chart.

Example 12.2

A manufacturer of 300 grams weight wants to carry out a process capability study. For this purpose, he has picked up 25 sub-groups of 4 samples of weights manufacturing over the period of 2 days. Values of 300 grams weights are given:

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
301	299	302	300	306	300	300	301	303	301	295	301	300
299	300	301	298	299	299	298	299	300	294	301	302	296
299	299	299	302	302	301	301	299	295	310	300	300	302
300	301	300	302	307	300	301	302	300	302	312	301	304

The corresponding *x* bar and the range of each group are given below:

x bar	299.75	299.75	300.5	300.5	303.5	300	300	300.25	299.5	301.75	302	301	300.5
range	2	2	3	4	8	2	3	3	8	16	17	2	8

Values of 300 grams weights – x

14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
302	299	303	299	306	302	298	301	303	301	302	301
298	300	301	298	298	299	298	299	301	299	303	301
297	300	298	302	302	301	301	299	299	300	302	301
304	301	301	301	304	304	302	302	301	301	302	302

x bar	300.25	300	300.75	300	302.5	301.5	299.75	300.25	301	300.25	302.25	301.25
range	7	2	5	4	8	5	4	3	4	2	1	1

The *R* bar, UCL and LCL for the above data are calculated and given below:

R bar = 4.96

UCL = D4 × Rbar = 11.309, LCL = 0

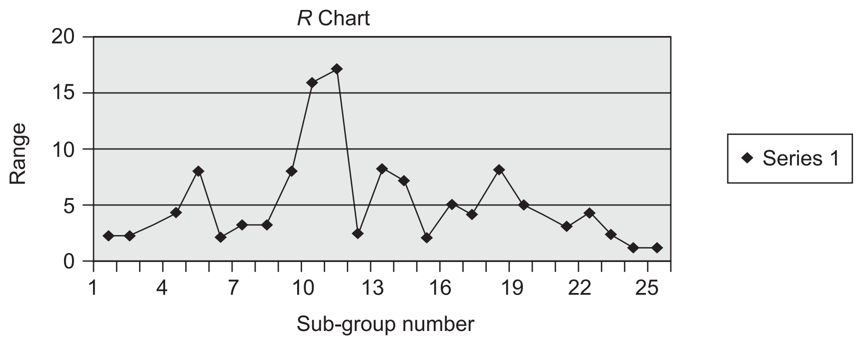


Figure 12.9

It is found that the range of sub-groups 10 and 11 are beyond the UCL. Therefore, these two outliers are eliminated and given below:

First revision after eliminating outliers

	301	299	302	300	306	300	300	301	303	301	300	302	299
	299	300	301	298	299	299	298	299	300	302	296	298	300
	299	299	299	302	302	301	301	299	295	300	302	297	300
	300	301	300	302	307	300	301	302	300	301	304	304	301
$\bar{x}$:	299.75	299.75	300.5	300.5	303.5	300	300	300.25	299.5	301	300.5	300.25	300
R:	2	2	3	4	8	2	3	3	8	2	8	7	2

	303	299	306	302	298	301	303	301	302	301
	301	298	298	299	298	299	301	299	303	301
	298	302	302	301	301	299	299	300	302	301
	301	301	304	304	302	302	301	301	302	302
$\bar{x}$:	300.75	300	302.5	301.5	299.75	300.25	301	300.25	302.25	301.25
R:	5	4	8	5	4	3	4	2	1	1

The *R* bar, UCL and LCL for the range chart calculated after revision are given below:

R bar = 3.9565

UCL = D4 × *R*bar = 9.0209   LCL = 0

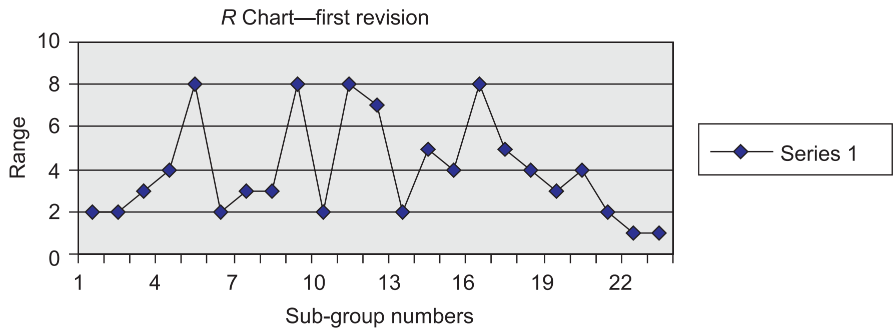


Figure 12.10

Now, there are no outliers. Hence, we will now proceed to plot the *x* bar chart. But, before that we have to calculate the grand average and the control limits. The calculation is given below:

$$x \text{ bar bar} = 300.65$$
$$\text{UCL} = X \text{ bar bar} + \text{A2} \times \text{R bar} = 303.54$$
$$\text{LCL} = X \text{ bar bar} - \text{A2} \times R \text{ bar} = 297.76$$

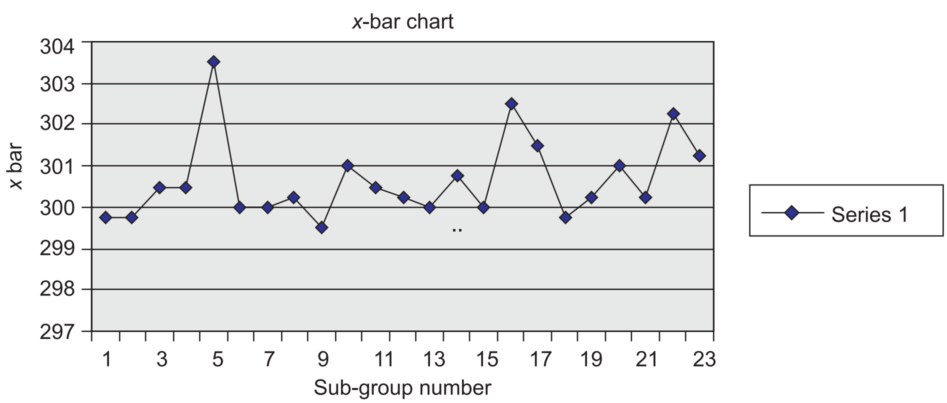


Figure 12.11

In the *x* bar chart also, there are no outliers.

x bar and R charts are quite useful for study of process performance when we collect data as variables. The control chart indicates whether the process is in control. It indicates clearly the variation due to assignable causes. The points we were eliminating in the subsequent iterations in the worked examples can be due to assignable causes or error in measurements.

Warning and Action Zones

The warning zone starts at $\bar{\bar{x}} \pm 2\,\sigma/\sqrt{n}$ or

$\bar{\bar{x}} \pm 2/3\ A_2\ R$ bar

The action zone starts at $\bar{\bar{x}} + \sigma/\sqrt{n}$ or

$\bar{\bar{x}} \pm A_2\ R$ bar

Thus the action zone starts at UCL and LCL in the average chart. The warning line starts at 2/3 of UCL and LCL.

Example 12.3

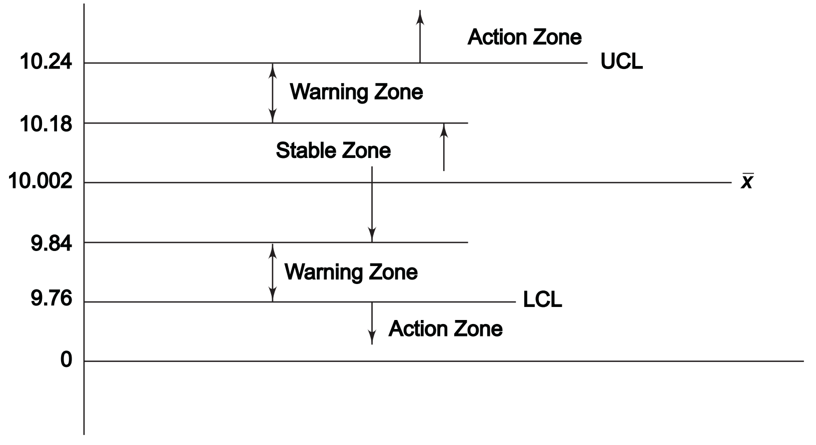
In our worked example 12.1, in the $\bar{x}$ chart action zone lies above 10.24 and below 9.76.

The warning zone starts at 10.18.

Similarly, the lower warning limit starts at 9.84.

Therefore, when the results fall above 10.24, but below 9.76, then we have to analyze and take action.

The warning and action zones for $\bar{x}$ chart are illustrated in Fig. 12.12:



Warning and Action Zones

Figure 12.12

Control limits for Range

	Known R	Known σ
Upper action line	$D^1_{\cdot 001}\ \bar{R}$	$D_{0.001}\sigma$
Lower action line	$D^1_{\cdot 999}\ \bar{R}$	$D_{0.999}\ \sigma$
Upper warning line	$D^1_{\cdot 025}\ \bar{R}$	$D_{0.025}\ \sigma$
Lower warning line	$D^1_{\cdot 975}\ \bar{R}$	$D_{0.975}\ \sigma$

The values of constants can be obtained from Table C. For the worked example 12.1:

Upper action line = $2.57 \times 0.33 = 0.85$
Lower action line = $0.1 \times 0.33 = 0.03$
Upper warning line = $1.93 \times 0.33 = 0.64$
Lower warning line = $0.29 \times 0.33 = 0.1$
We know UCL = 0.75, LCL = 0.

The control lines for the worked example are given in Fig. 12.13:

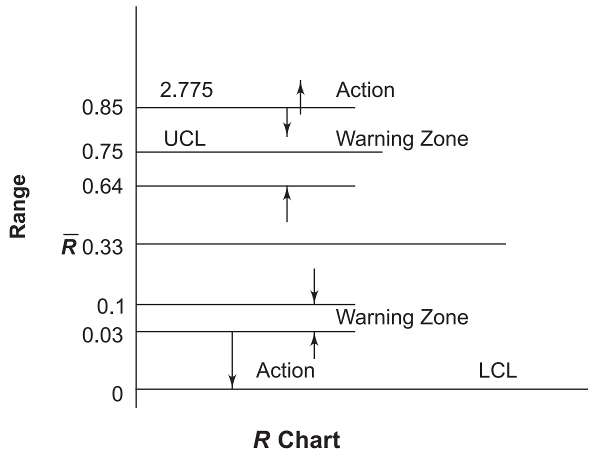


Figure 12.13

Let us look at another example to reconfirm our understanding.

Example 12.4

The peanut manufacturer has observed the following at the end of the day.
No. of sub-groups = 20
Size of sub-group = 5

$$\Sigma \bar{x} = 6000$$
$$\Sigma R = 40$$

Draw the control limits for $\bar{x}$ and Range.

Step 1 : Find out $\bar{\bar{x}}$

$$\bar{\bar{x}} = 6000/20 = 300$$

Step 2 : Find out $\bar{R}$

$$\bar{R} = 40/20 = 2$$

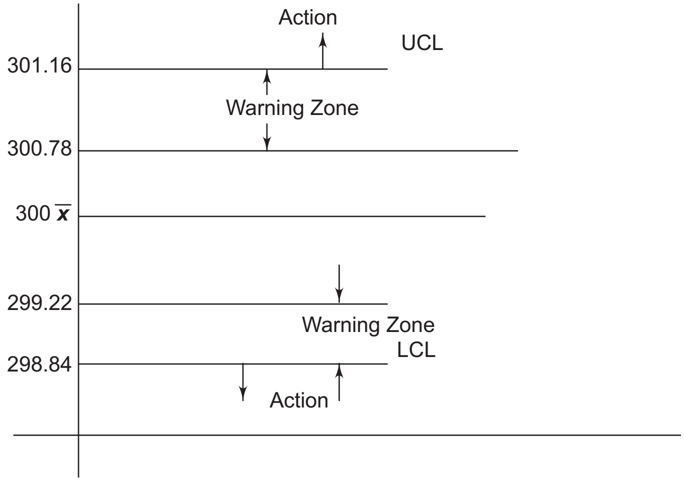
$\bar{x}$ Chart

$$\begin{aligned} \text{UCL} &= \bar{\bar{x}} + A_2 \bar{R} \\ &= 300 + 0.58 \times 2 \\ &= 301.16 \\ \text{LCL} &= 300 - (0.58 \times 2) \\ &= 298.84 \end{aligned}$$

Upper warning line $= \bar{\bar{x}} + 2/3\ A_2\ \bar{R}$
$= 300 + 0.39 \times 2 = 300.78$

Lower warning line $= 300 - 0.78$
$= 299.22$

Now we can draw the control limits for $\bar{x}$



$\bar{x}$ Chart

Figure 12.14

$\bar{R}$ Chart

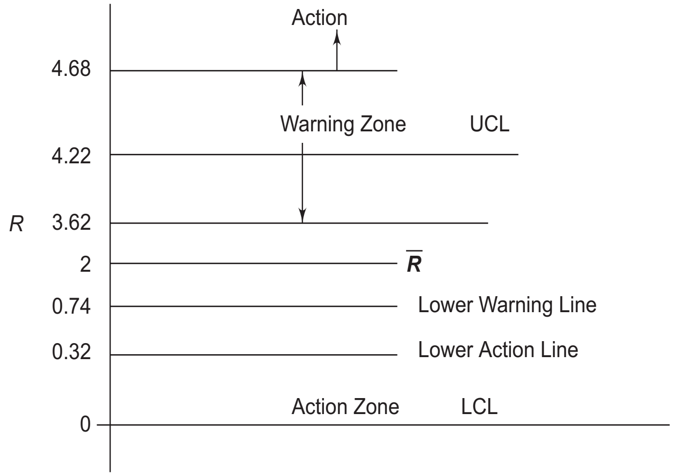
UCL = D4 $\bar{R}$ $= 2.11 \times 2 = 4.22$
Upper Action Line $= 2.34 \times 2 = 4.68$
Upper Warning Line $= 1.81 \times 2 = 3.62$
Lower Warning Line $= 0.37 \times 2 = 0.74$
Lower Action Line $= 0.6 \times 2 = 0.32$
LCL = 0, since D3 = 0

The control limits for R Chart are shown in Fig. 12.15:

Indications of Abnormality in the Process The process is said to be out of control, when the performance lies outside $\pm 3\ \sigma$ limits (UCL or LCL) in the x bar chart. The performance of the variable should preferably lie between $\pm 2\ \sigma$. However, the performance of some patterns as given below calls for immediate action to analyze the causes and taking corrective actions:

Performance within $\pm 2\ \sigma$

1. Seven consecutive points showing a continuously increasing or decreasing pattern.
2. Seven points remaining close to the central line.
3. Seven consecutive values showing either a continuous upward trend or downward trend.
4. Values showing a cyclic pattern.



***R* Chart**

Figure 12.15

Performance in the warning zone (outside ± 2 σ, but within ± 3 σ)

5. No incidence of two consecutive points in the warning zone.
6. Not more than four points in warning zone.

PROCESS CAPABILITY INDICES

The fundamental requirement of any process is that it should be stable first. Stability is indicated by consistent performance of the process within the limits set. Only variations allowed are the common cause variations. Therefore, statistical control implies performance of the process within the set limits. Only thereafter, the process will be predictable. Therefore, capability can be assessed only on a process, which is consistently stable over a period of time.

The process is abnormal when there are variations due to special or assignable causes. The abnormal process is out of control. When there are special causes, the process should be stopped to find out the special causes and eliminating them.

We will study the capability of the process, which has variations only due to common causes. The process capability indices are deduced to find a relationship between variations due to common causes and tolerance.

Recall the areas under the normal curve. We know that the area under the curve between ± 2 σ is 95.45%. This means 4.55% of the curve is outside this total 4 σ limits. If the tolerance of the process is equal to ± 2 σ, then 4.55% of the products will be defective. If the tolerance is equal to ± 3 σ, then 0.27% of the products will be defective. The tolerance limits are actually set by customer and what is under the manufacturer's control is the process performance and statistical control limits.

The process capability has two indices namely *Cp* and *Cpk*.

Cp

Cp = USL – LSL/6 σ

Where USL : Upper Specification Limit
LSL : Lower Specification Limit

$$\sigma = \overline{R}/d_2$$

Let us consider various possibilities with regard to Cp.

$Cp < 1$: This means that the normal curve extends beyond $\pm 3\ \sigma$ limits (UCL and LCL). Therefore, the process is incapable. When $Cp > 1$, it becomes increasingly capable, provided the grand average is maintained at (USL + LSL)/2.

Cpk

Cp can be applied only when the process is correctly centered about the mid specification since it takes into account the precision with the total tolerance. To know how well a process is performing both accuracy and precision should be compared. C_{pk} takes into account both the degree of random variation and accuracy. This is the most popular process capability index.

$$C_{pk} = \text{minimum of } (\text{USL} - \overline{\overline{x}}/3\ \sigma,\ \overline{\overline{x}} - \text{LSL}/3\ \sigma)$$

When $C_{pk} <= 1$, the variations and centering may cause infringing into one of the tolerance limits and hence process not capable. If the process means coincides with mid specifications, then both C_{pk} and Cp will give the same value. C_{pk} gives additional information about the centering. Therefore, it is also called process performance index. Hence, increasing value of C_{pk} means that the process is increasingly becoming capable.

Example 12.5

Look at worked example 12.1 after eliminating outliers.

Let USL = 10.5 and LSL = 9.5

$$\overline{\overline{x}} = 10.002$$

$$\overline{R} = 0.3304$$

$$\sigma = \overline{R}/d_2 \text{ (take value of } d_2 \text{ from Table B)}$$

$$= 0.3304/2.059 = 0.13$$

$$Cp = 10.5 - 9.5/6\ (0.13) = 1.28$$

$$\text{USL} - \overline{\overline{x}} = 10.5 - 10.002 = 0.498$$

$$\overline{\overline{x}} - \text{LSL} = 10.002 - 9.5 = 0.502$$

Therefore, $C_{pk} = 0.498/3\ (0.13) = 1.27$

Since C_{pk} is almost equal to C_p, we can conclude that the process is nearly centered. Since they are greater than 1, it is capable provided we maintain grand average at mid-specification limits.

Example 12.6

Let the specification limit be 300 ± 10 for data is Example 12.2

$$\overline{\overline{x}} = 300.65$$

$$\sigma = \overline{R}/\text{d}_2 = 3.9565/2.059 = 1.9$$

$$C_p = 20/6 \times 1.9 = 1.8$$

$$\overline{\overline{x}} - \text{LCL}/3 \times 1.9 = 300.65 - 290/5.7 = 1.9$$

Or

$$\text{USL} - \bar{\bar{x}}/5.7 = 310 - 300.65 / 5.7 = 1.7$$

$\therefore$ $$C_{pk} = 1.7$$

The process is capable but not centered as the data also reveals.

Example 12.7

Given sample size = 4 and 25 samples were considered. The process is under control.

$$\bar{\bar{x}} = 105$$
$$\text{USL} = 110$$
$$\text{LSL} = 90$$
$$\sigma = 2$$
$$Cp = 20/6 \times 2 = 1.66$$

USL – $\bar{\bar{x}}$ is the lowest.

Therefore, $$C_{pk} = 110 - 105/3 \times 2 = 5/6 = 0.83$$

Since, Cp is 1.66, the process could be highly capable. But $Cp = 0.82$ indicates that the capability has been reduced due to shifting of the mean to the right. There may be processes, which are under statistical control, meaning that the variation is due to random causes. But the process may not be capable as inferred from the C_{pk} value. This may be overcome by widening the tolerance limits, provided the customer accepts it. If not, the rejects will be high which have to be weeded out before supply. Irrespective of sample size, $C_{pk} < 1$ indicates an incapable process. If C_{pk} greater than 1, but upto 2, we have to confirm the process capability through more samples. $C_{pk} > 3$ is definitely a capable process.

X and *MR* Chart

$\bar{x}$ and R chart requires at least four items in each sub-group. In some industries such as chemical industry or when the cost of samples is high, we can have only one item per subgroup. In such cases, we cannot find the range R. In such situations, we can use moving range (*MR*) chart. Moving range is the difference between the value and the one immediately preceding it. In this case, we use the *X* and *MR* chart. Thus, there are two sets of data, one is the measurement called '*X*' and the other is the moving range called '*MR*'.

The parameters of *X* and *MR* charts are given below:

Parameter	***X***	***MR***
Centre	$\bar{x}$	$\overline{MR}$
UCL	$\bar{x} + 3\ (\overline{MR}/1.13)$	$\overline{MR} \times 3.27$
LCL	$\bar{x} - 3\ (\overline{MR}/1.13)$	0

Example 12.8

The 11 subgroups of 1 sample each had values as indicated below:

100	101	100	102	100	99	100	98
99	100	101					

Calculate control limits for *MR* chart.

Solution

Let us first calculate the average of the values $\bar{x} = 100$

We will get 10 moving ranges for 11 subgroups or values. The absolute value of the difference between one value and the next is to be calculated. Thus *MR* will be:

1	1	2	2	1	1	2	1	1	1

$$\therefore \quad \overline{MR} = 13/10 = 1.3$$

$$\text{UCL MR} = \overline{MR} \times 3.27$$

$$= 1.3 \times 3.27 = 4.251$$

$$\text{LCL } MR = 0$$

Now, we can calculate control limits for the *X* chart.

$$\text{UCL} = \bar{x} + 3\,(\overline{MR}/1.13)$$

$$= 100 + 3\,(1.3)/1.13 = 103.4$$

$$\text{LCL} = \bar{x} - 3(\overline{MR}/1.13)$$

$$= 96.6$$

Now we can plot the values in *X* and *MR* Chart.

Example 12.9

The temperatures of a steam bath were recorded and shown below (*x* values). Plot *x* and *MR* chart,
x values

100	101	100	102	103	101	100	99	101	102	103	102	101	100
101	102	102	103	101	99	98	100	101	102				

The moving range is the difference between the adjacent values (*MR*). The moving ranges are calculated and given below:
MR values

1	1	2	1	2	1	1	2	1	1	1	1	1	1
1	0	1	2	2	1	2	1	1					

Then, we calculate *X* bar, which is the average of the x values. The average of *MR* values which is *MR* bar. The control limits for *MR* charts are given below:

UCL = *MR* bar x D4

Note:

Since the sample size is one always, in the moving range chart, we take D4 as 3.27 corresponding to a sample size of 2.

LCL = 0

For *x* chart,

UCL = *x* bar + 3 (*MR* bar/1.13)

LCL = *x* bar – 3 (*MR* bar/1.13)

The charts are given in Fig.12.16:

UCL *MR* 3.9809
LCL 0

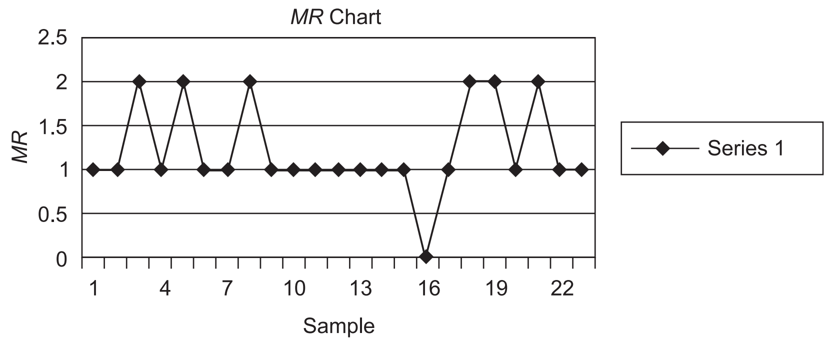


Figure 12.16

Since there are no outliers, we do not have to eliminate any points. Now, we can plot x chart and see whether there are any outliers.

x bar = 101
MR bar = 1.2174
UCL *X* = 104.23
LCL *X* = 97.768

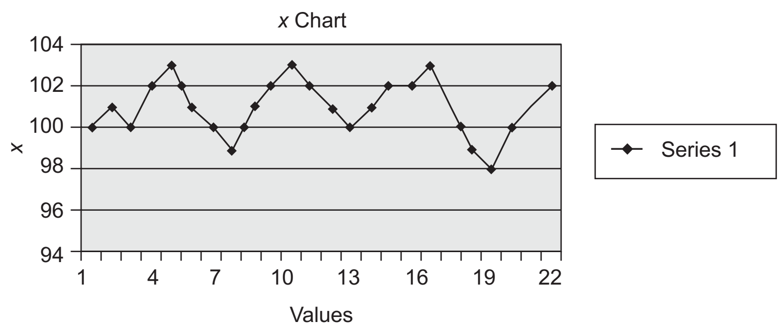


Figure 12.17

This chart is useful in the following situations:

- Samples are more expensive
- The data is accumulated slowly over a period of time
- Each lot consists of only one sample

CONTROL CHARTS BY ATTRIBUTES

The control chart by variables is quite useful to study the performance against individual characteristics of products. The control charts are to be plotted for each quality characteristics. An entity may contain hundreds of quality characteristics. This means that we need to plot one chart for each characteristic. This may neither be feasible nor desirable in the normal circumstances. Hence, this chart is more expensive. At the same time, the usefulness of the chart should not be undermined because this gives micro level analysis of the quality of the products manufactured. This can be used selectively.

When a quality problem is found and if the organization wants to carry out further analysis, then specific characteristics of the entity can be measured and controlled using *X* bar and *R* control charts.

Usually, the organizations collect data on the number of non-conforming products. This data is readily available. Hence, it is rather easier to prepare control charts by attributes. The attribute charts are likely to be less expensive. Furthermore, the top management will be interested in the overall results and hence attribute charts fit the bill. Thus, the control chart by attributes could be the starting point in every organization. Here, we count the occurrences of failures or defects in a product or number of defectives, percentage of non-conforming products, etc. The *x* bar and *R* chart is based on normal frequency distribution. However, the attributes charts are based on distributions as given below:

Binominal Distribution	**Poisson Distribution**
np chart	*c* chart
p chart	*u* chart

Let us now look at the charts based on binominal distribution. Here, we count the number of non-conforming products, i.e. the number of defectives. The *np* chart helps us to analyze the quality of the process by looking at the number of non-conforming entities. The *p* chart on the other hand looks at the fraction rejected due to non-conformances to specifications or fraction defectives.

Let us first look at the *np* chart.

np Chart

The *np* chart is used when the sample size is constant. Such conditions occur in manufacturing organizations. The organization may carry out inspection of constant size of products and records the number of defective units in each sample.

Example 12.10

The following table indicates the number of defectives in a toilet soap manufacturing organization. Sample size is constant and equal to 100. The steps involved in finding out the control limits are given below:

- Collect data about the number of defective units in each sample. The sample size may be 100 or any convenient number, which is called *n*. The number of defectives in each subgroup is called *np*.
- Collect these data periodically say 25 times. The number of samples, i.e. the number of sub-groups = *N*.
- Calculate the average number of defectives – *np* bar, which is equal to $\Sigma np/N$.
- Calculate *p* bar, which is the average fraction defective. This is equal to *np* bar/*n*.
- Now, the central line is *np* bar.
- The control limits are *np* bar +/– 3 × √*np* bar (1–*p* bar)

np = defectives	0	1	5	6	4	2	8	2	1	5	3	4	6	1	0	5	7	2	6	1

np bar = 3.45
p bar = 0.0345
UCL = 8.925288
LCL = 0

The *np* chart plotted as per Fig. 12.18 is a graph of fraction defective vs. time or the sample number. We can also plot percent defective chart using the same data. The differences lie in the following:

- Percent defective is 100 × fraction defective
- In the control limits, we will have (100 – *p* bar) instead of (1 – *p* bar).

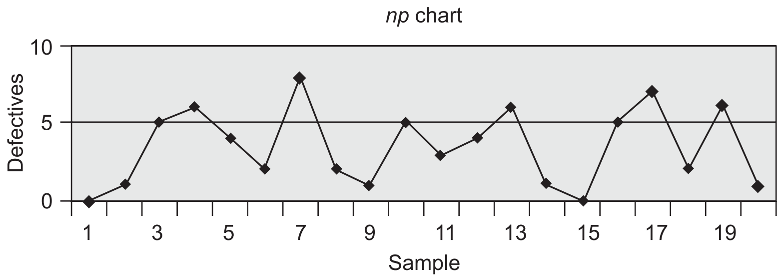


Figure 12.18

p chart

In the above example, if the sample size is not constant, then we can plot a *p* chart. The *p* chart is more popular and is widely used. This chart is used to plot the fraction rejected. The fraction-rejected *p* is defined as the ratio of number of non-conforming items to the total number of items inspected. As the name suggests, it is a fraction less than 1.

The *p* chart can also be plotted as per cent rejected which will be hundred times *p*.

The steps involved in finding out the control limits are given below:

- Collect the data about the number of defective units in each sample of unequal size. The sample size may be noted along with the number of defective units.
- Calculate *p* (per cent or fraction defective). When the number of defects are divided by the number of samples and expressed as a fraction or a percentage, it is called *p*.
- The individual size of samples is equal to *n*. *n* is not a constant and it may vary from sample to sample.
- Collect these data periodically say 25 times. The number of samples is equal to *N*.
- Average sample size is equal to $\Sigma n / N$.
- Average fraction or per cent defective, *p* bar is equal to $\Sigma p/N$.
- Now, the central line is *p* bar.
- The control limits for fraction defective chart are *p* bar ± 3 × √*p* bar(1–*p* bar)/*n* bar.
- The control limits for per cent defective chart are *p* bar ± 3 × √*p* bar(100–*p* bar)/*n* bar.
- If the lower control limit is less then zero, then LCL = 0.

Example 12.11

In a cell phone manufacturing plant samples were taken from each day's production and tested and number of defectives found each day was recorded. It is given below:

No of defectives	2	1	5	1	4	5	2	3	1	0	0	2	5	4	1	3	2	1	5	0
Sample size	50	55	80	70	90	60	72	80	90	50	81	92	55	63	70	59	58	62	70	75
percent defectives	4	1.8	6.3	1.4	4.4	8.3	2.8	3.8	1.1	0	0	2.2	9.1	6.3	1.4	5.1	3.4	1.6	7.1	0

Average sample size = 69
p bar = 3.51224

UCL = 10.15595
LCL = 0

The *p* chart follows.

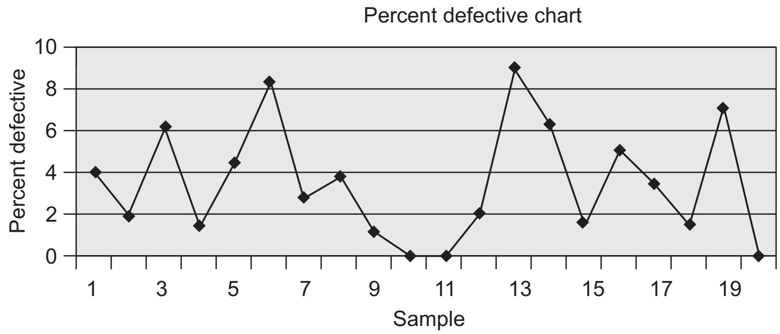


Figure 12.19

The selection of a p chart or np chart depends on the convenience. If the number of items inspected varies from sample to sample, then p chart is ideal. However, if the sample size is constant, then np chart will be useful.

c CHART

The control chart by variables namely X bar and R chart is plotted for chosen quality characteristics, which is measured on the continuous scale. The p or np charts are useful for characterizing the number of defectives. The control charts for non-conformities is called c chart. It is useful when a non-conforming item contains one or more non-conformances, i.e. it contains one or more defects. When it is necessary to study the total number of non-conformances in a product or a group of equal number of similar products, we can use the control chart techniques based on Poisson distribution. The c and u charts are based on Poisson distribution. The c chart is applicable when the number of products inspected is a constant. Usually it is one item. The variable c is the number of defects found in the constant sample size. When the sample size varies, i.e. when the opportunity for occurrence of non-conformities change from sample to sample then a u chart is used.

c charts are used for understanding the number of defects in a specific portion of the population. For instance, this can be used to analyze the number of defects in a specified area like 10 cm × 10 cm in a printed circuit board. The requirement is that the samples should have the same area or dimensions. For instance, the contamination in one litre of water can be studied using a c chart by drawing samples periodically.

The steps involved in finding out the control limits are:

- Collect data about the number of defects per unit of the same size. Collect 25 such samples. Call them c.
- Calculate c bar, which is $\Sigma c/n$.
- The control limits for c are c bar $\pm 3 \times \sqrt{c}$ bar.

Example 12.12

An automobile company has a painting section. The number of defects were counted in an area of 1 metre by 1 metre of the chassis. The number of defects for the same area in different samples is listed in table below. Plot a c chart.

C, no . of defectives	0	1	5	6	4	2	8	2	1	5	3	4	6	1	0	5	7	2	6	1

Solution

c bar = 3.45
UCL = 9.022253
LCL = –2.12225 (treat as zero)

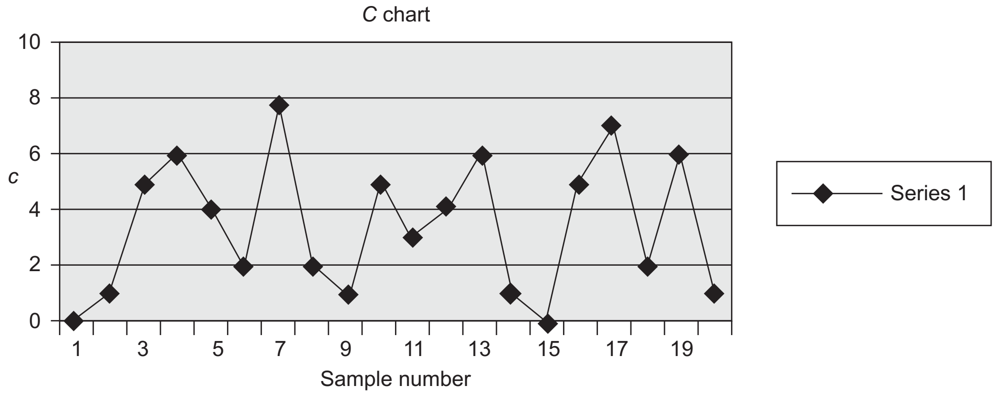


Figure 12.20

u Chart

The *u* chart is quite useful in software industry. It is more flexible than the *c* chart. In a *u* chart, the unit inspected is not a constant. Therefore, we normalize the defects for a standard unit.

Example 12.13
The number of defects found in the software program and the total number of lines of program are given in the table below. Plot a *u* chart.

No. of defectives	2	1	5	1	4	5	2	3	1	1	1	2	5	4	1	3	2	15	2
Sample size (kilo lines of code)	5	5	5	5	4	4	4	4	4	4	4	4	4	5	5	5	5	55	5

Solution
The number of defects and sample size are indicated in the above table. We have to normalize the above by finding out defects per kilo line of code. The normalized defects per unit are given below. The central line is *u* bar.

u bar = $\Sigma u/N$
where N = No. of samples

However, we have a difficulty in finding out the control limits. Here, we will have multiple control limits depending upon each sample size. The general formula is:
Control Limit = u bar $\pm 3 \times \sqrt{u \text{ bar}/n}$

Therefore, while drawing the control limits corresponding to each sample size, we have to determine both UCL and LCL for the size of the sample. In the above example, there are only two sample sizes. Therefore, we have to calculate the control limits for the sample size of 4 and 5 separately. Once this is done, we can plot the *u* as well as the control limits.

Defects per unit u 0.4 0.2 1 0.2 1 1.3 0.5 0.8 0.3 0.3 0.3 0.5 1.3 0.8 0.2 0.6 0.4 0.2 1 0.4

U bar	0.57
UCL for 5 samples	1.6
LCL for 5 samples	–1 treated as zero
UCL for 4 samples	1.7
LCL for 4 samples	–1 treated as zero

The u chart is given below along with the control limits.

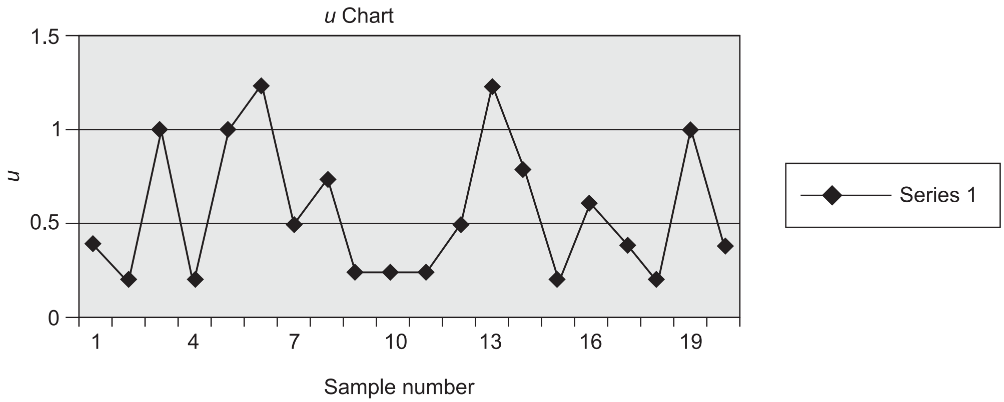


Figure 12.21

Comparison between control chart by variables and by attributes

	Variable Charts	*Attribute Charts*
Chart type	X bar and R or σ , x and MR	*np, p, c, u*
Type of data	Measured on a continuous scale	Number of defectives or defects
Advantages	Useful for improvement of product quality characteristics	Data collection is easy and economical
	Detailed information about chosen characteristics of a process or product	Provides a holistic view
	Focused on specific parameters	Data readily available in every organization
	Suitable for detailed analysis	Easily understandable since it is pass or fail criteria only
Disadvantages	Cannot be used with go/no go type inspection	Not suitable for control and improvement of individual parameters of processes or products
	Expensive	Severity of defects not visible
		Not detailed enough
Application	Control and improvement of individual parameters of processes such as temperature, dust, etc. and every characteristics of products such as length, noise, gain, etc.	Control of number of defects in a unit or number of defectives—usually product oriented.

The need for control charts:

- Provides information about process capability
- Provides a basis for predicting future performance
- Provides a basis for measuring improvement
- Control charts help in getting the process under control and thereby prevent defects from occurring.
- In accordance with Juran's chain reaction, the above leads to improving quality, productivity and increased market share.
- Prevents unnecessary process adjustments and enables necessary process adjustments
- Provides a lot of diagnostic information
- Helps in identifying assignable causes immediately
- Gives feedback to the process owners
- Helps the management to keep the processes under control and effect savings
- Enables highest ROI.

The summary of control charts discussed in this chapter is:

Variables

Chart Name	*Measures plotted*	*Centre line*	*Control limits*	*Remarks*
x bar	Average of individual samples—*x* bar	*x* bar bar	*x* bar bar ± A2 × *R* bar	*x* bar bar Σ *x*bar/*N* (*N* = No. of samples)
R	Range of each sample—*R*	*R* bar	UCL = D4 × *R* bar LCL = D3 × *R* bar	*R* bar = Σ*R*/*N* *N* = No. of samples
x	Individual values—*x*	*x* bar	*x* bar ± 3 (*MR* bar/1.13)	*x* bar = Σ*x*/*n*
MR	Moving range—*MR*	*MR* bar	UCL = *MR* bar × 3.27 LCL = 0	*MR* bar = Σ*MR*/*n*-1 (n = no. of values)

Attributes

Chart Name	*Measures plotted*	*Centre line*	*Control limits*	*Remarks*
np	*np* – number of defectives in samples of constant size of n	*np* bar	*np* bar ± 3 √*np* bar (1–*p* bar)	*n* – sample size *N* – No. of samples *np* – defects in the individual sub-groups *np* bar = Σ*np*/*N* *p* bar = *np* bar/*n*
p	*p* – fraction defectives in samples of varying sizes	*p* bar	*p* bar ± 3 √*p* bar (1–*p* bar)/*n* bar	*p* bar = Σ *p*/*N* *N* = No. of samples in the data *n* bar = average sample size

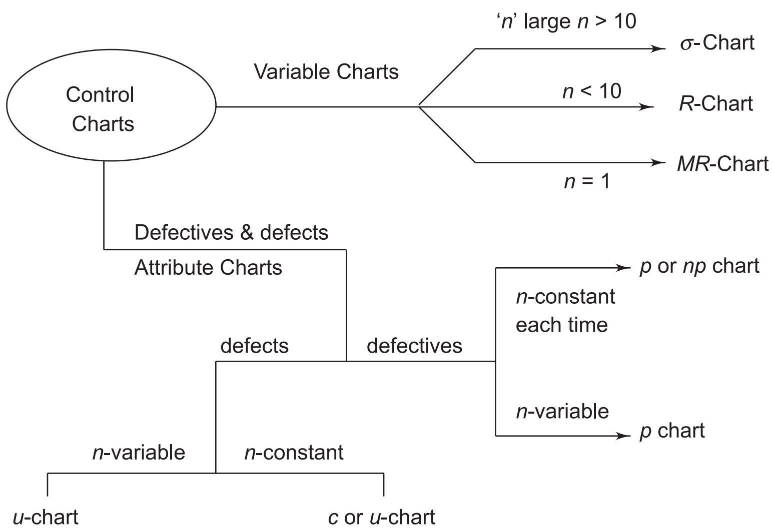
(Contd.)

(Contd.)

Chart Name	*Measures plotted*	*Centre line*	*Control limits*	*Remarks*
c	*c* – No. of defects or deviations in samples of constant size	*c* bar	*c* bar ± 3 √*c* bar	*c* bar - average number of defects in sample of constant size
u	*u* – No. of defects per unit in the samples of variable sizes	*u* bar	*u* bar ± 3 √*u* bar/*n* For each unique *n* we have to calculate the limits	*u* – defects per sample *u* bar = Σ*u*/*N* *n* – sample size *N* – No. of samples

GUIDANCE FOR SELECTION OF CHARTS

Guidance for selection of appropriate control chart is given in Fig.12.22:



(One defective module can have many defects)

Figure 12.22

SUMMARY

This chapter gives the most important tools to assess the process capability. The aim of TQM is continuous improvement of every process in the organization. The central limit theorem states that the sample averages distribute more closely around μ than the individual values of the population. Irrespective of the underlying distribution of the population, if four or more samples are drawn at random from the lot, the sample averages will be normally distributed. That is the basis for control charts. Control charts are plots of process performance with time. There are two types of control charts :

- by variables
- by attributes

When we measure a quality characteristics on a continuous scale, we use control chart by variables. On the contrary, when we count the number of defectives, we use control chart by attributes. We discussed $\bar{x}$ and R as well as x and MR charts belonging to the first category. R is a measure of variations. There are three zones in the control chart namely, stable zone, warning zone and action zone. We first plot the R chart. The chart is studied to see any assignable causes or measurement errors. Such points are eliminated and the R chart is revised to get the values of $\overline{R}$ and the three zones. Thereafter, $\bar{x}$ chart is made. We usually take at least four samples each and carry out the analysis after measuring 25 such subgroups. When it is expensive to test samples of size more than 1, we plot MR and x chart. Here, the moving range (MR) is the difference between the value and the one preceding it. Then, we discussed about the use of the following 4-control chart by attributes, np, p, c and u.

The np chart is used when the sample size is constant. np represents the number of defectives in each subgroup. p chart is used when the sample size is not constant. The charts can depict both the fraction defective and percent defective. c charts are used for controlling the variations in the number of defects in a specific portion of the population of constant size or unit like the number of defects in one square cm of a silicon wafer. On the contrary, a u charts can be used when the sample size or unit is varying. The control charts facilitate the following:

- Understand process performance
- Correct special cause variation
- Reduce common cause variation
- Improve the process continuously

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. Rectangular distribution is
   (a) Normal (b) Uniform
   (c) Gaussian (d) All the above
2. Warning zone
   (a) Ends at 2 σ (b) Starts at 2 σ
   (c) Starts at 3 σ (d) None of the above
3. Variable control charts include
   (a) c (b) np
   (c) σ (d) None of the above
4. Range chart has
   (a) UCL (b) LCL
   (c) Mean Range (d) All the above

5. Centering of data is taken into account while calculating
   (a) *Cp* (b) *Cpk*
   (c) USL (d) None of the above
6. The upper control limit of *X* bar chart whose details are given below:
   X bar bar = 0.5, *R* bar = 0.002, $n = 3$,
   (a) 0.503 (b) 0.502
   (c) 0.505 (d) None of the above
7. What is the UCL of the range chart where $n = 5$ and $R = 0.004$
   (a) 0.0085 (b) 0.007
   (c) 0.0065 (d) None of the above
8. What is the UCL of a *p* chart, (fraction defective) if a *p* bar = 0.05 and $n = 30$?
   (a) 0.09 (b) 0.14
   (c) 0.169 (d) None of the above
9. What is the UCL of a *c* chart, if *c* bar = 20?
   (a) 35 (b) 33.4
   (c) 40 (d) None of the above
10. What is the LCL of a *u* chart, if *u* bar = 12 and $n = 30$?
    (a) 0 (b) 1.1
    (c) 10.1 (d) None of the above
11. What is the *Cp* index given that sigma = 0.001, USL = 0.758 and LSL = 0.75?
    (a) 1.33 (b) 0.75
    (c) 1 (d) None of the above
12. What is the *Cpk* for the data in the above question, if *X* bar = 0.755?
    (a) 1.33 (b) 1.1
    (c) 1 (d) None of the above
13. A process has USL of 100 and no LSL. If *X* bar bar is 32 and standard deviation is 10, what is *Cpk*?
    (a) 1.27 (b) 2.27
    (c) 1.33 (d) None of the above
    Note : One sided tolerance, LSL, is not zero, it can be any value less than USL and hence not known exactly.
14. *R* bar indicates
    (a) Centering of the process (b) Percentage defectives
    (c) Variation (d) None of the above
15. *X* bar bar indicates
    (a) Centering of the process (b) Percentage defectives
    (c) Variable (d) None of the above
16. The control charts for percent defectives is called
    (a) *c* chart (b) *X* bar and *R* chart
    (c) *np* chart (d) None of the above

II True or False

1. *R* chart is control chart by attributes
2. Stable zone ends at 1 σ

3. In $\bar{x}$ and R chart, we have to start with $\bar{x}$ chart.
4. Even if 15 out of 25 subgroups exceed the UCL, process is stable
5. Seven points closer to central line means that the process is not stable
6. *Cpk* takes into account both precision and accuracy
7. *Cp* < 1 means a process is not capable
8. *MR* chart requires sample size of four
9. We plot percent defectives in *np* chart.

III Match The Following

A	B
c	Sample size 1
u	Number of defects in portion of the population
np	Percent defectives
p	Number of defects
MR	Along with $\bar{x}$
r	Number of defects in products of varying sample size

IV Explain Briefly

1. Differences between variables and attributes
2. Difference between *c* and *u* charts
3. Difference between *R* and *MR* charts
4. Differences between *p* and *np* charts
5. Three zones of control charts
6. Steps involved in plotting $\bar{x}$ and *R* chart
7. Steps involved in plotting *p* chart
8. Steps involved in plotting *MR* chart
9. Steps involved in plotting *u* chart
10. Central limit theorem
11. Differences between *Cp* and *Cpk*.
12. Comment on the following indices obtained on production of the same lot.

Cp	*Cpk*
1.5	1.5
2.0	0.7
0.5	0.5
2.5	0.5

V. Practice Problems

1. In a bolt manufacturing organization, 100 samples were drawn at random at periodic intervals. The number of defective samples in each subgroup is given below. Plot *np* chart and a *p* chart for the process.

np = defectives 1 1 1 3 4 2 3 2 1 3 3 1 2 1 2 1 2 2 1 1

2. In a biscuit manufacturing company, 200 samples were drawn at random. The number of defectives is given below. Plot a p chart and a np chart for the biscuit manufacturing process.

np = defectives 11 1 10 11 4 8 3 9 1 10 3 7 2 6 2 5 7 2 9 1

3. A tile manufacturer inspected each operator's output and noted the number of defectives and sample size. The data is given below. Plot a p chart.

No. of defectives 2 1 5 1 4 5 2 3 1 0 0 2 5 4 1 3 2 1 5 0
Sample size 120 56 278 311 123 254 17 35 45 67 56 92 235 123 70 45 58 62 278 75

4. A glassware production gave the following defectives on sample size indicated therein. Plot a p chart.

No. of defectives 2 1 5 1 4 5 2 3 1 0 0 2 5 4 1 3 2 1 5 0
Sample size 17 21 31 11 25 35 17 34 45 25 22 23 33 34 34 25 21 21 45 10

5. A TV receiver manufacturer measured the number of defects in each TV receiver on final inspection. Plot a c chart and a u chart for the assembly line.

No. of defects 12 11 7 6 5 4 3 2 1 5 4 6 7 8 9 5 7 8 6 7

6. A carpet manufacturer inspected and counted the number of defects in each carpet that was manufactured. The number of defectives and the sample size are listed below. Plot a p chart.

No. of defectives 2 1 5 1 4 5 2 3 1 1 1 2 5 4 1 3 2 1 5 2
Sample size 25 25 25 18 18 18 18 14 14 14 12 12 20 20 20 20 18 18 18 18

7. In a smithy the defects in axes made were counted and are indicated below along with the sample size. Plot a u chart.

No. of defective 12 9 5 7 8 8 8 7 8 8 9 10 5 4 1 8 7 9 8 5
Sample size 25 25 25 18 18 18 18 14 14 14 12 12 20 20 20 20 18 18 18 18

8. The specification for the width of table was 100 cms. The actual width measured on the samples is given below. Plot a X and MR chart.

99 101 100 102 98 101 100 99 101 100 103 102 99 100 101 98 102 98 101 99 98 100 101 99

9. A company manufacturing speedometers, picked up 4 samples each 25 times in a shift. For a setting of 10 Kmph, the values indicated by the speedometer samples are given below. Plot X bar and R chart. Draw the Action and Warning lines as well as the control limits.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
10.1	9.8	10.2	10	9.8	10	9.8	10.1	10.3	9.8	9.8	9	10
9.9	10	10.1	9.8	9.9	9.9	9.8	9.9	10	10	10.1	10.2	9.6
10	10	10	10.2	10.2	10.1	10.1	10	9.9	10	10	10	10
10	10.1	10	10	10	9.9	9.9	9.9	10	10.1	10.1	10	10.1

14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
10.2	9.9	10.3	9.9	10.6	10.2	9.8	10.1	10.3	10.1	9.8	10.1
9.8	10	10.1	9.8	9	9.9	9.8	9.9	10.1	9.9	10.1	10.2
10	10	10	10	10	10	10	10	10	10	10	10
10	10.1	10	10.1	9.8	9.9	9.9	10.1	10	10.1	10.1	10

10. 4 samples each of stopwatches were picked up at random from the assembly line. 25 times the samples were picked up. The indication of the speedometer for a true value of 300 seconds were checked and noted. The values indicated by the various samples are given below. Plot *X* bar and *R* chart. Draw the Action and Warning lines as well as control limits.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
301	299	302	300	306	300	300	301	303	301	295	301	300	302	299
288	300	301	298	268	299	298	299	300	300	301	302	296	298	300
299	299	299	302	302	301	301	299	295	310	300	300	302	297	300
300	301	300	302	307	300	301	302	300	302	300	301	304	304	301

16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
303	299	306	302	298	301	303	301	302	301
301	298	298	299	298	299	301	299	303	301
298	302	302	301	301	299	299	300	302	301
301	301	304	304	302	302	301	301	302	302

11. In Problems 1 and 2, if the data the corresponds to the number of defects, calculate a *c* chart.

Table A: Proportional under the Tail of the Normal Distribution

$Z = \dfrac{(x-\mu)}{\sigma}$	*.00*	*.01*	*.02*	*.03*	*.04*	*.05*	*.06*	*.07*	*.08*	*.09*
0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0216	.0211	.0206	.0201	.0197	.0192	.0187	.0183
2.1	.0179	.0174	.0170	.0165	.0161	.0157	.0153	.0150	.0146	.0142

(*Contd.*)

Table A: (*Contd.*)

$Z = \frac{(x-\mu)}{\sigma}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.2	.0139	.0135	.0132	.0128	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0101	.0099	.0096	.0093	.0091	.0088	.0086	.0084
2.4	.0082	.0079	.0077	.0075	.0073	.0071	.0069	.0067	.0065	.0063
2.5	.0062	.0060	.0058	.0057	.0055	.0053	.0052	.0050	.0049	.0048
2.6	.0046	.0045	.0044	.0042	.0041	.0040	.0039	.0037	.0036	.0035
2.7	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0028	.0027	.0026
2.8	.0025	.0024	.0024	.0023	.0022	.0021	.0021	.0020	.0019	.0019
2.9	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014	.0013
3.0	.0013									
3.1	.0009									
3.2	.0006									
3.3	.0004									
3.4	.0003									
3.5	.00025									
3.6	.00015									
3.7	.00010									
3.8	.00007									
3.9	.00005									
4.0	.00003									

Table B: Constants used in the Design of Control® Charts for Average

Sample Size (n)	*Constants for average charts using*						
	Hartley's Constant Sample (d_n or d_2)	*Sample Standard deviation*		*Average sample range*	*Standard deviation*		
		A_1	$2/3\ A_1$	A_2	$2/3\ A_2$	A_3	$2/3\ A_3$
2	1.128	2.12	1.41	1.88	1.25	2.66	1.77
3	1.693	1.73	1.15	1.02	0.68	1.95	1.30
4	2.059	1.50	1.00	0.73	0.49	1.63	1.09
5	2.326	1.34	0.89	0.58	0.39	1.43	0.95
6	2.534	1.20	0.82	0.48	0.32	1.29	0.86
7	2.704	1.13	0.76	0.42	0.28	1.18	0.79
8	2.847	1.06	0.71	0.37	0.25	1.10	0.73
9	2.970	1.00	0.67	0.34	0.20	1.03	0.69
10	3.078	0.95	0.63	0.31	0.21	0.98	0.65
11	3.173	0.90	0.60	0.29	0.19	0.93	0.62
12	3.258	0.87	0.58	0.27	0.18	0.89	0.59

Table C: Constants used in the control charts for range

	Constants for use with average range (R)				*Constants for use with standard deviation (σ)*				*Constants for use in range charts based on R*	
Sample Size (n)	$D'_{0.099}$	$D'_{0.001}$	$D'_{0.975}$	$D'_{0.025}$	$D_{0.999}$	$D_{0.001}$	$D_{0.975}$	$D_{0.025}$	D_2	D_4
2	0.00	4.12	0.04	2.81	0.00	4.65	0.04	3.17	0	3.27
3	0.04	2.98	0.18	2.17	0.06	5.05	0.30	3.68	0	2.57
4	0.10	2.57	0.29	1.93	0.20	5.30	0.59	3.98	0	2.28
5	0.16	2.34	0.37	1.81	0.37	5.45	0.85	4.20	0	2.11
6	0.21	2.21	0.42	1.72	0.54	5.60	1.06	4.36	0	2.00
7	0.26	2.11	0.46	1.66	0.69	5.70	1.25	4.49	0.08	1.92
8	0.29	2.04	0.50	1.62	0.83	5.80	1.41	4.61	0.14	1.86
9	0.32	1.99	0.52	1.58	0.96	5.90	1.55	4.70	0.18	1.82
10	0.35	1.93	0.54	1.56	1.08	5.95	1.67	4.79	0.22	1.78
11	0.38	1.91	0.56	1.53	1.20	6.05	1.78	4.86	0.26	1.74
12	0.40	1.87	0.58	1.51	1.30	6.10	1.88	4.92	0.28	1.72

Reference

1. John S. Oakland and Roy F. Followell, *Statistical Process control*, second edition, Affiliated East-West Press Pvt. Ltd. New Delhi, 1994

Chapter 13

Six Sigma

One cannot manage tomorrow's business with yesterday's methods.

INTRODUCTION

Global information society improves quality of life, but puts a lot of pressure on the manufacturing and service organizations to cut costs, improve productivity, reduce cycle time, reduce defects, reduce inventories, floor space, etc. This has to be carried out on a continuing basis. Six sigma is the result of culmination of quality concepts. World War II gave a new thrust to quality control and SPC. During the 1980s, the lean manufacturing and JIT of Japanese companies gave a threat to American companies. TQM was born in America to overcome the Japanese competition. In the 1990s, ISO 9000 standards created a new wave of quality. Thereafter, Motorola in order to give a sharper focus to TQM, embarked on six sigma. Thus, six sigma is very much in the ongoing tradition of quality control[1] . However, dramatic process improvement is the goal of six sigma. Some believe that Motorola gave the name six sigma to their special TQM initiative. Six sigma can even be considered as a methodology of implementing TQM. Six sigma is an innovative approach to continuous process improvement and a TQM methodology.

Six sigma became popular because of the involvement of many leading organizations. Although Motorola initiated six sigma, GE embraced six sigma in 1995. Six sigma resulted in better GE products. During the last decade, over 100 books have been published with six sigma as their titles. Every month there are about 5–10 workshops, training courses, or conferences on six sigma[2]. Six sigma concept unlike other programs such as ISO 9000, Capability Maturity Model (CMM) of Software Engineering Institute, etc. does not have a central organization to oversee the maintenance of standards. Many organizations are entering into six sigma and launching six sigma initiatives by using Black Belts, Green Belts, etc. American Society for Quality (ASQ) has been very active and supportive of six sigma. ASQ conducts examination for six sigma Black Belts. Many six sigma practitioners have joined the International Society of Six Sigma Practitioners (ISSSP). Motorola University offers courses to even those outside Motorola. In addition, many companies have acquired expertise by hiring Black Belts from Motorola, Kodak, GE or one of the other companies that were early users of six sigma. All these have lead to adoption of six sigma worldwide. Today six sigma is considered to be one of the enablers of prosperity for every sector of industry including IT, automobiles, etc.

DEFECTS AND SIX SIGMA

In the last chapter, we discussed about the process capability. The area under the tail in the normal curve gets reduced, as the sigma level goes up. This means that the number of defects gets reduced if the normal curve represents performance of product or service. We also concluded that the C_{pk} figure should touch three in order to get absolute confidence about the process. Such a level is ambitious and nearby zero defect. Looking from another angle, if the specification tolerance limits are reached at lower sigma levels, it means more defects in the tail of the normal curve beyond tolerance. With more defects, the cost of waste is going to be high. If waste can be eliminated, then the profit will go up by the same quantum for an organization. This is the fundamental concept of 6 sigma. This is also the concept of lean manufacturing as well as TQM. 6 sigma means controlling defects to a very low level, so that the waste is the least and profits are more. We don't adjust specification limits, but improve the process so that statistical control limits shrink, or in other words, we reduce variations in the process.

Figure 13.1 indicates the normal curve of a process with 3 sigma and 6 sigma marked.

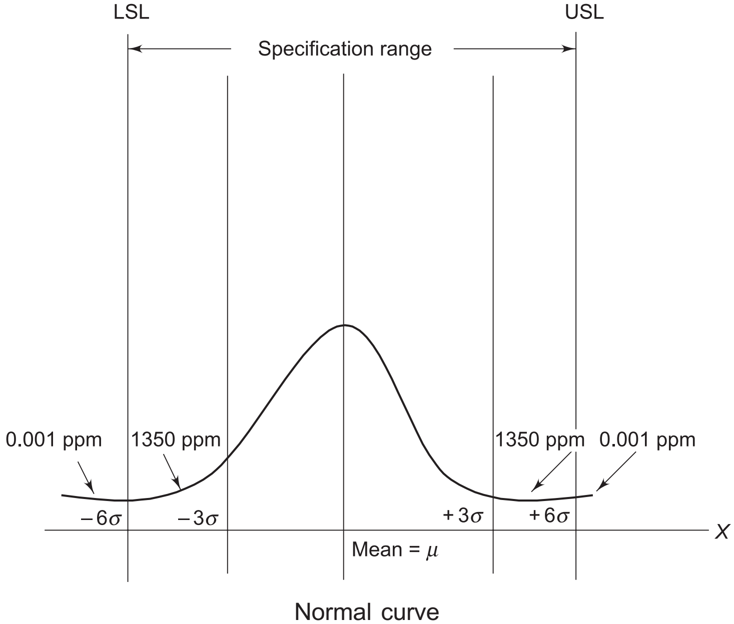


Figure 13.1

When the specification limits coincide with six sigma limits on both sides as illustrated in Fig. 13.1, one can expect total defects of 0.002 ppm, compared with 2700 ppm when we achieve the traditional 3 sigma quality level. This happens when the mean lies exactly at (USL+LSL) / 2. There could be a shift of the mean in the process due to various reasons. Assume that there is a shift by 1.5 sigma to one side. The number of defects will go up in such a process. In this case, if a process performance is 6 sigma, then actual effect will be equal to 4.5 sigma. To compensate for the inevitable consequences associated with process centering errors, the distribution mean is offset by 1.5 standard deviations. This adjustment provides a more realistic idea of what the process capability will be over repeated cycles of operation of the process. Table 13.1 indicates the various sigma quality levels with and without adjustment to take care of the shifting of the means.

Table 13.1 Sigma (σ) quality levels before and after shift in the average

Sigma (σ) Levels	*DPMO**	
	Without Shift	*With Shift*
1	317,4000	697,700
2	45,400	308,537
3	2,700	66,807
4	63	6210
5	0.57	233
6	0.002	3.4

* Defects per million opportunities.

Table 13.1 indicates the defects per million opportunities in a product or service, with both the shift of means and without shift. When there is a shift in the centering, the defects expected in a 6 sigma process is 3.4 in one million. What it means is that there will be 3.4 defects per million opportunities. It does not mean that 3.4 products out of 1 million will be defective. It means that in one million characteristic that is measured in a process, there is a likelihood of 3.4 characteristics outside the limits. It means that on an average, in a product 3.4 out of one million characteristics will be out of tolerance. Therefore, six sigma is essentially a tightening the process performance, so as to reduce the random variation in the process. It also means achieving C_{pk} of 1.5 and C_p of 2. Let us take some examples to understand six sigma defect level.

Example 13.1

Assume that a product has 10 Critical To Quality (CTQ) characteristics, and we produced 10,000 products. This means the total number of critical to quality characteristics is equal to 10,000 × 10. Or in other words, the total number of opportunities is 100,000 for the defects to occur. Six sigma means 3.4 defects per million opportunities. Therefore, for achieving 6 sigma in this case, the number of permissible defects is 3.4 × (100000/1 million) = 0.34 defects.

Example 13.2

Look at the problem in another way.
The number of units produced = 1000
Defective product = 1
Defect rate = 1/1000 = 0.001
Number of opportunities per product = 10; which is equal to critical quality characteristics = 10
Defect rate per CTQ = 0.001/10 means 0.0001
Defects per million opportunities = $0.0001 \times 10^6 = 100$
This means the process does not meet the requirements of six sigma.

Example 13.3

Let us take one more example to find out whether the process meets the requirements of six sigma.
Units produced = 100,000
Number of CTQs = 20
Number of defects found = 2
Defect rate = 2/(100000 × 20)
Defects per million opportunities = $(2/100000 \times 20) \times 10^6 = 2$

Since, six sigma allows 3.4 defects per million opportunities, this process is well within the six sigma limits.

DEFINITION OF SIX SIGMA

six sigma can be defined as[1] "*a business process that allows organizations to drastically improve their bottom line by designing and monitoring every day business activities in ways that minimize waste and resources while increasing customer satisfaction*". Although six sigma is a statistical technique, it was combined with a new methodology to control the processes at Motorola to result in dramatic improvements in the process. Six sigma is defined by GE as "a vision of quality which equates with only 3.4 defects per million opportunities for each product or service transaction and strives for perfection". Thus in one sense, six sigma refers to a measure of process consistency and aims at achieving the same. The other meaning of six sigma is a methodology for improving processes. It is also a movement that has established process improvement at many leading organizations and trained thousands of employees for improvement of processes in their organizations. Six sigma is probably the most widely used methodology for improving process performance and is increasingly popular as a way of organizing an entire organization to become more customer focused and more quality oriented.

THE ORIGIN OF SIX SIGMA

Six sigma was born in the 1980s at Motorola. Bill Smith, an engineer at Motorola's Communications Sector, was quietly working behind the scenes studying the correlation between a product's field life or reliability and how often that product had been repaired during the manufacturing process. He presented a paper, which concluded that if a product was found defective and corrected during the production process, other defects were bound to be missed and found later by the customer during early use of the product. However, when the product was manufactured error-free, it rarely failed during early use by the consumer[1]. They also found that the foreign competitors were making more reliable products. As a result, Motorola began to improve the quality and simultaneously reduce the cost by focusing on product design and manufacturing. The 6 sigma architects of Motorola focused on making improvements in all operations within a process. This led to quantum leap in manufacturing technology in Motorola. The company saved $ 2.2 billion in 4 years[1]. In the year 1988, Motorola received the first Malcolm Baldrige National Quality Award from the US government for its improvement record based on six sigma program[2] .

In 1990, Motorola joined with IBM, Texas Instruments and Kodak to establish Six Sigma Research Institute (SSRI). SSRI conceptualized the concept of the Black Belt—an individual trained to facilitate six sigma projects. Subsequently, Motorola University began to offer a course to train and certify Black Belts.

ESSENCE OF SIX SIGMA

We discussed in the previous chapter that there are two process performance limits:

(1) Statistical Control Limits
- Upper Control Limit (UCL) and Lower Control Limit (LCL)

(2) Specification Limits
- Upper Specification Limit (USL) and Lower Specification Limit (LSL)

Assume that specification limits are fixed (say 100 ± 6 grams for the peanut packet produced). There will be variations in the packing process. Assume that the standard deviation of two grams was achieved in the process. It means that the 3 sigma limits and specification limits coincide. In the early days, the organizations were happy with such a process, namely controlling the process variations within 3 sigma limits or in other words, the 3 sigma limits covered the specification limits. This means, that they did not mind allowing 0.27% defects (area contained in the tail corresponding to 3 sigma). Six sigma is a rigorous concept of applying Statistical Process Control, to control the defects to 3.4 parts per million. If the peanut manufacturer controls variations in the process to such an extent that only 3.4 out of 1 million packets deviate from the specification limits, then he has established 6 sigma process. Therefore, application of six sigma concept means controlling variations and thereby defects closer to the level of zero defects.

We will discuss about Taguchi's design of experiments in Chapter 17, where we will conclude that the process should be set, so as to meet the target value, which could be the mean value. We will also discuss and understand that the target value is not set by the manufacturing organization, but by the customer. When we talk about Taguchi's techniques, we will realize that performance beyond the target value is going to be a loss. There is no tolerance band. We will conclude that we have to minimize loss by always being close to the target value. Three sigma allowed deviations to the extent of 0.27% defects. Six sigma however allows deviation to the extent of 3.4 ppm defects. This also means that loss is minimized in a 6 sigma process, rather than 3 sigma process. This brings out the importance of 6 sigma over 3 sigma. A day may come when the deviations reduce further and the industry is able to produce at the target value, all the time.

General Methodology

Six sigma is a rigorous concept in order to control the defects to the minimum. Along with six sigma, a number of methodologies have evolved to make this happen. However, the general methodology for process improvement remains the same.

Assume that we apply six sigma to the peanut manufacturing discussed above. Assume that the target value is 100 grams. This is also the mean. The upper and lower specification limits are 106 and 94 grams respectively. The first step in six sigma effort is to know the current level of performance. Therefore, six sigma team studies the process and measures the capability. They found that currently the three sigma limits extend to 6 grams on either side. Naturally, they may look to improve and reduce the variations. Therefore, the second step is to experimenting. They then carry out modifications to the processes and measure the result.

Assume that after the modification, four sigma limits now extend to 6 grams. This means there is an improvement. It may so happen that if the experiment is not properly chosen, then the deviation may increase. Therefore, the new levels achieved are to be measured again. If we do not reach the stage of 3.4 ppm defect, then we have to continue to experiment so that the deviation finally comes down and settle down. This may call for improving the process. By and large, major process improvement can be achieved by improving the performance of human beings.

Then the next step is process continuance. If we have achieved the six sigma performance, it does not mean that we can stop measuring. On the contrary, we have to continue to carry out the measurements and see that the process does not deviate. After some experience, we will be able to predict the symptoms of deviation. Thus, it is a continuous effort to make sure that the process performance is as per the needs of six sigma.

To summarize, any process involves the following:

- Measurement of current process performance
- Improvement of performance through experimentation
- Achieving six sigma process through continuous measurement, analysis and improvement.

Process experimentation may also be called process redesign.

Essentially six sigma projects aim at reduction of the deviation from the mean value or target value.

SIX SIGMA PROCESS MODELS

6 sigma is a disciplined process, which helps the companies to focus on developing and delivering nearly perfect products and services by avoiding variations in the process. Six sigma calls for extremely rigorous data collection and statistical analysis to find source of errors and find out the ways to eliminate them. Six sigma facilitated proactive approach through rigorous measurement. Although PDCA could be used for process improvement, to give a new thrust 6 sigma was introduced with modified models. There are a few 6 σ models for process improvement.

DMAIC

The first one is DMAIC as shown in Fig. 13.2 below. It is a 5 step process improvement model as explained in Fig. 13.2.

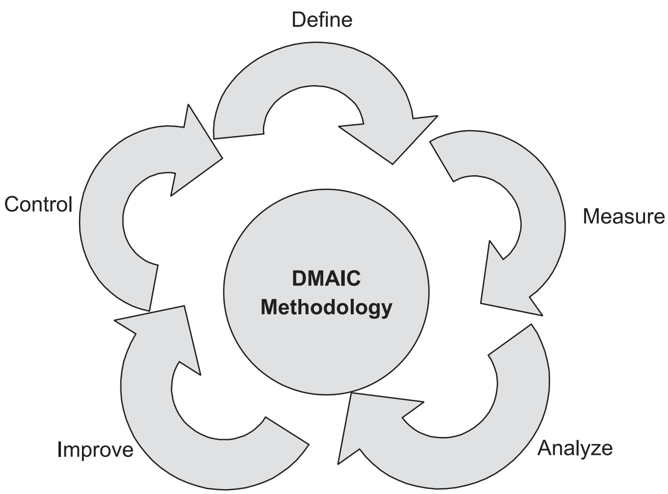


Figure 13.2 DMAIC Model

Step 1: Define This is the first phase of the process improvement effort. It is similar to the plan phase of PDCA cycle. During this phase, the six sigma project is defined. Definition of project requires that information pertaining to the customer requirements is available. They are documented. Therefore, it necessitates identifying the customers (both internal and external) and their critical to quality (CTQ) issues. CTQ refers to the product or service characteristics, which are defined by the customer. They are the key measurable characteristics whose performance standards should be met to satisfy the customer. The current process as it exists is documented. With these documents, the goals for the project are to be finalized and given as an approved charter to the six sigma team. The team may also have access to high-level process map for the entire organization. Assume that we want to reduce the defects in soldering of electronics assembly. Let us develop a process map for operating the product or process. In this case, it is a process of soldering. Process mapping involves identifying the sequence of events. It is given in Fig. 13.3.

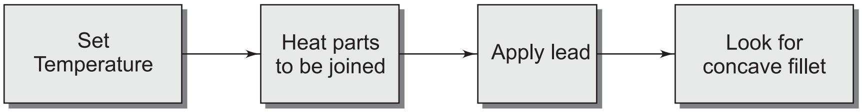


Figure 13.3 Hand Soldering Process

Step 2: Measure The team identifies the key internal processes that influence CTQs and measures the defects currently generated relative to those processes. This phase consists of a number of sub-processes.

(i) Identify measures — the appropriate measures for the process have to be identified. The measures are to be finalized by the project team after brainstorming.

(ii) Once the measures have been identified, the measures have to be defined unambiguously. This step is essential in order to get the correct picture about performance of the process as well as enabling repeatability of the measurements.

(iii) The next step is to identify the target performance for the process as deduced from the customer requirements. Benchmarking will be useful for identifying target performance.

(iv) Measure current performance and identify the gaps.

In our example of hand soldering, assume that the current defect level is 1% and the benchmarking indicates the industry best as 0.1%. The gap is clear and the organization should make efforts to bridge the gap.

Step 3: Analyze The team discovers the causes for defects. They identify the key variables which cause the defect or which are most likely to cause or create a process variation. For this purpose, a cause and effect diagram can be used. A cause and effect diagram is shown in Fig. 13.4. The cause and effect diagram in this case helps us to understand the following:

Constant (C)—As the name indicates, these factors cannot be changed

Noise factors (N)—While efforts are to be made to reduce the noise, these factors cannot be eliminated

Experimental factors (X)—These factors can be modified to improve the response (Y)

The response or the quality of soldering is marked 'Y'.

This can be converted into a CNX diagram as shown in Fig. 13.5.

The project team can make use of the CNX diagram to experiment to improve the performance and reduce variations. This is one way of analyzing the process.

The cause and effect and CNX diagram helps in identifying the parameters to be experimented with in order to improve the process. From CNX diagram, it is clear that the quality of soldering (response Y) has to be improved by controlling X factors. In this case, they are the skill of operator, duration of soldering and bit shape. By controlling the bit shape and duration of soldering, as well as improving the skill of operator through training we can achieve the required quality of soldering. We cannot experiment with constants, since they are fixed for a process. For instance, types of solder and flux cannot be changed for a given application. The environment factors namely the dust level; room temperature, etc. should be controlled, but not experimented with. Thus, CNX diagram is quite useful in analysis and experimenting improvement actions to reduce variations.

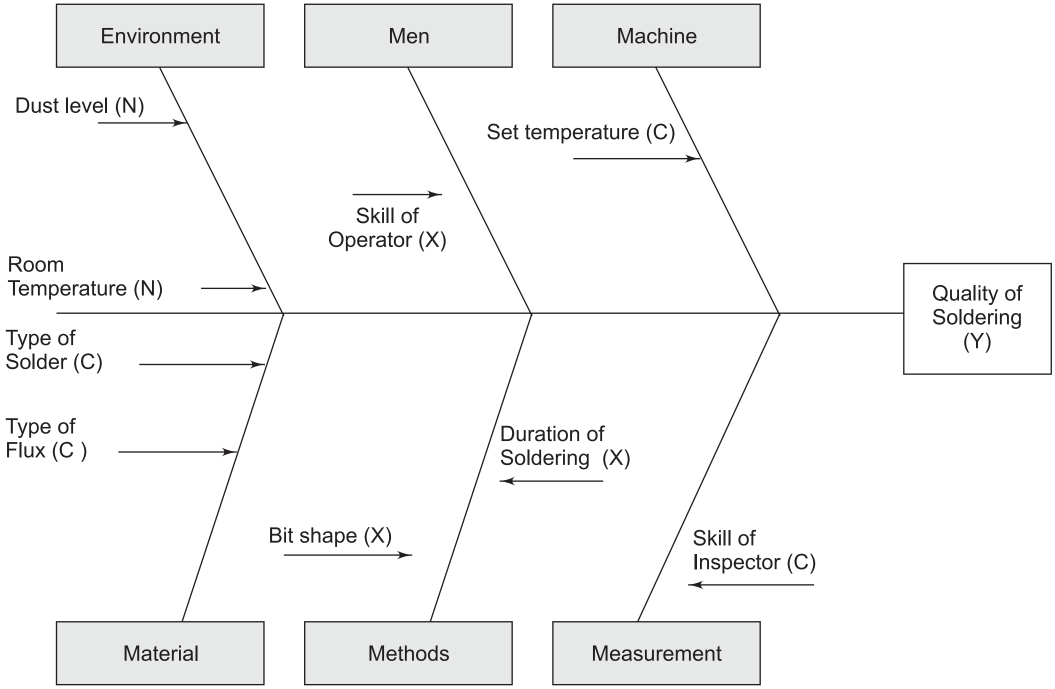


Figure 13.4 Cause and Effect Diagram for Hand Soldering Process

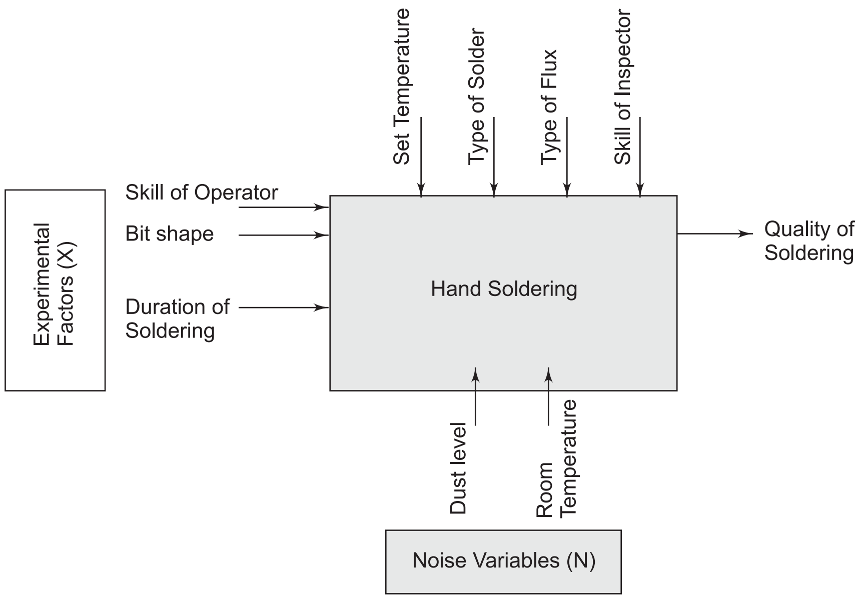


Figure 13.5 CNX Diagram for Hand Soldering

Step 4: Improve The team identifies maximum permissible ranges of the key variables and proposes a system for measuring deviations of the variables. The team modifies the process to stay within the maximum permissible range of the performance of the key variables. The process performance has to be monitored and measured. If it is satisfactory, then it can be institutionalized. The solution has to be implemented on a pilot basis before large scale application in the plant.

Step 5: Control In this phase, tools are put in place to ensure that the key variables remain within the maximum permissible ranges continuously.

DMADV

The second model for process improvement is DMADV. DMAIC is used for improving existing processes, whereas the DMADV is employed for design of new products, which aim at achieving 6 σ quality. DMADV stands for Define, Measure, Analyze, Design and Verify as shown in Fig. 13.6.

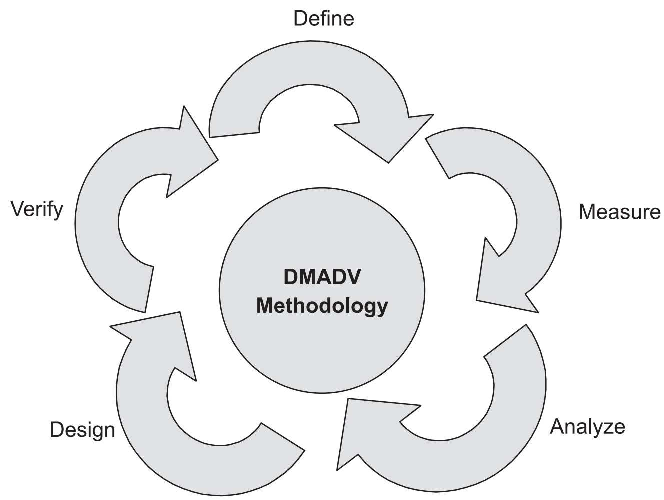


Figure 13.6 DMADV Process Model

Six sigma is applied to a new design by using DMADV. DMADV methodology is explained below:

Define—Define phase is similar to DMAIC. Six sigma team gets a charter for the new design.

Measure—During this step, the organization may need to use Quality Function Deployment or House of Quality. House of Quality, which will be discussed later in the book, will enable the organization to convert the voice of the customer to a prioritized technical requirements. Six sigma team identifies measures for each of the technical requirements identified through Quality Function Deployment (QFD). They should also define the performance standards, i.e. the expected performance of the new product or process.

Analyze—In this phase, the team has to design the concept or top level design for the new project. They should generate various design options. They should evaluate and finally select the right option.

Detailed Design—At this stage, the detailed design of the product or process is carried out. Detailed design involves identifying the finer details and identifying all the required steps. The six sigma team will evaluate available options before finalizing the most suitable process steps. The process steps selected should be experimented and improved. Finally it is the system integration that takes place.

Detailed design will lead to fabrication of prototypes, in case of product development. It may be establishing the pilot plant in the case of process.

Verify—The last step in DMADV is verification. At this stage, the functionality of the process or product is verified. Full-scale verification of the design is carried out. In case of products, it will be validation of the complete product in the form of a prototype in a test laboratory. Lessons learnt are documented and the product is transferred to regular production.

Thus, DMADV is aimed at development of a new product or process. On the contrary DMAIC is for improvement of the existing process or a product. Thus, appropriate methodologies are to be chosen by the six sigma team.

DESIGN FOR SIX SIGMA (DFSS)

Design plays quite an important role in achieving six sigma. The Design for Six Sigma (DFSS) is used to design or redesign the product or service ab initio. Design is quite important for controlling the variations and reducing costs. If one analyzes the pricing of a product or a service and the actual expenditure incurred in various activities such as design, cost of materials and other resources, interesting scenarios emerge. While the design effort may cost 5% of the actual expenditure, it has a major influence of more than 50% in the cost of the product or service. Therefore, it is very essential to design the product or process correctly. For design of products or processes, Taguchi's technique of design of experiments should be adopted. QFD should be used to understand the real requirements of customers. Failure Mode Effects Analysis (FMEA) could be used for determining the various modes of failures of the constituents and their effects on the end product or process. The DFSS is used extensively for optimizing the design, so that the number of defects during manufacturing or service comes down within the limits of 3.4 defects per million opportunities.

SIX SIGMA IMPLEMENTATION

Six sigma implementation varies from organization to organization. In a larger organization, six sigma is implemented in three levels as given below:

- Business level
- Operations level
- Process level

This also indicates the hierarchy of activities in the organization. Six sigma should be implemented in a seamless manner at all the three levels. Of course, a senior level management person will carry out the business level improvements. At the process level, a Black Belt will implement it. At the operations level, the level of person will be in between the two. The characteristics of the three levels will be different and the time taken for implementing six sigma will also vary.

To achieve six sigma, at the business level, it may take a few years. At the operations level it may take about 12–18 months and in the process level, the Black Belts may take about 6–8 weeks to complete the project. There will be a number of projects at the process level, but fewer projects at the higher levels. Therefore, a clear strategy for implementation has to be evolved by the management. The ultimate objective of six sigma is to achieve business success through defect free operations by controlling variations at the process.

Six Sigma projects may be initiated by the six sigma steering committee or by senior executives. Each project is assigned to a champion, who sponsors the project. He may be at the senior level; he may be a member of the steering committee. A manager level person heads six sigma team for each project. He may be called a Black Belt. He can take guidance from an expert in statistical tools. Such consultants are usually called Master Black Belts. The team members are trained in statistics. It would be advantageous if they are qualified Green Belts. Teams usually meet for 2–3 hours at a time. Initially, they meet 2–3 times a week. But this frequency may be reduced as progress is achieved[2]. It usually takes a team to work at the rate of a few hours a week for a period of few months to characterize the machine or a process. If the organization wants to characterize all the activities in a manufacturing site, it usually takes continuous effort for few years. Thus six sigma is a long-term project.

Brief details about 6 σ implementation teams is given below along with the roles of the various persons.

Champions Senior management persons assume the role of a champion. They are to be familiar with basic and advanced statistical tools. They usually receive one week training. 6 sigma implementation requires one champion per business group or manufacturing site.

Master black belt They need to be a technical degree holder. They should be thorough with the basic and advanced statistical tools. They typically attend two, one-week training program. They receive black belt training. An organization needs to have a one Master Black Belt for every 30 Black Belts. Master Black Belts are senior level persons. The champion selects the Master Black Belts. They are employees working on full time basis on six sigma projects. They assist the champions in identifying improvement projects. They train Black Belts and Green Belts and additionally carry out coordination of six sigma projects. They transfer six sigma knowledge to Black Belts.

Black Belt A Black Belt is also a technical degree holder. The black belt may be at a junior level with five years or more of experience. They should be thorough with the basic and advanced statistical tools. They typically undergo four, one-week training programs with three weeks between sessions to apply the strategies learnt to assigned projects. There should be one Black Belt per 100 employees. The Black Belt working under a Master Black Belt need not necessarily be in the same location. They also work on full time basis. They are responsible for specific projects.

Green Belt Green Belts should have technical and support background. They should be familiar with all the basic statistical tools. They also attend training sessions. The green belts are the process owners. They execute 6 σ projects as part of their normal job. They focus on day-today work and assist black belts in data collection.

The 6 σ approach varies from company to company, consultant to consultant and author to author. However the above are the common characteristics.

Companies Which have Adopted Six Sigma

Many companies in the West have adopted 6 σ looking at Motorola's success. Some of them are:

- Motorola
- Sony
- IBM
- Bombardier
- Lockheed Martin and
- Allied Signal
- Honda
- Raytheon
- Canon
- Polaroid
- General Electric
- Maytag
- Texas Instruments
- Hitachi

Six Sigma Means More Profits

The success of six sigma projects are evaluated based on the financial impact. The CFO is an important member of the executive management team and most project teams have a member from finance who documents the financial impact. The expectation in USA is that each project has a financial impact of about $ 175,000.

Motorola achieved five-fold growth in sales between 1987 to 1997 with a growth in profits of 20% per year. They achieved a cumulative savings of US $ 14 billions and the stock price gains compounded to an annual rate of 21.3%[3]. Motorola was also cited as the first winner of America's Malcolm Baldrige National Quality Award in 1988. This led the other companies to become interested in the six sigma program. Even the software companies are getting into 6 sigma.

Six Sigma at GE

6 σ is all about making money, rather more money. When a company is operating at traditional 3 sigma, the cost of quality could even range from 5 to 10 per cent of sale value. On attaining 6 sigma quality level, it could come down to as low as 1 per cent. This results in increase in profits by 20–30 per cent per annum. When GE reduced their cost of quality, the company achieved a $ 1 billion increase in net income in just two years. This is the money that gets into profit. This is the reason it has become popular. Thus, 6 sigma proves that being better is cheaper.

GE believes that "the central idea behind six sigma is that if you can measure how many defects you have in a process, you can systematically figure out how to eliminate them and get as close to "zero defects" as possible[4]".

GE started its quality initiatives in the late 1980s. They claim that the six sigma is embedding quality thinking—process thinking—across every level and in every operation of their company around the globe. There are three key elements of quality for GE as explained below:

(i) The Customer–Delighting Customers
Customers are the centre of GE's universe, they define quality. They expect performance, reliability, competitive prices, on-time delivery, service, clear and correct transaction processing and more. Delighting customers is the necessity, because if you don't do it, someone else will.

(ii) The Process – Outside-In Thinking
Quality requires them to look at their business from the customer's perspective and not from their own perspective. In other words, they look at processes from outside-in. By understanding the transaction life cycle from the customer's needs and processes, they can discover what the customer is seeing and feeling. With this knowledge, GE can identify areas where they can add value or improvement from the customer's perspective.

(iii) The Employee – Leadership Commitment
They believe that people create results. Involving all employees is essential to GE's quality approach. GE is committed to providing opportunities and incentives for employees to focus their talents and energies on satisfying the customers. All GE employees are trained in the strategy and statistical tools and techniques of six sigma quality. Employees are provided with the following trainings:

- Basic six sigma awareness
- Team Training—Basic tool introduction to equip employees to participate on six sigma teams
- Master Black Belt and Black Belt and Green Belt training

- Design for six sigma Training: to prepare the teams for the use of statistical tools to design the products and processes right the first time.

They believe that quality is the responsibility of every employee. Every employee must be involved, motivated and knowledgeable if the organization has to succeed.

Six sigma focuses on reducing process variation and then on improving the process capability. GE's success with six sigma has exceeded their most optimistic predictions. Across the company, GE associates embraced six sigma's customer-focused, data-driven philosophy and applied it to everything they did. They are building on these successes by sharing best practices across all of their businesses, putting the full power of GE behind their quest for better and faster customer solutions.

Six Sigma at Ford

Ford Motor Company entered into six sigma in the late 1990s. They called it Consumer Driven 6-Sigma. Soon after launching Consumer Driven 6-Sigma, Black Belt teams worked to define the "Top 25" customer concerns across all vehicle lines. Top customer concerns were identified within business processes as well. Since its inception at Ford, it has saved Ford about $1 billion in reduced waste. In 2002, it saved Ford $ 359 million world-wide, including $ 186 in North American operations. Most projects follow the DMAIC model. There are also Design for Six Sigma (DFSS) projects underway.

Ford currently maintains a pool of 2200 Black Belts from all areas of Ford Motor Company. Black Belts serve two-year assignments, full time, before they move back into the mainstream positions within the company. So far more than 40,000 Green Belts have been trained worldwide. It is expected that all salaried and many hourly employees will be trained as Green Belts by 2004. More than 6000 consumer driven 6 sigma projects have been completed to date.

Wipro Technologies, (Worldwide) HQ Bangalore, India

Wipro is the first PCMM Level 5 and SEI CMMI Level 5 certified IT services company globally. Wipro studied many existing quality systems—the Japanese and American models. After carefully studying these, six sigma was chosen. Some of the reasons were:

- It is a tool, methodology to remove defects in products, processes and services.
- It can give them a competitive edge, which could sustain them for a decade or more
- It is global and world leaders like GE and Citibank have it
- It focuses on customer who has become so important in today's business
- It is project-based and hence project successes gives them intermediate milestones to measure themselves
- Six sigma is based on data and on facts

Six sigma can be integrated with other quality initiatives that their various units have embarked upon like SEI CMM and ISO 9000. While SEI CMM and ISO 9000 form the base, six sigma gave the tools and methodology to remove the defects[5].

CASE STUDY
DuPont

Overview
DuPont (www.DuPont.com)[6] is a $24 billion science company, delivering science-based solutions in markets such as food and nutrition, health care, apparel, home and construction, electronics and transportation. DuPont's ability to adapt to change and its belief in unending scientific inquiry have enabled this centuries-old company (founded in 1802) to become one of the world's most innovative concerns.

In the face of constant change, innovation and discovery, the firm reached what it believed to be a plateau in growth and innovation. DuPont retained Six Sigma Academy in October 1998 to achieve sustainable growth, increase productivity, and improve quality.

Goals
- Achieve sustainable growth through productivity and quality improvements
- Significantly increase productivity using six sigma
- Increase shareholder and societal value
- Pursue "knowledge intensity" in all businesses.

Business Benefits
- Many of the 3,000 completed six sigma projects have resulted in reduced environmental impact or increased safety.
- More than 10,000 Master Black Belts, Black Belts and Green Belts trained around the world.
- More than 500 financial analysts and managers have been trained in the specifics of six sigma financial metrics and reporting.
- Over 12,000 projects are underway around the world in all the regions and lines of business.
- Top Line Growth (TLG) champions were named in 2001 and by mid-year 2002 more than 1,000 TLG projects were active in the business.

We are pursuing a 'knowledge intensity' business model, which leverages the value of our market knowledge, our brands, our technology and know-how. This is being accomplished while also using six sigma to enhance productivity, build marketplace Competitiveness and grow revenues.

Mr Chad Holliday
Chairman, DuPont

Six Sigma Success Factors
- Used six sigma as an enterprise-wide business strategy, not merely as a toolkit.
- Approach was more company-wide than segment-wide. Six sigma was rolled out to all strategic business units, including agriculture, petrochemicals, pharmaceuticals—all were involved from the start.
- Six sigma was integrated into all DuPont operations, including distribution, sales, marketing, human resources, finance, legal, and manufacturing.
- Design for six sigma being deployed to create the new products and processes.
- One of every five DuPont employees are participating in six sigma projects.

"We've seen benefits, reduction in fixed costs, reduction in variable costs and top line growth. Where I get excited is when I travel around the world and talk to Black Belts. You can see the sparkle in their eye, you can see they're excited, you can see they're juiced and they're making a difference at DuPont. The vehicle that led them to that is six sigma."

Mr Don Linsenmann
Vice President & Corporate Champion, Six Sigma
DuPont

SIX SIGMA, LEAN, *KAIZEN* AND TQM

We discussed all these concepts in the book. A clear understanding of the relationship between these concepts is essential. Debates over which concept is better is irrelevant, since each one of them is a tool for improvement of processes in the organization. One has to use the appropriate tool for a given situation.

Let us briefly review the characteristics of each one of them.

Kaizen

Kaizen, as we know, is continuous and incremental improvement. Some improvement opportunities will be quite obvious. Hence, they can be made easily using *Kaizen Blitz*. *Kaizen* is simple, obvious and common sense based improvement. It is a quick strike taking less than a week for improvement. *Kaizen* calls for process mapping, analysis of cause and effects and training of employees on *Kaizen*. There is no doubt that *Kaizen* is a part of TQM.

Lean

Lean manufacturing as discussed in Chapter 7, typically focuses on speed of processing, reducing WIP, elimination of waste, standardization of processes, flexibility of workstations, etc. Lean manufacturing encompasses one-piece flow, cellular manufacturing, and visual controls, *Kanban*, TPM, etc. Here, we concentrate more on reducing wastes and removing non-value adding processes. Speed and cycle time is quite important. Lean facilitates just-in-time production by reducing work-in-progress and inventory. Dramatic results occur when lean manufacturing is implemented. Lean processes focus heavily on logistics distribution, plant layout, supply-chain management, etc. Lean is a part of TQM.

Six Sigma

Six sigma provides the highest impact opportunities for improvement. It reduces quality costs tremendously. Six Sigma is a data driven methodology. It tries for perfection in the entire organization. Six sigma focuses on variations and finally the root cause for the variation and reducing the variation, so as to achieve 'zero' defects' manufacturing. Six sigma projects get attention of top management and are aimed at showing dramatic savings in cost. Statistical tool is the nucleus of six sigma efforts. DMAIC, Cp, Cp_K, design of experiments, Process FMEA, etc. are pervasive in six sigma projects. It enables improvement of process capability, defect prevention, stability and predictability of the processes and variation reduction. It is also a TQM strategy. Six sigma is a methodology for disciplined quality improvement. It is felt that since quality improvement is the prime ingredient of TQM, many companies find, adding a six sigma program to their current business system covers almost all the elements of TQM.

SUMMARY

6 σ concept initiated by Motorola has given remarkable gains. GE and many other leading companies in USA contributed to the evolution of six sigma. 6 sigma aims at controlling variations very significantly. 6 sigma quality level means 2 defects per billion. Since shift of the mean is unavoidable in process, six sigma is accepted in practice as 3.4 defects in one million opportunities. This is a very high quality level. When organizations go from 3 sigma to 6 sigma, the cost of quality could go down to less than 1% of sales. This is clearly a profit for the organization. Thus, six sigma is aimed at nearly eliminating wastes and rework and dramatically improving profit margin.

There are two views as to whether 6 sigma is a new concept or whether it is one of the methodologies of TQM. Six sigma is a top down approach. It is a disciplined approach. It is a data oriented approach. Processes and variations are the central theme. Deming and Walter A Shewhart did pioneering work in this direction. The Taguchi techniques and SPC apply equally well to TQM as well as six sigma. So some critics say it is not new, it is only a tool like BPR and it can be called a special TQM strategy, which results in dramatic reduction in waste due to excellent process control.

Six sigma provides a strict approach for improving the product and process quality. Six sigma uses DMAIC and DMADV, which are modified Plan, Do, and Check & Act cycles. A major advantage of six sigma is that it is perceived to be a business system that improves the bottom-line. One of the causes for the success of six sigma is that six sigma projects set ambitious targets to achieve 3.4 defects per million opportunities.

Six Sigma implementation is top-down. The CEO is usually the driving force and top management team provides a champion for each project. The champion is responsible for the success of the project, providing necessary resources and breaking down organizational barriers. Involvement of the upper management champions ensures that the projects will have a larger impact on the business.

The project leader is a Black Belt. The Black Belt candidates are selected based on the basis of their track record. The Black Belt is usually assigned for two years during which he leads from 8 to 12 projects. The Black Belts and Green Belts are agents of change in the organization. They always look for new ideas. Companies train large number of employees as Green Belts to spread six sigma. Master Black Belts are resources for the project teams. They provide consultancy to the Black Belts.

TQM is also a management system consisting of values, methodologies and tools, which aim at improving customer satisfaction with reducing amount of resources. Hence, one can argue that six sigma is a methodology within TQM. Despite all the controversies, 6 sigma methodology based on SPC is an important milestone in the evolution of quality and TQM. In this chapter we compared the various approaches such as lean manufacturing, *Kaizen*, six sigma and TQM. Nevertheless, the six sigma has created the necessary enthusiasm amongst the people for applying quality for higher profits and reducing muda (wastes). 6 sigma is all about making more money.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. 6 sigma does not call for
   (a) Top management commitment (b) Employee involvement
   (c) Quality department (d) None of the above
2. 6 sigma was initiated at
   (a) Allied Signal (b) Motorola
   (c) General Electric (d) None of the above
3. DMAIC includes
   (a) Define (b) Control
   (c) Improve (d) All the above
4. 6 σ process improvement models include
   (a) DMAIC (b) DMADV
   (c) DFSS (d) All the above
5. Achievement of 6 σ means
   (a) Less process variations (b) More profit
   (c) Improved customer satisfaction (d) All the above

II. True or False

1. 6 sigma is same as business process reengineering
2. 6 sigma calls for benchmarking
3. 6 sigma calls for metrics
4. 6 sigma means 3.4 defects per million business opportunities
5. 6 sigma means 3.4 ppm defectives
6. 6 sigma was born out of SPC
7. 6 sigma requires a *Cpk* value of 1
8. 6 sigma requires *Cp* value of 1
9. 6 sigma means more profit
10. 6 sigma means less waste
11. 6 sigma uses PDCA for process improvement
12. 6 sigma does not aim at continuous improvement
13. 6 sigma is beneficial to customers also
14. CTQ does not address requirements of internal customers
15. Noise factors should be experimented with for improvement
16. Six sigma is top-down approach

III. Explain Briefly

1. 6 sigma and quality cost

2. 6 sigma and process variations
3. 6 sigma implementation
4. Explain with control chart
   (a) What do you understand by 6 sigma, indicating variation of μ also in a simple diagram?
   (b) Tabulate the percentage defects from 1 sigma to 6 sigma with both shift of mean and without shift.
5. Compare lean, *Kaizen*, six sigma and TQM
6. Write an appreciation of six sigma efforts at
   - Ford
   - GE
   - Motorola
   - DuPont
7. Various phases of DMAIC
8. Various phases of DMADV
9. CNX Diagram
10. Why six sigma is successful?
11. Benefits of six sigma.
12. Six sigma implementation

IV. Match the following

A	B
Champion	Responsible for one project
Master black belt	Responsible for the organization
Black belt	Responsible for multiple projects
Green belt	Works on part time basis

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Chapter 14

Seven New Management Tools

Restlessness and discontent are the first necessities of progress.

—Thomas A. Edison

INTRODUCTION

We learnt the application of seven QC tools in Chapter 12. The Japanese developed seven more tools in their second wave of quality. These tools are also called the New Seven Management Tools. The tools are useful for process, product and system improvement. The tools can be used by the middle and top management of organizations to find causes of problems and solutions to the same. In comparison with seven QC tools, the new seven tools are qualitative in nature unlike the former which are data oriented. These tools are further oriented towards assisting the teams in finding solutions and innovative management ideas. They are also called graphical tools. These tools are used along with brainstorming by teams of employees. The tools are meant for improving the processes. The process improvement could be one or more of the following:

- Reducing the defect level
- Reducing the cycle-time
- Reducing the cost
- Improving the quality
- Improving project management
- Improving customer satisfaction etc.

These tools can also be used for strategic planning, organizing complex projects in the most optimal manner and new product development. The tools initially developed and used extensively in Japan were popularized by an organization called GOAL / QPC in USA. A large number of firms are now using the new seven tools for management and deriving immense benefits.

In this chapter we will look at the following new seven management tools:

1. Affinity Diagram
2. Relationship Diagrams

3. Tree Diagram
4. Matrix Diagram
5. Prioritization Matrix
6. Activity Network Diagram
7. Process Decision Program Chart

TOOL 1: AFFINITY DIAGRAM

Usually, a cross-functional team meets to find out the various causes for an effect. For instance, they may need to find out the causes leading to defects in products, customer requirements or in design, etc. The affinity diagram is quite useful to such teams for carrying out their work more effectively and efficiently. Assume that an organization is finding 25 per cent defects in materials. Then the organization constitutes a team to find out the causes. Such teams can use an affinity diagram to organize their discussions and coming out with the most effective solutions. This tool is devised to capture the suggestions of every team member. The various steps involved in creating an affinity diagram, for a given problem is listed below:

Step 1: Constitution of six to eight member team for finding a solution to a problem

Step 2: The moderator fixes the meeting, venue and time

Step 3: Each member comes out with what he thinks is the solution to the problem and writes down his ideas, one in each Post-it card (which can be pasted to a white board and removed easily) or sheet and fixes it on the board. No idea is discarded at this stage.

Step 4: After all the members have exhausted their ideas, the team discusses and removes those sheets or cards containing ideas, which either may be duplicate ideas or may not be directly relevant.

Step 5: Now the team discusses and clubs related ideas into groups. Each group of ideas is given a logical group name.

Step 6: Now each card or sheet is pulled out and placed under a group name, depending on the affinity of the idea to the group. The team may meet, may be the next day and finalize the affinity diagram and transfer it into a computer.

Example

A team formed for finding out the causes of defective incoming materials put all the ideas on the Post-it sheets. Then they found that the causes of defects could be grouped into three categories:

1. Material specifications
2. Supplier commitment
3. Unsystematic purchase department

Then the Post-it sheets were moved to the corresponding groups. An affinity diagram for the causes of defective incoming materials is given in Fig. 14.1.

The theme of an affinity diagram is to allow the free flow of ideas, opinions and facts without causing any interruption. Then they are grouped depending upon the affinity of the causes. Kawakawa Jiro, a Japanese anthropologist, developed the tool in the 1960s. The affinity diagram is also called KJ method, which are the initials of the developer. The tool helps in forming the basis for identifying process improvement actions.

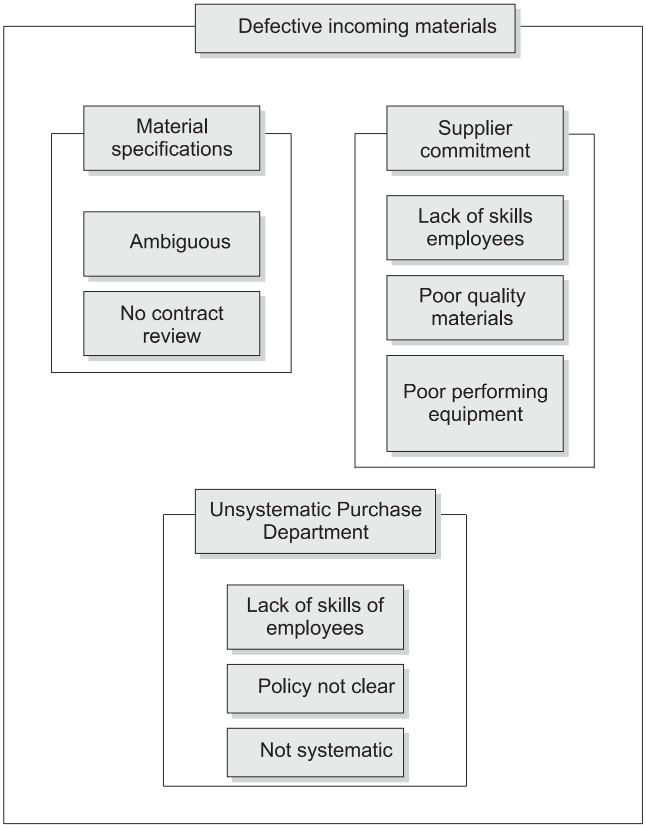


Figure 14.1 Affinity Diagram for Finding Causes of Defective Incoming Material

Affinity Diagram Methodology

Step 1: Define the problem or issue to be explored. Ensure that the problem is stated as clearly and unambiguously as possible.

Step 2: Brainstorm for ideas, but instead of everyone shouting out ideas, everyone silently writes down their ideas on Post-it cards.

Step 3: When brainstorming is complete mix all the notes or cards and stick them on a wall or spread them out on a table.

Step 4: Let the group arrange the notes or cards into related groups as follows:

- Take two cards that are related in some way and put them together
- Find other cards that belong to this group and put them with the first two
- Build other groups of cards in the same way until all of the cards have been grouped (about 10 groups maximum)

Step 5: Now the team can decide what to call each group. Header cards are created and placed at the top of each grouping. The header card should clearly define the common thread that ties all the cards in the group (usually a 3–5 word description).

TOOL 2: RELATIONSHIP DIAGRAMS (RD)

A relationship diagram is drawn usually after making an affinity diagram for a problem. The RD brings out the relationship of the identified causes. One identified cause in the above may be caused by another factor. Thus, the diagram helps in establishing a relationship between the factors identified and grouped using an affinity diagram in a brainstorming session.
This diagram can be used to:

- Determine and develop QA policies
- Design steps to improve market share
- Improve quality
- Vendor development
- Improve cycle time
- Reduce defects
- Reduce quality cost, etc.

Let us take the same example of causes of defective materials and express it as RD, which is also called a relationship diagram.

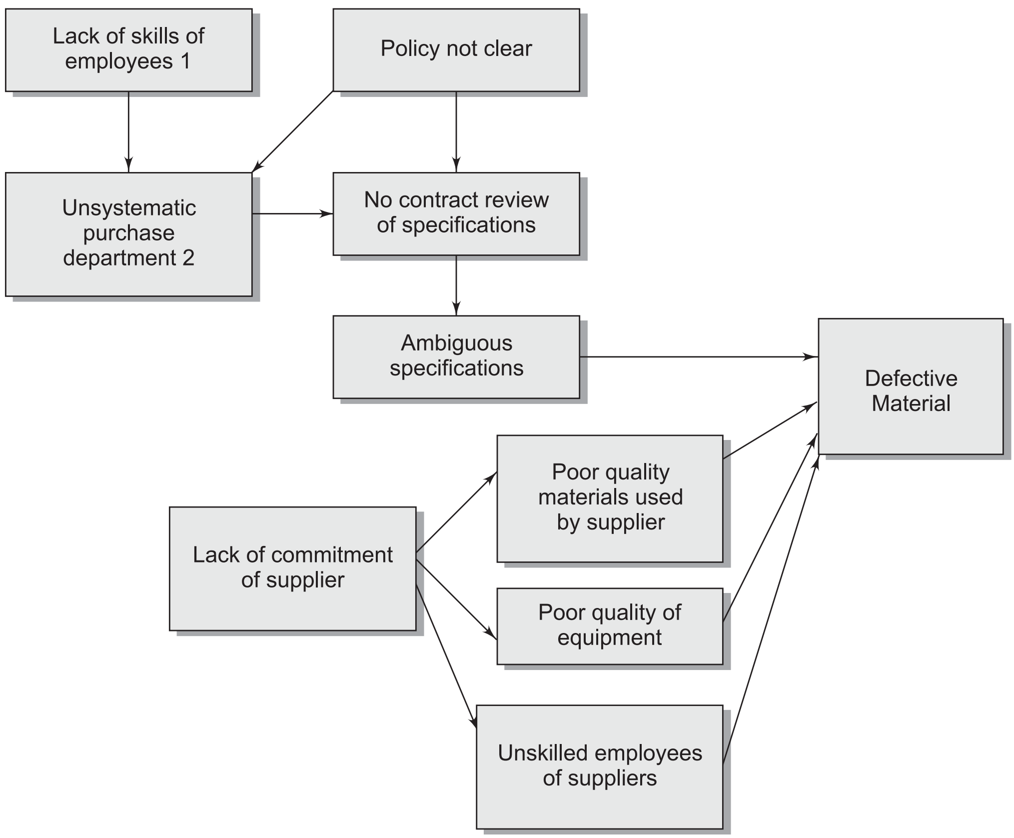


Figure 14.2 Relationship Diagram for Defective Material

Steps Involved in formulating a Relationship Diagram

- The self-adhesive cards prepared for formulating affinity diagram can also be used in a relationship diagram. The diagram may also need preparation of new cards as the above figure illustrates.
- The cards containing causes are placed on a white board.
- Two cards, which have a relationship between them, are chosen. For the sake of convenience, the two cards in figure above are marked 1 and 2.
- Through brainstorming we identify cause 1 is stronger than cause 2 or cause 2 is caused by cause 1. Therefore we connect them by a line, arrow points to the weaker cause.
- Now we compare cause 1 with all the other causes one at a time. If there is a relationship we draw a line from stronger to the weaker cause.
- Since it does not have any relationship with any other cause, we move to cause 2.
- Now we compare cause 2 with all other causes, one at a time and draw lines appropriately.
- Then we start with one of the causes it has a relationship and compare it with all other causes. Since we had already compared it with causes 1 and 2, there is no need to compare again.
- We repeat it till all causes have been compared with all others.

Once the diagram is completed we can find out the root cause and its outcomes.

Root Causes

A cause, which has no incoming arrow, is called a root cause. There are three root causes. But, the most important root cause is the one with maximum number of outgoing arrows. This is also called driver. In the above – lack of commitment of supplier is a driver.

Measure of Success

A cause, which has a maximum number of incoming arrows, is called an outcome. It will also be a good measure of success. In the above diagram, "Defective material" is the outcome of all these causes.
Thus, Relationship Diagram is an improvement over an affinity diagram. It gives much more information about the problem. It helps in identifying the root causes easily.

TOOL 3: TREE DIAGRAM

A tree diagram is used to break down the improvement project into a plan for detailed actions to be carried out. A tree diagram is a highly effective way of organizing large and complex projects and breaking down into activities and specific tasks to be carried out for successful completion of the project. A tree diagram is usually drawn after an affinity diagram has been finalized for the same project. The steps involved in drawing a tree diagram are given below:

Step 1: Agree on the objective to be achieved

Step 2: Draw an affinity diagram to deduce high-level means of achieving the objectives

Step 3: Break down each of the high level means to sub-means or tasks. Each sub-mean can be further divided into specific tasks. Make sure that the final list of actions consists of everything that is needed to accomplish the objective. A tree diagram is also called a systematic diagram. This diagram searches for the most appropriate and effective paths and tasks needed to accomplish a specific project. An example of tree diagram for the same project of improving the quality of incoming material is given in Fig. 14.3.

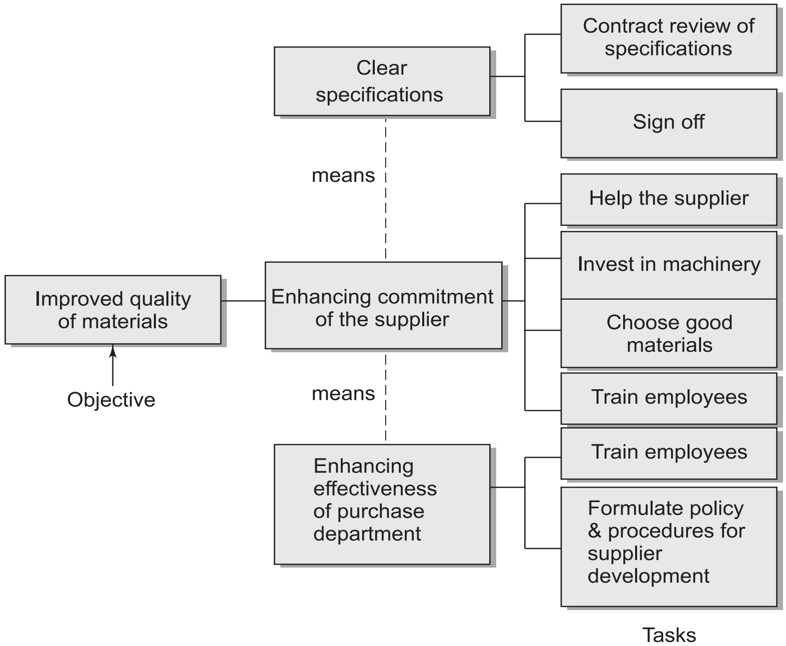


Figure 14.3 Tree Diagram for Improving Material Quality

The objective, namely the improvement of quality of incoming material is displayed on the left hand side. This can be achieved through three means as identified in an affinity diagram. The means are identified from the causes, identified in an affinity diagram. The means to achieve the objectives are:

- formulating clear specifications
- enhancing the commitment of the supplier
- enhancing the effectiveness of the purchase department

There are no sub-means, hence we can go straight into the tasks to be carried out. The tasks are listed corresponding to each of the means. Therefore, a tree diagram facilitates identifying specific tasks to be carried out for a specific improvement project. A relationship diagram may also be useful in formulating a tree diagram. A tree diagram essentially gives the steps required to be carried out for solving the problem. The diagram can bring out the activities and recommended time frame for the same.

In summary, the diagrams consist of objectives, means and how to achieve the means.

Another example of a tree diagram is given in Fig. 14.4. This tree diagram depicts the means and tasks undertaken by ETDC, Chennai to meet its long-term objective of becoming world class testing, calibration and quality education centre.

The diagram also illustrates the application of a Balanced Score Card for achieving the objective.

TOOL 4: MATRIX DIAGRAM

Matrix diagram is used in particular for describing the actions required for a process or product improvement. The matrix diagram is different from the tree diagram. Matrix diagram is also called Quality Function Deployment (QFD), discussed in detail in Chapter 18. It is used to arrange large data

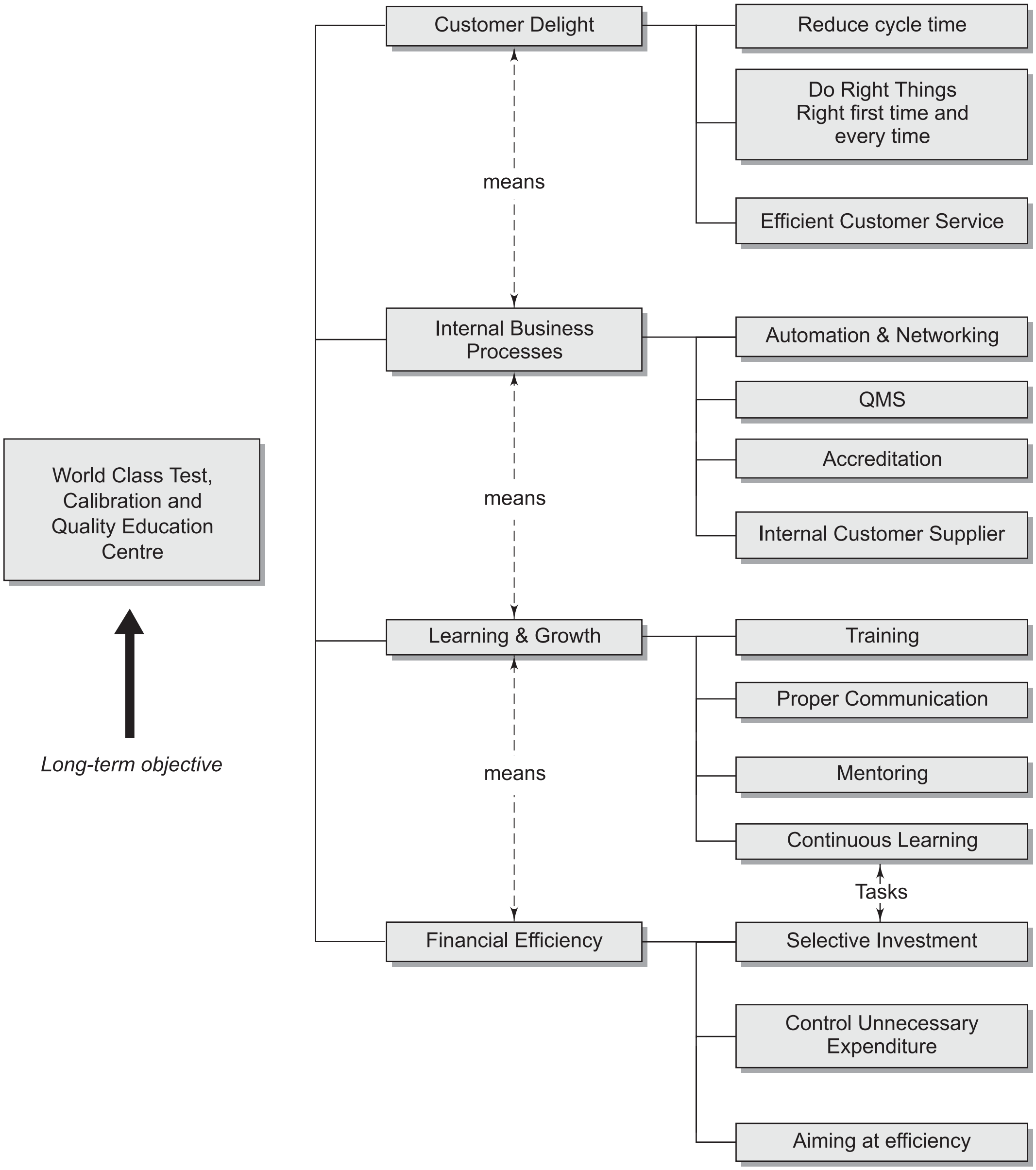


Figure 14.4 Tree Diagram Used for Balanced Growth of ETDC, Chennai

relating to two or more items and capture the relationship between them. The diagram has different types as given below:

- L shape
- T shape
- C shape
- 3 dimensional
- Inverted Y shape

The L shape and T shape matrix are the most commonly used matrix diagrams. The L shape is used to show the inter-relationship between the two product or process or system variables in a matrix format. As we know, matrix consists of rows and columns. The columns are used for representing sub-categories of one variable and the rows represent sub-categories of the second variable. These two variables should have a relationship. The matrix brings down the correlation between the two variables. The steps involved in a matrix diagram are given:

1. Select the problem
2. Form a team with 4-5 people.
3. Choose a facilitator for the coordination of the team's activities
4. Determine the product or process variables to be studied
5. Decide on the matrix shape based on the task
6. Place the information in the matrix
7. Draw the lines of the matrix
8. Determine the symbols to be utilized for representing degree of relationships between the variables. Include a legend also for the symbol definitions. An example is given below:

   ○ **Always**

   ◎ **Frequently**

   △ **Sometimes**

9. Enter the symbols into the correct cells depending on their relationships
10. Analyze

The matrix diagram for finding out the causes of defects in a test laboratory is given in Fig. 14.5:

Cause \ Defect Category	Error in Testing	Error in Report	Crossed PDC
Employee Training	○	○	
Employee motivation	△	△	◎
Machinery			△
Methods	◎	△	△
Supervisor	◎	△	

Figure 14.5 Matrix Diagram for Finding Causes of Defects in a Test Laboratory

As the figure indicates, the rows contain the different category of causes and columns contain the defects. There are some elements of the matrix without any symbol indicating that there is no relationship between rows and columns. A look at the figure brings out the important causes of defects.

Let us draw a L shaped matrix diagram for selection of a hotel to stay. Here, the variables are the status of hotels and facility available.

Status of Hotel

Facilities	5-Star	3-Star	Economical
Expensive	○	◎	
Swimming pool	○		
AC failure		◎	△
Restaurant attached	○	○	△
Clean	○	◎	△
Airport drop available	○	◎	
Credit card facility available	○	○	△

Figure 14.6 Matrix Diagram for Selection of a Hotel

The advantage of a matrix diagram is that it helps in presenting complex information in easily understandable form. It is important to study and understand the relationships for the decision making process. This will help to clarify the relationship between the factors involved.

Analysis is quite important for decision-making. If no symbol is put in the column, then it means there is no relationship. Thus, matrix diagram is essential for identifying the relationship between the two variables.

TOOL 5: PROCESS DECISION PROGRAM CHART (PDPC)

Every process has to be achieved through predetermined tasks with clear objectives. Some tasks may fail to deliver the expected results. A contingency plan should be ready to meet such eventualities. A contingency plan should be identified in order to avoid failure of the process. The PDPC is quite useful in executing the tasks without any surprises. In order to draw the PDPC chart, the objective should be clearly identified. For instance, let us evolve PDPC for an expert to give a guest lecture in another organization. We should identify the tasks needed for meeting the chosen objectives. Three tasks are involved in giving a guest lecture assuming that the expert is ready with the lecture material. The tasks are:

1. Reach the venue in a car
2. Prepare the presentation in the laptop
3. Make the presentation using a video projector

Such simple tasks can also give surprises. Let us analyze what can go wrong!

Have a car to reach the venue There is a possibility that a car breaks down either at the place of starting or midway. Then, what is our contingency plan? Hire a car or take a public transport. If we are sure to get a taxi, then the possibility of taking a public transport does not arise.

Use a laptop for presentation The laptop can give the following failures:

- File containing the Power Point Presentation in the laptop could not be found
- Laptop fails to operate

When the file is not found, the CD containing the presentation can be used, if taken. When the laptop fails, one can ask the organizer to give a PC and use the CD in the PC to make the presentation. However, the prospect of laptop failure is quite remote.

Use a video projector Video projector is used along with a laptop. There is a possibility that the video projector fails. In the event of a video projector failure:

- Use an overhead projector(OHP)
- Use a white board and speak

If the organizer has been advised in advance, the OHP will be readily available and if the speaker has identified the possibility of non-availability of a video projector, he would have taken OHP transparencies.

All the above contingency plans can be depicted in the PDPC diagram given in Fig. 14.7.

Some of the steps involved in making a PDPC chart are:

- write down the objective
- then list the steps involved
- for each step, identify the counter measures

The steps and counter measures are to be arrived at by brainstorming. The counter measures are placed as circles in the lowest level of the chart. The next step is to look at the counter measures and select the optimal ones by placing a '0' below the balloon. If the optimal solution will surely take place, then there is no need for the other option. Therefore, we can place 'X' on those counter measures, which are rejected. Thus, PDPC gives a representation of a contingency plan for meeting an objective. Although, a simple example is given above, it is useful for carrying out contingency plan in complex tasks such as development of software or organizing an international conference. This is a good tool for identifying counter measures and taking suitable actions so as to avoid failure of projects.

PDPC can be used in the following situations:

- Establishing an implementation plan for technology-development and product development
- Establishing a policy for forecasting and responding in advance to major events predicted in an organization or in a plant or in a country
- Implementing counter measures to minimize nonconformities in the manufacturing process
- Organizing major events such as elections, campaigns, etc.

TOOL 6: ACTIVITY NETWORK DIAGRAM

The Activity Network Diagram (AND) is also called an arrow diagram. The arrow diagrams have been used in many projects in the form of Critical Path Method (CPM) and Program Evaluation Review Technique (PERT). Both these names are quite popular in project management. The names of Activity Network Diagram and Arrow Diagram are of recent origin. The activity network diagram helps in planning complex

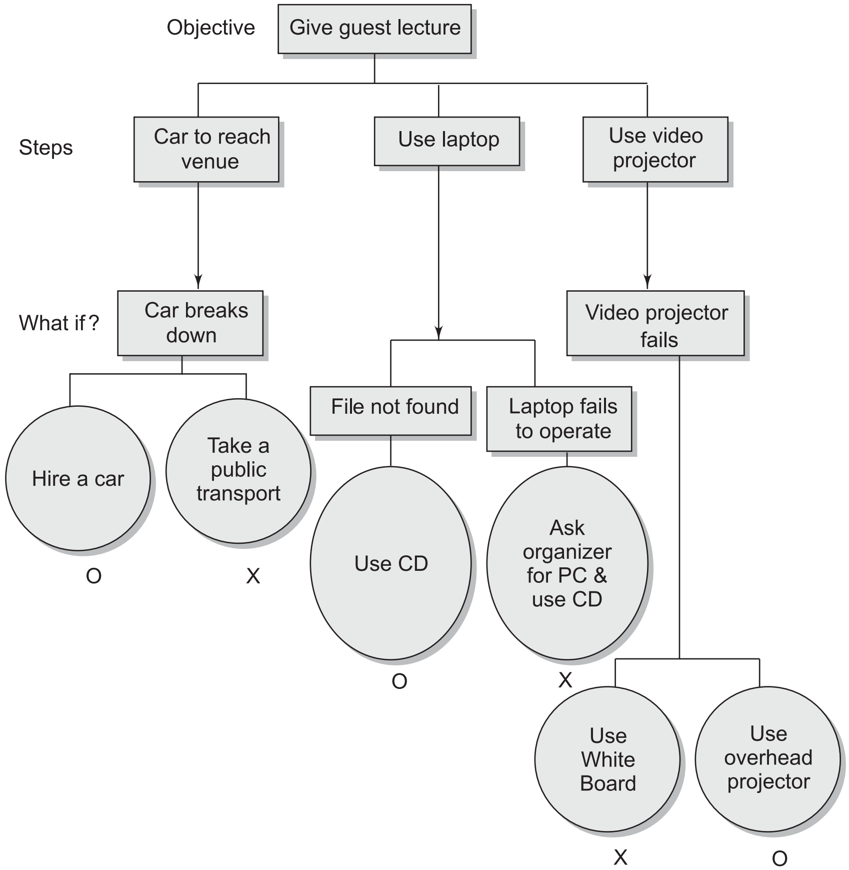


Figure 14.7 Process Decision Program Chart for Giving Lecture

projects with a sequence of events. It also enables to create a realistic project schedules. This tool will help the planners to identify the total amount of time needed to complete a project and the tasks that can be carried out in parallel and the critical tasks, which are to be monitored carefully. The steps involved in drawing AND are:

- Step 1: Tree Diagram also gives the list of tasks that are to be carried out for completion of the project. If the tree diagram is not available then a team should carry out brainstorming and find out all the tasks that are necessary to complete the project.
- Step 2: Each task may be written on a post-it note or adhesive sheet and pasted in a white board.
- Step 3: Establish which task is the first one that must be carried out and place the card on the left hand side of a white board.
- Step 4: Determine whether there are any tasks that can be done at the same time, i.e. tasks that are not dependent on this first task finishing before they can be carried out. If there are, place the cards vertically above or below the first card.
- Step 5: Then decide which is the next task that must be carried out and place its card on the right of the first card. Determine whether there are any tasks that can be done at the same time as this task, if it is so place the respective cards vertically above or below.

Step 6: Repeat the process until all of the cards have been arranged in sequence and in parallel.

Step 7: Assign a number to each task and write it on the card.

Step 8: Draw an arrow from each card to the one that immediately follows it.

Step 9: Estimate the elapsed time that it will realistically take to complete each job and write this length of time at the bottom of the card. Don't forget to agree on a standard time and use it throughout, e.g. days, weeks.

Step10: Determine the project's implementation time by working out its critical path. The critical path is the path of connected activities on the diagram that has the longest completion time from start to end.
The tasks on the critical path are to be monitored carefully. A delay in any one of these tasks will increase the project's total completion time and make it later. Conversely, if we want to reduce our project's completion time we need to reduce the elapsed time of one or more of the tasks on the critical path.

Step 11: The project schedule can be calculated by simply adding up the times of every activity in each path of connected activities on the diagram and finding out the longest path. There is an alternative way of determining the critical path by calculating what is known as the 'slack' in the start times of each task. This identifies which tasks must be completed exactly as scheduled (these ones will be on the critical path) and those that have some leeway.

Earliest Start (ES) of tasks

Step 12: Beginning with the first task, calculate the earliest time each task could be started (ES). We do this by adding the duration of each task to the cumulative duration of its previous tasks. This is called the forward pass.
For instance:

Table 14.1 Finding Earliest Start

Previous task numbers 1 to 5	21 days
Earliest start for task number 6	22nd day
Task number 6 takes	3 days
Earliest start for task number 7	25th day

Write ES on the respective cards.

Latest Start (LS) of tasks

Step 13: Starting at the last task, calculate the latest time each task could be started and still finish the project on schedule as the Table 14.2 illustrates:
For instance:

Table 14.2 Finding latest start

Total implementation time	60 days
Last task (number 12) takes	15 days
Latest start for task number 12	45th day
Task number 11 takes	12 days
Latest start for task number 11	33rd day

Write the LS on the card.

Step 14: When we have worked our way through every task on the diagram in this way we will notice that some ES will be lower than the corresponding LS. In other words, we will have some leeway as to when exactly we can decide to start these tasks. This leeway is what is known as the slack time for those tasks. However, we will also find that for some tasks ES and LS are exactly the same. In other words, there is no slack. Those tasks for which the ES = LS form the critical path. There is no schedule flexibility for these tasks.

Step 15: We can now schedule the dates for our final plan.

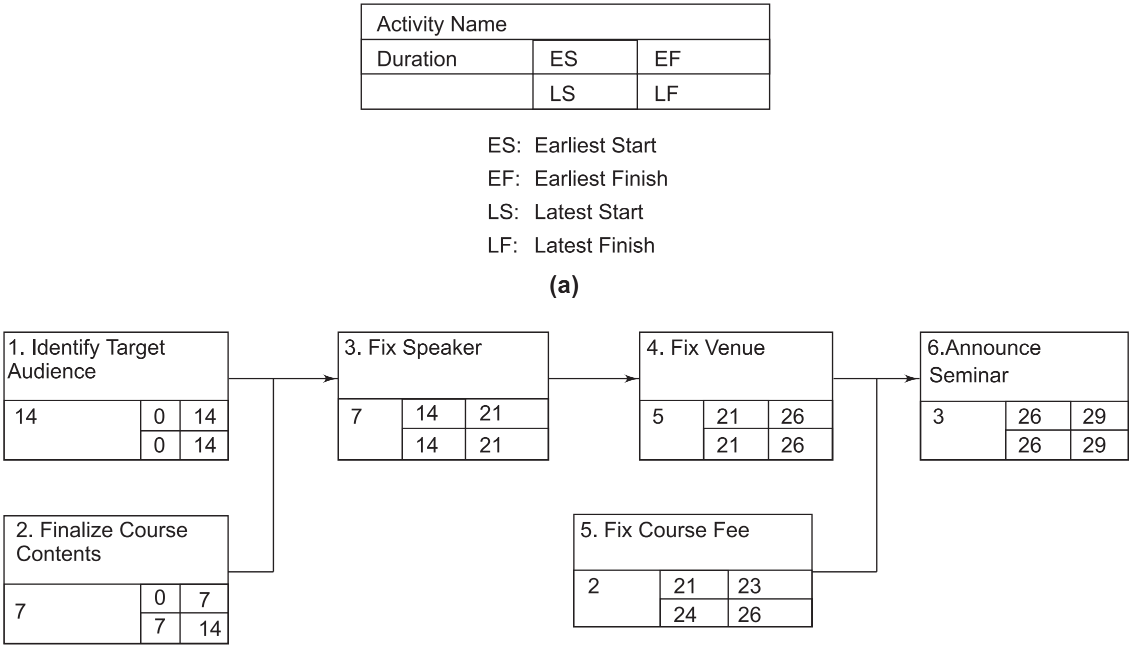
Let us take an example to understand drawing an activity network diagram. The task in hand is preparing and announcing a seminar for public. If a tree diagram is available for the project, all the tasks required to be carried out will be visible from the tree diagram. If not, a team has to brainstorm and identify the tasks involved in implementing the project.The various tasks to be completed before announcing are listed below:

1. Identify target audience
2. Fix speaker
3. Finalize course contents
4. Fix course fee
5. Fix venue

The tasks are to be written and pasted on the white board. Now, we have to identify the first task. In this case, to identify the target audience is the first task. This task has to be moved to the left hand corner. Then, we have to look for any other tasks, which can also be carried out in parallel to this task. We can place this also on the left most corner below the first task. In some cases, there may be one or more tasks that could be started with. In this case, there are two activities, which can be carried out in parallel. The activity that can be carried out in parallel with "identify the target audience" is "Finalize course contents". We can move this card also to the left extreme in the board and place it either above or below the other first card. The next task is "fixing the speaker". Place this at the next column. Then there are two other tasks, which can be executed in parallel, i.e. "fixing up venue" and "fixing up the course fee". They can be placed next to the task 3. We can now announce the seminar, the seminar fee and date. Now we have to identify the time taken for each one of the activities. The time estimate has to be written on each one of the cards. The format for the card is given in Fig. 14.8 (a).

On the top most we write the name of the activity, on the left most we write the duration for completion of the task. Then there are four parameters, which are to be written—the earliest start and the earliest finish (ES –EF), latest start and the latest finish (LS – LF).

The first task will take 14 days and the parallel task (number 2) will take seven days. Therefore there is no choice for LS of task 1; it will be 0. However, we have a choice with regard to task No. 2. The LF for task 2 is 14 days since it has to finish by the time task 1 finishes. By subtracting LF by the duration, we can fix LS. The ES can be zero and LS as 7 days and LF 14 days, so, that the next task (3) will not be delayed. If these two tasks are completed, then we are ready to fix up the speaker, task 3. Therefore, the early start and the latest start for task 3 namely fixing up the speaker will be 14 days. The first and the second task are to be completed before fixing up the speaker. Since it takes 7 days to complete the task 3, we would have fixed up the speaker by 21 days. Now fix the venue and the course fee. These two tasks will consume 5 and 2 days respectively. The ES and LS for task 4 are 21 days and hence EF and LF will be 26 days. However there is leeway in respect of the parallel task number 5. Start task 5 earliest by 21 days or latest by 24 days as shown in the figure.



(b)

Figures 14.8 (a) & (b) Activity Network Diagram for Announcing a Seminar

After completion of task 4 and 5 we are ready to announce the seminar, which is task 6. Since this is the last task, ES and LS will be the same and hence EF and LF will also be same. This is how the activity network diagram is drawn. The steps involved are summarized below:

- Step 1: If a task list is not available from a tree diagram, carry out brainstorming and identify the tasks.
- Step 2: Write down each task on a post-it note.
- Step 3: Determine which is the first task and place it on the left hand side.
- Step 4: Determine parallel tasks, place the corresponding cards vertically above or below the first card.
- Step 5: Then decide which is the next task and place this card on the right of the first card. Determine any other parallel tasks and place their cards vertically above or below the card and repeat the process until all the cards are arranged in sequence and in parallel.
- Step 6: Assign a number to each task and write it on the card.
- Step 7: Draw an arrow from each of the card to the one that immediately follows it.
- Step 8: Estimate the time required for completion of each job.
- Step 9: Determine the time for completion of the job by working out its critical path.
- Step 10: The critical path is the path connecting the activities in the diagram that has the longest completion time from the beginning to the end. Critical path can be calculated by simply adding up the times of every activity in each path of connected activities on the diagram, to find out which is the longest path. If required the critical tasks can be connected in red ink.

Step 11: Calculate ES, EF, LS and LF for each task and write them on the respective cards along with the duration for each task.

The benefits of activity network is given below:

- Identify the activities involved in a project
- Document the estimated time for each task
- Arriving at a critical path
- Finding out the time schedules
- The organization understanding the tasks involved and finding out which tasks are critical and which tasks should be completed before a task is taken up
- Facilitating fixing of critical tasks

TOOL 7: PRIORITIZATION MATRIX

This tool is also called matrix data analysis. The matrix data analysis is useful to prioritize the actions to be taken. This can be used to analyze the causes of non-conformities. Identify the top most causes. ETDC, Chennai used this technique for finding out Customer Satisfaction Index. The technique is very simple. Each one of the significant customers were requested to rank their level of satisfaction against the following 4 parameters:

- Quality of testing / calibration carried out
- Quality of testing / calibration reports issued
- Quality of customer service rendered
- Promptness of service rendered

They were given 5 attributes against each parameter as given in Table 14.3 and requested to rank the services rendered:

Table 14.3 Feedback form of ETDC, Chennai

	Excellent	*Very Good*	*Good*	*Average*	*Poor*
Quality of testing / calibration					
Quality of reports					
Quality of customer service					
Promptness of service					

After the receipt, the responses were quantified by assigning the following marks:

Excellent	*Very Good*	*Good*	*Average*	*Poor*
5	4	3	2	1

Each customer feedback was given equal weightage and the indices for each one of the parameter were found out. If a customer had marked excellent for promptness of service, 5 marks were added to the promptness of service and if he has marked good for quality of reports, then 3 marks will be added for quality of reports etc. Similarly, each customer's marks were noted against each one of the four parameters. The total marks obtained for all the services were found out and listed in Table 14.4.

Table 14.4 Quantified Feedback

Quality of testing/calibration	245
Quality of reports	300
Quality of customer service	190
Promptness of service	210

From this, the first area to be improved is no. 3 namely quality of customer service. The next higher priority goes to no. 4—promptness of service. This way, we can prioritize the actions to be taken for improving the quality of the process.

This technique has been used by United Nations Children's Fund (UNICEF) to prioritize the problems in health care. The list of problems identified include the following:

- Not enough doctors
- Break-down of ambulance
- Disrespect for patients
- Incomplete laboratory
- Delay in registration, etc.

For each problem the participants of the brainstorming session were asked to vote according to:

- Frequency
- Importance
- Feasibility of the problem occurring

If the problems occur more frequently, then they gave a mark of 3, if not frequently the mark of '0'. Similarly, if the problem is important, they give a mark of 3 and '0' if it is not important. If the occurrence of the problem is feasible they give 3 marks and if not feasible give a mark of '0'. For identified 10 problems and the 3 criteria, they found out that the most important problem is the long waiting time. (Reference www.erc.msh.org/quality/example/example9.cfm)

Table 14.5: Prioritizing Problems using a Prioritizing Matrix

Problems	*Frequency*	*Importance*	*Feasibility*	*Total Points*
1. No appointments for the afternoon	5	0	0	5
2. Delays in registration	6	1	5	12
3. Incomplete laboratory	9	11	6	26
4. Insufficient care in dentistry	10	12	8	30
5. Not enough doctors	6	0	5	11
6. Not enough materials for the lab	3	0	0	3
7. Broken down ambulance	0	3	0	3
8. Segregation of patients	7	12	11	30
9. Long waiting time	7	14	15	36
10. Disrespect of patients	4	6	10	20

To summarize, what is a prioritization matrix? A prioritization matrix is a useful technique that can be used by the team members to achieve consensus about an issue. The matrix helps ranking the problems of issues by chosen criteria that are important to the organization. Then, one can say clearly which problem is the most important one and to be solved first. The prioritization matrices are arrived at by brainstorming or through survey. Thus, prioritization matrix is a useful technique for arriving at priorities when there are a number of actions to be taken.

Matrix data analysis can be used in the following situations:

- Analyze production processes where factors are intertwined in a comple manner
- Analyze causes of nonconformities that involve a large volume of data
- Grasp the desired quality level indicated by the results of a market survey
- Accomplish complex quality evaluations

SUMMARY

In this chapter, we discussed about the tools for management — the new seven management tools. These tools were developed much later than the seven QC tools. The management tools are more qualitative in contrast with the seven QC tools, which are mostly quantitative. Teams to identify large number of ideas and group them logically for a chosen purpose can use the affinity diagrams. This could be for improvement, for finding out causes of defects or delays, excessive expenditure etc. The relationship diagram brings out the relationship between the causes. The tree diagrams are drawn from the affinity diagram and inter-relationship diagram. Tree diagram gives the objective, the means to achieve the objective and the tasks required to achieve the means. Matrix diagram can be drawn as a two-dimensional graph of the two variables. It brings out for each variable, the relationship with the other variable and the degree of relationship. The prioritization matrices helps in prioritizing the actions to be taken based on voting by the team members. This is a consensus decision-making process where clearly the top most areas of concern are brought out by the total votes polled for each cause. The top most improvement actions can be clearly identified through the marks. The Process Decision Program Chart is useful for implementing a task successfully by identifying the risks and contingency plans. It helps the user to identify the objective and the tasks involved. For each task a contingency plan is prepared. The activity network diagram is a project-planning tool, which is also called an arrow diagram. The conventional CPM and PERT charts can also be considered to be ANDs. The activity network diagram helps in identifying the tasks, the duration of each task, a critical path and a total duration that will be required for completing the job. It gives a complete plan, sequence of activities and schedule for the project. Thus, the seven new tools invented by the Japanese are quite useful in the TQM journey.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. The other names of activity network diagram are
   (a) Arrow diagram (b) CPM
   (c) PERT (d) All the above
2. PDPC indicates
   (a) Objective (b) What if ?
   (c) Counter measures (d) All the above
3. The shapes in a matrix diagram could have

(a) L (b) Y
(c) T (d) All the above

4. Tree diagram indicates
   (a) Objectives (b) Means
   (c) Activities (d) All the above
5. Prioritization matrix is carried out through
   (a) Voting (b) Survey
   (c) Identifying problems (d) All the above

II. True or False

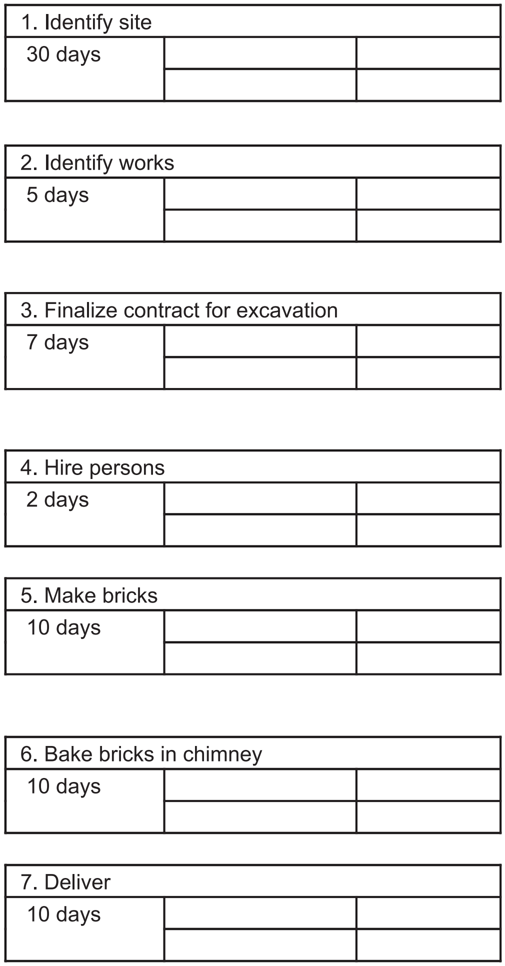
1. Prioritization matrix is derived from a matrix diagram
2. Tree diagram is derived from affinity diagram
3. Relationship diagram is an alternate to tree diagram
4. Project planning is best carried out through tree diagram
5. Activity diagram cannot be drawn using brainstorming
6. The management tools also help in planning
7. Seven Management tools were invented before seven QC tools
8. Usage of self adhesive notes is common across the new seven tools
9. A moderator is necessary for brainstorming
10. Cause and effect can be depicted using PDPC

III. Explain Briefly

1. Affinity Diagram
2. Relationship Diagrams
3. Tree Diagram
4. Matrix Diagram
5. Prioritization Matrix
6. Activity Network Diagram
7. Process, Decision Program Chart

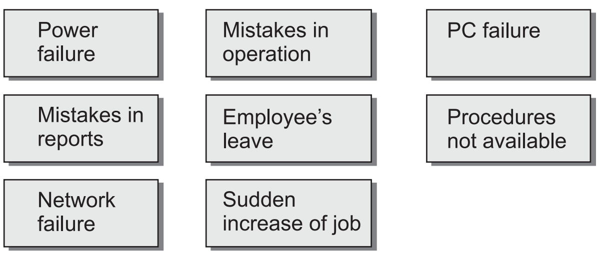
IV. Problems

1. The activity network diagram of a brickwork project is given as follows. Complete the diagram with ES, LS, and EF & LF.



Identify the critical path in the above diagram.

2. Failure to meet PDC of calibration jobs was brainstormed by a team. The causes were written on Post-it slips as shown below:



(a) Organize the above as an affinity diagram
(b) Draw a relationship diagram for the above
(c) Draw a tree diagram to complete the job within PDC

3. Draw a L shaped matrix diagram for analysing the causes of students coming late to class.
4. To overcome the problem in 3 above, draw a process decision program chart.

Reference

(1) Subburaj R, 17th IETE Lal C Verman Lecture, delivered at IETE Mid-Term Symposium held at Nagpur, India on April 3-4, 2004

Reference on the Web

www.goalqpc.com/

Section IV

TQM Tools

We discussed about SPC tools in the previous section. In this section, we will look at some of the tools for TQM as given below:

15. BUSINESS PROCESS BENCHMARKING (BPB)

16. QUALITY FUNCTION DEPLOYMENT (QFD)

17. TAGUCHI'S ROBUST DESIGN

18. TOTAL PRODUCTIVE MAINTENANCE (TPM)

19. FAILURE MODE EFFECTS ANALYSIS

Chapter 15

Business Process Benchmarking

Imagination is more important than knowledge...

—Albert Einstein

INTRODUCTION

Malcolm Baldrige National Quality Award (MBNQA) is one of the most prestigious awards instituted by the government of United States of America. It is awarded to the organizations in recognition of achieving the highest standards of quality in the organizations. An organization awarded MBNQA is recognized as a quality leader. In the criteria for MBNQA award, the word 'benchmarking' appears 200 times[1]. This shows the importance of benchmarking for continuous process improvement and TQM. Benchmarking will help in identifying the current level of performance of the processes in the organization and bringing them up to the level of the best processes. Benchmarking can be used to compare product features also. However, in this chapter, we will learn the following concepts pertaining to processes, namely Business Process Benchmarking (BPB), one of the tools of TQM.

- Importance of BPB
- Triggers for benchmarking
- Types of benchmarking
- Benchmarking partner
- Benchmarking process models
- Reasons for failure of benchmarking

DEFINITION OF BENCHMARKING

Benchmarking is a process of comparison of two or more products, services, processes or organizational practices. Business process benchmarking is comparing a business process with the best process in that area. The dictionary meaning of benchmark is "standard or point of reference". Benchmarking has been in vogue in the computer industry for quite some time. Benchmarking computer systems involves executing a set of common programs developed by independent agencies to ascertain the relative performance of computers of various makes. They essentially compute the time taken to carry out certain standard computations such as sorting. Benchmarking computers is a process of comparing the performance of computer systems. Similar concept is now applied to measure not only the performance of products such as cars, but also the business processes in various organizations. The measurement and comparison of performance of processes is known as Business Process Benchmarking (BPB). Xerox Corporation, USA, carried out pioneering work in the area of benchmarking. The success of Xerox Corporation in the field of photocopying machines can be visualized from the fact that in India photocopiers of any make are known as Xerox machines. They became market leaders through benchmarking with Japanese companies. All successful organizations such as Toyota Motors, Ford, IBM, etc. carry out benchmarking of their processes on a regular basis to improve their processes. Robert C Camp has given the definition of benchmarking in his book on "Business Process Benchmarking"[1]. The generic definition of benchmarking is "*a basis for establishing rational performance goals through the search for industry best practices that will lead to superior performance*"[1].

TRIGGERS FOR BENCHMARKING

There are two categories of benchmarking based on what triggers it, as given below:

(a) Problem based benchmarking
(b) Process based benchmarking

The categorization arises out of how the benchmarking effort is initiated. The two categories of benchmarking are:

Problem Based Benchmarking

The problem based benchmarking arises out of a problem in the organization. The trigger for benchmarking in this category comes out of a problem that is faced by the organization. Hence, it is called problem based benchmarking. Some of the triggers that could motivate the organization to carry out benchmarking are:

(i) Adverse feedback from customer
(ii) Increasing quality cost
(iii) Alarming error rates
(iv) Increase in cycle time

Process Based Benchmarking

The other category of benchmarking is the process based benchmarking wherein it is initiated as a part of process improvement strategy of the organization. Such a benchmarking arises out of the following:

(i) Defined mission
(ii) Defined objectives
(iii) Defined priorities

The top management without reference to the current practice will define organization's mission, objectives and priorities. The mission, objectives and priorities would have been arrived at by looking at the level of performance achieved by the competitors and other similar organizations. In this case, the objective of the organization is very clear and to achieve these objectives, the organization carries out benchmarking. Thus, the former category namely problem based benchmarking is a reactive approach. The latter is proactive benchmarking.

Benchmarking is not Comparison Alone

The performance of benchmarking is not only to measure the current level of performance of the process or the product or services, but also to improve to the level of the competitors or the market leaders or to the level indicated in the mission statement. Therefore, benchmarking helps an organization to measure the attributes of current operations, practices and identify pitfalls. During benchmarking, one has to understand the level of performance of the competitors and the leaders in the same area or similar areas. When there is a gap between the current level of performance and that of the best in the industry, then the organization tries to emulate the processes of the best of the best. Through benchmarking the organization will improve its process and gain superiority in manufacturing or providing services. The superiority should be revealed by the quality of the product or services, the quality of the business process and the other performance indicators. Therefore, benchmarking helps the organizations to make a quantum jump and reach the level of the best practices in the industry.

TYPES OF BENCHMARKING

There are three types of benchmarking as given below:

(i) Internal
(ii) Competitive
(iii) Functional

Internal Benchmarking

There may be a number of teams or divisions within an organization. Although each division may be manufacturing different products, some common performance measures may hold good for all of them. For instance, the measures such as cycle time, error rate, quality cost and customer feedback are common to every manufacturing or service division. Therefore, the organization need not always look outside to find out the best practices. They could study the best performing division in-house. For instance, if the error rate in one particular division is 1 ppb (parts per billion) and in the other division it is 1%, then the objective of BPB is to improve the error rate in the weaker (1%) division to 1 ppb. The best practices to achieve superior performance are available within the organization in this case. Thus, in such cases, there is no need to look outside for best practices. This type of benchmarking is called internal benchmarking. Of course, those processes, which are the best in the organization (such as the process with an error rate of 1 ppb) should look outside for further improvement.

Competitive Benchmarking

The second type of benchmarking is to improve the performance to the level of the competitors. The competitor's performance data is collected from published data. We may wonder as to how to get the competitor's performance data. When an organization is performing well, they will definitely advertise and make their performance indicators public. Such data could be collected and compared with the current performance in the organization. This comparison is known as competitive benchmarking.

Functional Benchmarking

The third type of benchmarking is functional benchmarking. In the first two types, we were comparing only the processes of similar nature. For instance, in internal benchmarking, we were comparing the manufacturing of bolts with the manufacture of nuts in the same organization. In the second type of benchmarking, we were comparing the performance of manufacturing bolts in the organization with that of a competitor who is also manufacturing bolts. In the third type of benchmarking, we will compare the methods of organizations with similar processes. For instance, there may be two different kinds of service organizations, one can be a calibration laboratory, where the instruments are received, calibrated and despatched. The other type could be a diagnostic centre, where the tests are conducted on patients. These are entirely different service organizations, but with similar processes. Therefore, comparison of similar processes in both the organizations can be made for carrying out benchmarking. For instance, the cycle time can be a common performance indicator in both the cases. This method of benchmarking is called functional benchmarking.

REASONS FOR BENCHMARKING

Benchmarking is carried out to bring out clearly and objectively the real status with regard to the performance of the organization as well as the processes. After ascertaining the real position, the processes can be improved to the level of the best, so that the organization performs better than ever before. Benchmarking is a way to improve the processes and reach the top. With time, competitors will also improve their performance. Hence, benchmarking has to be carried out periodically so as to maintain the leadership position.

IDENTIFYING PROCESS TO BENCHMARK

Every process in an organization has inputs and outputs. The inputs are what are supplied to the process. The processes are a repeatable sequence of events and the output is what is delivered. To carry out benchmarking, one has to measure the characteristics of the output. For instance, completion of a job is an input to the billing process. The output is the invoice. This is indicated in Fig. 15.1.

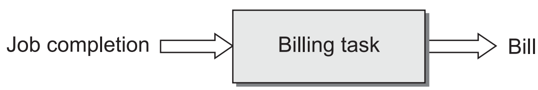


Figure 15.1 Example of a Billing Process

One measure of the billing process is the percentage of invoices with errors. Number of errors contained in an invoice is also a measure of the output. Such measures could be easily found for every process output. To give another example, in a diagnostic centre, the event is that of checking a patient and measuring various pathological parameters. The input is the prescription by the physician and the output is the diagnostic reports as indicated in Fig. 15.2.

Figure 15.2 A Process in a Diagnostic Centre

One of the measures is the accuracy of the report. The other measure could be the timeliness of delivery of reports. Thus, for each output, the measure could be easily identified. The right candidate for benchmarking is essentially the performance measures of the output. For instance, in the billing process, the error in an invoice is to be benchmarked or in other words compared with that of the best processes. The errors in an invoice of an organization could be compared with the best in the field. The invoice being such a common, item, there need not be any similarity between the processes of organizations compared. One could find out what is the best error rate in case of an invoice and find out the current error rate in the organization. The gap has to be reduced by improving the process. Similarly, in diagnostic centre, there are two-performance measures as given below:

(i) Accuracy
(ii) Timeliness

These two measures or parameters are to be benchmarked with the best in the field. Thus, what to benchmark is essentially the performance measures of the output of the processes.

Steps Involved

The following steps are involved in identifying what to benchmark:

- Select processes
- Determine vital measures
- Prioritize processes and measures

Select Processes An organization consists of a finite number of processes. It is important to select the right processes for benchmarking. The appropriate processes are those which when improved will give the highest return on investment. The return could be improved quality and/or productivity and the investment is time, resources and efforts spent on improving the process. To identify all the processes, there is no better method than formulating a process flow chart of the organization. There may be hundreds of processes. But improving some process might give much higher return than others. Therefore, a few vital processes should be selected for benchmarking, which will give higher return on investment.

Determine Vital Measures For each process selected for benchmarking, the measures are to be documented. Each process could be measured by a number of measures. For instance, in case of a diagnostic centre, many other measures could be thought of like waiting time, late arrival of patients or late arrival of staff, machine down time and so on. No doubt all the measures could be considered for benchmarking and improvement, but then, we have to work smartly, so that the benchmarking can be carried out at a lower cost with higher return on investment. Therefore, one should select a few vital performance measures for each process for benchmarking. Improvement of such selected measures should in turn be able to improve the current performance of the process to the level of industry leaders. Thus, a few vital processes and measures for each process selected are to be identified for carrying out benchmarking.

Prioritize Processes The prioritization of processes for benchmarking is not an easy task. A duly constituted team for prioritization should carry out an objective study. The team assigns priority to the processes to be benchmarked in the organization. The team for finding out the few vital processes, which can yield higher returns, could carry out a Pareto analysis. This could be further discussed in the quality council and order of priority assigned to the processes for benchmarking. In the same manner, the measures in each selected process should also be prioritized during the second round. One of the yardsticks for selecting the processes and the measures is the linkage of the processes and the measures to the major goal of the organization, which will lead to satisfying the customers. Then depending upon the availability of the resources, the processes could be taken up one after another for benchmarking.

BENCHMARKING PARTNER

Benchmarking essentially improves the processes in the organization to the level of the best. Therefore, the next important question is who should be the role model who could be imitated or benchmarked with. It is equally a difficult task to select the role model. Selecting the role model requires extensive study of literature and information available in the public domain. The help of customers and suppliers could also be taken to know who is performing better in the industry. The organization should also look for statements of pride made by the good performers in the press, Annual General Body Meeting (AGM), etc. After a detailed study, they should make a list of potential organizations, which could be imitated through benchmarking. The organization chosen as a role model is called a benchmarking partner. While selecting the benchmarking partners, it may be advisable to consult the employees in the organization and particularly those working in the processes selected for improvement. This is an indirect method of reducing the resistance to change later on. *Fortune 500* companies or other such companies can be identified, as leaders could be the obvious choices for benchmarking partners.

BENCHMARKING PROCESS

Benchmarking involves a number of steps, which are to be carried out systematically. The steps are illustrated in Fig. 15.3.

The various steps are discussed below:

Selection of Process Improvement Team

The management should select a cross functional team and persons working in the process and constitute a process improvement team for benchmarking. If the team consists of only outsiders, then it may be difficult to change over to the new system later on due to non-involvement of the process owners. It is therefore, essential to involve those engaged in the process in the benchmarking team. At the same time, a senior manager, who understands both the details of the process and also the management aspects and can convince the CEO about the changes needed in the current process, should head the team. If a senior manager does not head it, the benchmarking may not actually take place.

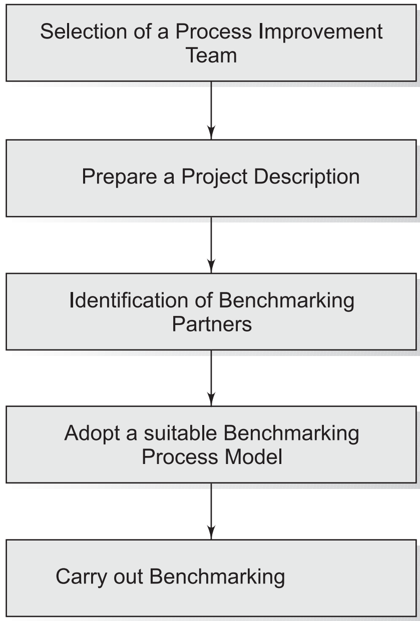


Figure 15.3 Benchmarking Process

Prepare Project Description

The benchmarking team after its constitution should prepare a project description comprising of the following:

(i) Purpose
(ii) Process selected
(iii) Reasons for selection
(iv) Scope
(v) Description of key practices
(vi) Process measures identified
(vii) Estimated opportunity for improvement
(viii) Anticipated impact after benchmarking is completed

Identification of Benchmarking Partners

The team after discussing with various employees in the organization, process owners, external suppliers, customers and other internal experts will prepare a list of benchmarking partners. For this purpose, they should also carry out an extensive study of public domain information. If benchmarking databases are available, they could make use of them.

For instance, the Industrial Technology Institute (ITI), USA is running a performance benchmarking service. Currently, it is reported that more than 800 manufacturers of discrete parts and assemblies are contributing to this benchmarking database. It is funded by US Department of Commerce. It is also reported that more than 40 key performance measures ranging from value added per employee to warranty cost as percentage of sales are collected and tabulated by ITI. The small manufacturers in USA can contact ITI directly and complete the performance-benchmarking questionnaire for their own company and receive their ranking results against other companies in the same industry for a nominal price.

This is the easiest method of carrying out benchmarking. In the absence of such a database and non-availability of adequate information about the performance of processes in other industries, the team has to locate a benchmarking partner for carrying out this activity. If an organization engaged in the same type of manufacturing or service activity is not available for benchmarking, the team has to look for industries or service organizations having similar process functions. Establishing a link with a benchmarking partner is one of the toughest tasks in the benchmarking exercise and quite often it is the cause for failure of benchmarking. If the benchmarking partner is another division of the organization, it solves a lot of problems and hence a role model, if available within the organization should be preferred.

Adopt a Suitable Benchmark Process Model

A number of models are available for carrying out benchmarking. For instance, Motorola has a five-step model, Westinghouse a seven-step model and Xerox a 10-step model. An organization should adopt a suitable model.

We can use Deming's PDCA to carry out benchmarking as given in Fig. 15.4.

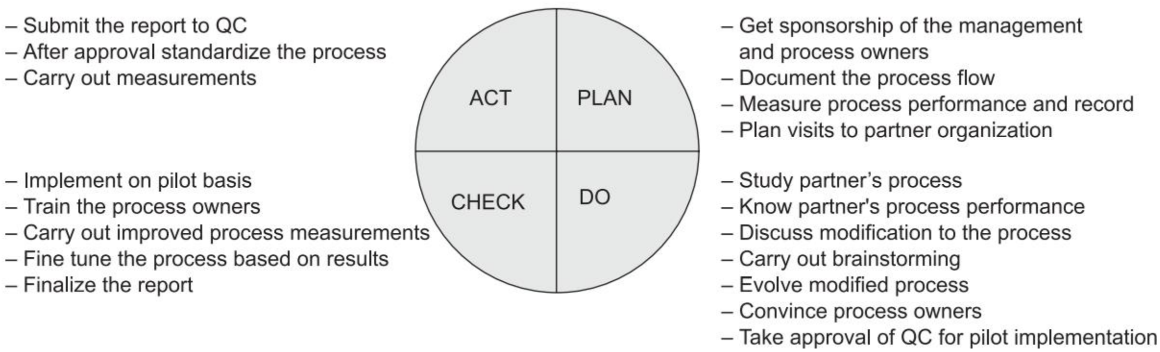


Figure 15.4 Benchmarking Process Model

The various steps carried out in the four step-benchmarking model are indicated in Fig. 15.4. During the planning stage the improvement team holds discussions and prepares a blueprint for the project including performance measurement of processes. The sponsorship of the management and process owners is taken. Visits to partner organization is also planned. During the "Do" phase the team visits the partner and studies their process and notes down the performance. The team should collect information about the reasons for success of partner's process and the key steps in their process. Thereafter, a blueprint for the improved process is made and presented to the Quality Council (QC) and process owners. In the "Check" phase the new process is implemented on a pilot basis. The performance of the improved process is measured and a report is prepared. After the QC gives the go ahead, the process is institutionalized in the "Act" phase. Periodic measurements are carried out to confirm effectiveness of the process.

CASE STUDY[2]

Benchmarking in Practice

AN EXECUTIVE ABSTRACT | Published by *American Productivity and Quality Center* Issue 15

Ford Motor Company

Business Case

Process benchmarking can help the Ford Motor Company to improve quality, reduce cycle time, improve customer satisfaction, increase shareholder value, and adopt quick and nimble behaviour. But the organization needed a centralized, coordinated resource to promote benchmarking and the sharing of best practices within the company.

Ford Motor Company has a long history of benchmarking. But Mark Slagle, benchmarking specialist, realized that the company wasn't doing it as effectively as it could. In fact, much of it could be termed "industrial tourism".

A small, cross-functional team of benchmarkers within product development was performing clearinghouse functions, including promoting benchmarking. Most of them, however, could only provide part-time resources. The team proposed to the management that Ford create a dedicated organization to align benchmarking efforts companywide. Management agreed, and the Process Benchmarking Clearinghouse began in November 1997.

Ford has a number of tools to support its benchmarking efforts. The virtual network has 25 lead contacts from each major organization within Ford. These contacts support benchmarking in their areas and share learning throughout the network.

Ford's External Contact Database provides a central repository for the employees to look at best practices and discussions with other companies for external contact / benchmarking knowledge.

Ford's clearinghouse also created a process benchmarking website on Ford's intranet. The site contains core benchmarking information as well as links to internal web sites and external benchmarking resources.

Process benchmarking is now being strategically positioned to support the Ford 2000 strategies to help Ford become the world's leading consumer company in automotive products and services. Slagle says benchmarking can be and should be an integral part in helping the company achieve this overall goal.

Enablers

Slagle credits Ford's membership with the American Productivity and Quality Center (APQC) as a turning point for increasing benchmarking awareness within Ford. APQC conducted a weeklong benchmarking training program at Ford.

Management also agreed to allow the Process Benchmarking Clearinghouse to spend dedicated resources to support and promote benchmarking within Ford.

Results

The Ford Process Benchmarking Clearinghouse has enabled more people within more organizations at Ford to be aware of what's going on in other areas around the company that potentially benefit them. Employees are also sharing benchmarking discussions and results through the External Contact Database.

REASONS FOR FAILURE OF BENCHMARKING

There are a number of reasons why benchmarking efforts fail. Some of them are:

Lack of Commitment

Benchmarking does not lead to immediate profit. It only helps the organizations to identify whether they are lagging behind and where they have to improve. Quite often, the activity stops there. The team does not push it further for getting the approval of the management and implementation of the required change. Therefore, this exercise lands up in failure except giving some opportunity for the employees for industrial tourism. This can be avoided by the following:

Before the project is started, the team members should estimate how much time they will take, how much it will cost the organization, how much change may be required in the process and the individuals concerned. Initially, there may be reluctance from the process owners and may be even from the management to put in so much efforts. If the management is not willing to commit the resources for improvement, there is no purpose of carrying out benchmarking. This should be made clear, right at the beginning. The benchmarking process should be started only after taking the consent and cooperation of the process owners and top management. In such a situation, the chances of failure of the benchmarking project are rare. Therefore, the sponsorship of the top management and the process owners together is important which will lead to the success of the benchmarking exercise.

Wrong Selection of Process

As discussed, a few vital processes, which will give the highest return on investment, should be selected for benchmarking. If too many processes are selected or if a process with low potential for returns is selected first for benchmarking, then the organization may not be able to continue benchmarking due to failure. People always measure return on investment. If a project after an investment of about $ 100,000 in benchmarking studies, results in an additional profit of $ 10,000 in a year, then nobody will be interested in benchmarking. Therefore, the organization should be selective in deciding the processes for benchmarking. They should select the process where, through benchmarking highest return on investment can be achieved.

Not Being Cost Effective

The benchmarking team will be happy to go on tour or for meetings and make project proposals, but they may not put in adequate time to study the current processes in the organization which are to be benchmarked. The benchmarking team will straight away jump into the industrial visits. Industrial visits are definitely not bad, but then before the visits, they have to survey the literature, talk to various people and look at other divisions of the organization. They should see whether there is an organization like ITI in the country, which can give information at a very low cost. Only when all these efforts do not bears fruit, they should look for a partner for information. The over-enthusiasm of the benchmarking teams for industrial visits has given a negative impression about the benchmarking concept itself.

Wrong Selection of Team Members

The team selection is very crucial for the success of benchmarking. It is ideal if the team consists of members who are working on the process to be benchmarked in addition to cross-functional experts. Of course, the team should be headed or supported by a senior person, so that the recommendation could be put forth fearlessly. Each member should have a role to play in the benchmarking exercise. If the benchmarking exercise fails, it can also be due to the wrong selection of people for the benchmarking team.

Under Estimating the Time Required

Sometimes, the efforts needed for benchmarking is under estimated. The rule of thumb is that a team of four or five individuals will require one third of their time for five to six months to complete a benchmarking project[4]. Therefore, depending upon the complexity of the problem and the level of improvements proposed to be made, the efforts required will also vary. If efforts needed are under estimated then the project might fail in the middle.

Not Positioning the Benchmarking within a Larger Strategy

As discussed benchmarking on its own cannot yield results. It has to be combined with the TQM strategy to bring in the results such as reduced cycle time, reduced cost, reduced variation, which will all give visibility to the benchmarking project. No effort will gain support, if it is not aimed at finally improving profitability of the organization and well being of the employees and customers. Therefore, benchmarking should lead to the satisfaction of customers, employees and shareholders.

Lack of Involvement of Management

The benchmarking project will become successful only if the top management is involved in the benchmarking exercise. Unless the top management takes keen interest in finding out the progress made by the benchmarking team, it may not get due importance in the organization. Therefore, like other TQM concepts, benchmarking can only be successful with the support and active involvement of the top management.

SUMMARY

Business Process Benchmarking (BPB) is "a basis for establishing rational performance goals through the search for industry best practices that will lead to superior performance". This is the definition given by Robert C. Camp, who carried out pioneering work at Xerox Corporation, USA. This is so important that MBNQA refers 200 times to benchmarking in the award criteria. The triggers for carrying out benchmarking could arise due to a problem in the organization or process improvement initiative. There are three types of benchmarking as given below:

- Internal
- Competitive
- Functional

Benchmarking reveals current performance of the processes in the organization and enables improvement to higher levels. For the success of the benchmarking exercise, the following are important:

- What to benchmark?
- Whom to benchmark?
- How to benchmark?

PDCA can be used for actual implementation of benchmarking projects. There are various reasons why benchmarking projects fail. However, as benchmarking has the potential to improve processes, the pitfalls should be avoided for. Benchmarking can be used as a part of a larger goal such as Total Quality Management (TQM) for it to be more effective.

REVIEW QUESTIONS

I. Choose the most appropriate answer

1. Business Process Benchmarking aims at improving the performance of
   (a) Products (b) Processes
   (c) Services (d) None of the above
2. Triggers for process based benchmarking include
   (a) Excessive warranty costs (b) High employee attrition
   (c) High value of scrap and rework (d) All the above
3. Types of benchmarking include
   (a) Functional (b) Competitive
   (c) Internal (d) All the above
4. The goal of benchmarking is
   (a) Establishing a rational performance goal
   (b) Search of best industry practices
   (c) Just comparison of performance with best practices
   (d) All the above
5. Benchmarking requires determining
   (a) What? (b) How?
   (c) Whom? (d) All the above

II. True or False

1. Benchmarking is a TQM tool.
2. Benchmarking is only for comparison.
3. Process based benchmarking arises from the mission statement.
4. Problem based benchmarking arises from objectives of the organizations.
5. Benchmarking needs a partner.
6. Partner has to be outside the organization only.
7. All processes in an organization have to be benchmarked.
8. Alarming error rate can trigger an exercise.
9. Looking at another division of the organization can carry out competitive benchmarking.
10. Benchmarking can be carried out only by looking at the processes of another organization making similar product.

11. Adverse feedback cannot be a cause for benchmarking project
12. Benchmarking team may consist only of process owners.
13. Process measures need to be compared with the best during benchmarking
14. Benchmarking projects fail due to under estimating of time required.
15. PDCA can be used for carrying out benchmarking.

III. Explain briefly

1. Define benchmarking.
2. Explain the two triggers for benchmarking.
3. Explain the three types of benchmarking.
4. Describe the steps involved in what to benchmark.
5. Explain the process of benchmarking.
6. Give five reasons why benchmarking efforts fail.
7. Explain with an example, gap between perception and reality.
8. Benchmarking project description.
9. PDCA benchmarking process model.
10. Importance of process measures in benchmarking.
11. Explain how will you fit in benchmarking in a TQM implementation.

IV. Match the following

A	B
What to benchmark	Organization
Trigger	Measure
Partner	Process
How to benchmark	Problem
Performance	PDCA

References

(1) Camp, Robert C, *Business Process Benchmarking,* ASQC Quality Press, Wisconsin, 1995.
(2) Powers, Vicky J., *Ford Creates Clearing-house, Virtual Network, Web Site to Support its Benchmarking Efforts*, Benchmarking In Practice, APQC USA Issue 15, first Quarter 1999—With permission to reproduce from American Productivity & Quality Center.

Reference on the Web

(1) Ford Motor Company—American Productivity and Quality Center: http://old.apqc.org/free/case studies/Bench-15.pdf

Chapter 16

Quality Function Deployment (QFD)

The thing always happens that you really believe in;
and the belief in a thing makes it happen.

—Frank Lloyd Wright (1869–1959)

INTRODUCTION

The success of business is becoming more and more customer driven. It has become very important to meet the real and the latent needs of the customers to be successful in the market place. As organizations realize the importance of customer delight, they trust QFD as the only solution to plan products and services to meet the customers current and future, stated and unstated needs. It is increasingly being recognized as the right methodology for ensuring that "voice of the customer" is taken note of and efforts of the entire organization are directed towards it. QFD is a structured and systematic approach to ensure that the voice of the customer is heard during the design of the process, product or service. This will enable design, production and sale of products and services that meet the requirements of the customer. QFD is also a matrix diagram (one of the new seven management and planning tools discussed in Chapter 14). It is also a matrix of matrices, which will be evident shortly. Since this diagram resembles a house with a roof and is aimed at improving the quality of the products, processes and services, this diagram is popularly known as "house of quality". Construction of house of quality requires input from benchmarking as well.

The tool was developed in Japan in the late 1960s when they moved from reverse engineering to product development based on originality. The tool gave its birth when the Kobe Shipyards of Mitsubishi Heavy Industry working under the guidance of Dr Shigeru Mizuno and Dr Yasushi Furukawa, created and published a quality chart[1]. Many Japanese companies such as Mitsubishi, Toyota, etc. use QFD extensively. The first companies in the Toyota group to use QFD were Hino Motors under the guidance of Prof. Yoji Akao and Toyota Auto Body under the guidance of Mr Nobuo Takezawa (who learnt the QFD methods from Akao)[1]. Prof. Akao's work was published in the journal, *Quality Progress*. This led the American companies such as Ford, GM to use this technique since 1983. The term QFD is the translation of the Japanese term *hinshitsu tenkai*. QFD is an effective tool for eliciting customer's stated and implied requirements. Since QFD for a product will be developed through brainstorming, it brings together the talents of every employee. It is also an effective quality-planning tool. The tool enables conversion of customer need into specific quality plans. Thus, it is one of the essential TQM tools to be used in the industry.

WHAT IS QFD?

"Time was when a person could order a pair of shoes directly from the cobbler. By measuring the foot himself and personally handling all aspects of manufacturing, the cobbler could be sure that the customer was satisfied" is one of the quotes of Prof. Yoji Akao, one of the founders of QFD. QFD was developed to bring this personal interface to modern industry. In modern industry, many suppliers might not know who the end users are. QFD links the needs of the customer with design, engineering, production and service functions in the supplier organization as shown in Fig. 16.1.
American Supplier Institute's four phase approach

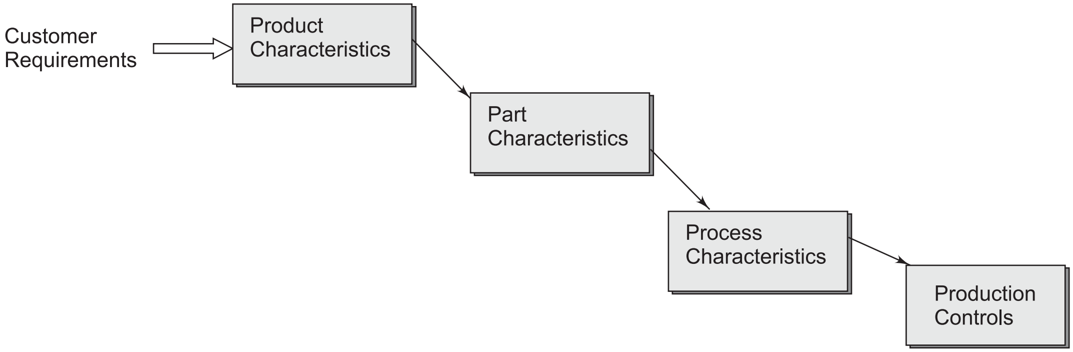


Figure 16.1 American Supplier Institute's Four-Phase Approach

Figure 16.1 illustrates American Supplier Institute's (ASI) four-phase approach, devised on the basis of QFD. The QFD team uses customer requirements to find product characteristics. This in turn is converted into component or part characteristics. Then a process is designed to make the part. The process characteristics decide the characteristics of manufacturing, which will deliver products meeting customer requirements. QFD thus improves the entire product life cycle. This technique ensures that the organization solicits both the stated and implied needs of the customer.

One of the achievements of Toyota was reduction in product development cost by 61%, a decrease in the development cycle time by one third and near elimination of rust related warranty problems, all due to QFD.
Yoji Akao's definition of QFD is:

> *"QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demands into design targets and major QA points to be used throughout the production phase".*

Benefits of QFD

- Reduces product development time upto 50%
- Design cycle time shortened by 30 to 50%
- Start up and engineering costs reduce by 20 to 60%
- Reduces time to market
- Focuses the organization on customer needs
- Useful for gathering customer requirements
- Design quality improves
- Improved performance of the products
- Improves communication within the organization about customer needs
- Helps in identification of conflicting requirements and resolving them
- Improves customer satisfaction and thereby increasing sales
- Reduces rework
- Reduced warranty and field service costs
- Reduction of quality costs
- Enables concurrent engineering
- Enables understanding of competitors and hence identification of competitive advantages of their products and also their weaknesses
- Since most of the requirements are clearly understood, the requirement changes are few. A boon to the software industry.

The advantages should motivate every organization to invest employee time to get such high returns.

QFD TEAM

QFD team of six to eight persons has to be constituted for every project. It should be a cross-functional team consisting of representatives of the following functions:

- Marketing / Sales
- Design
- Production
- QA
- Testing
- Purchase
- Vendors, etc.

The team should have a senior employee as moderator or facilitator. The team members should be able to spend the required time for successful completion of the project. They should meet for about two hours in each sitting. The QFD task is carried out for design of a new product as well as improvement of an existing product. By and large, the Japanese use QFD for improving existing products whereas the Americans use it for design of new products.

The Voice of the Customer

The voice of the customers represents the requirements of the customers. Many a times the voice does not reach the appropriate persons in the supplier organization. Even if it reaches, no action is taken. The employees in the supplier organizations modify the voice of the customers to be in tune with their thought about the product or their own impressions about the product. If the customer voice is same as the receiving employee's ideas, then the employee feels happy and takes actions to fulfill the customer's requirements. If not, the voice may be suppressed. QFD is a technique to record every requirement expressed by the customer and take a conscious decision about the voice of the customers.

WHATs in QFD is the list of what the customer wants in the product or service. Many times, customers instead of bringing out their requirements, may tend to suggest a possible solution. It is more so in the area of software development. They would say that they want the implementation of the software in say Oracle platform. This is not a requirement, but a solution. We have to take care to see that the requirements of the customer are captured and not their solution to the implementation.

Requirements elicitation The starting point in QFD is finding the customer requirements of a product or service from a number of formal and informal channels. There are a number of sources of information for finding out customer requirements as given below:

- Market survey from customers
- Information from sales team
- Information from service team
- Customer complaints
- Customer feedback
- Testing of products in labs
- Comparative analysis of competitor's products through benchmarking
- Advertisement in newspapers and journals of competitors
- Customer direct feedback
- Product related exhibitions
- Uninformed visit to a customer site
- Beta testing reports

Data analysis and organization The information received should be checked for authenticity. Conflicting requirements should be analyzed and resolved.

Data organization can be best served by the affinity diagram and inter-relationship diagram discussed in Chapter 14. QFD team should carry out brainstorm and by using the above two tools should come out with specific customer requirements for the product or service.

HOUSE OF QUALITY

The primary tool for QFD is the house of quality. It is also known as product planning matrix or matrix diagram.

House of quality is an excellent quality-planning tool. It consists of six major building blocks as illustrated in Fig. 16.2.

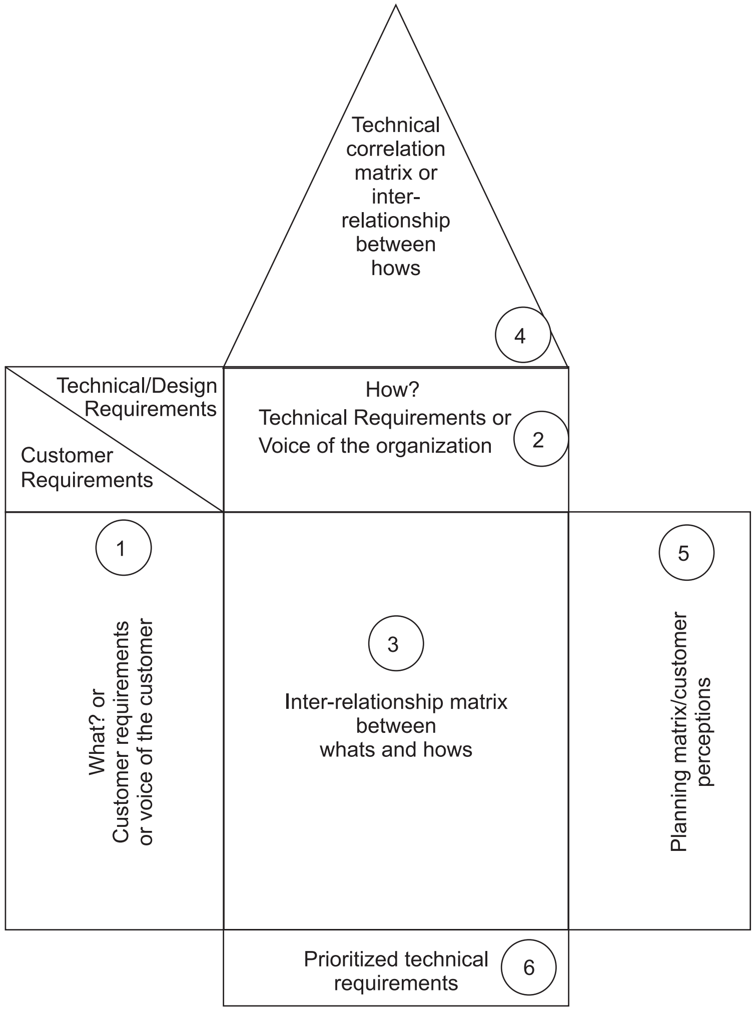


Figure 16.2 Simplified House of Quality

A cross-functional team, called a QFD team translates a set of customer requirements into an appropriate number of prioritized engineering targets to be met by a product design and utilizes it. The six major blocks of house of quality are:

1. Customer requirements (WHATs)—a structured list of customer requirements
2. Technical requirements (HOWs)—a structured set of relevant and measurable product or service characteristics
3. Inter-relationship matrix—illustrates the QFD teams perceptions of inter-relationships between customer requirements and technical requirements. The degree of relationship is marked using symbols.
4. Technical correlation (roof) matrix — used to identify where technical requirements support or impede each other in the product or service design.

5. Planning matrix—illustrates relative importance of customer requirements, customer perception of company and competitor performance in meeting customer requirements. It also contains prioritized customer requirements.
6. Prioritized technical requirements

Let us try to understand the various blocks of house of quality in detail.

1. The Voice of the Customer—Customer Requirements—WHATs?

We discussed how to capture the voice of the customer and use affinity diagram followed by inter-relationship diagrams to group them, structure them and write down specific requirements. The lists of requirements are to be entered on the left wall of the house—marked 1 Fig. 16.2.

Let us take an example of a clinical laboratory to illustrate QFD. The steps involved in identifying customer requirements are:

(1) Identify customers
- Users of the lab
- Physicians who prescribe tests
- Hospitals which receive reports
- Marketing employees of the lab
- Customer service persons

(2) Determine customer requirements/constraints. Some voices of customers in this case were:
- I want report quickly
- Cost is high
- They take too much time.

(3) Prioritize customer requirements

Use prioritization matrix tool (one of the seven management tools) and arrive at the top requirements

(4) Put them in house of quality

The requirements of customers after analysis were found to be as given below:

Table 16.1: Customer Requirements of a Clinical Laboratory

Sl.No.	*Requirements*	*Rank*
1.	Accurate reports	1
2.	Friendly technicians	5
3.	Friendly customer feedback	6
4.	Quick turn around	2
5.	No delay at counter	4
6.	Reasonable cost	3

The requirement could be ranked as shown in Table 16.1. The ranking is based on customer's choice and what is important to customers. Alternatively, the list of customer requirements can be divided into the following:

- Primary
- Secondary
- Tertiary

The above illustrates the hierarchy of requirements. The primary requirements will be generic in nature such as performance, aesthetics, quality of front desk, general, etc. Each one of the primary requirements will contain one or more secondary requirements, which will be specific. Each secondary requirement can be further expanded into one or more tertiary level requirements.

· Two levels of requirements are shown in Fig. 16.3 as an example of a clinical laboratory.

	Primary	Secondary
Customer requirements (WHATs)	Process Performance	Accurate Reports
		Quick Turn Around
		Reasonable Cost
		No delay at counter
	Front Desk	Friendly Technician
		Friendly
		Pleasant
		Prompt reply over phone

Figure 16.3 Two Level Customer Requirements

Whichever method is suitable can be adopted for depicting the WHATs.

2. The Voice of the Organization—Technical Requirements—HOWs?

QFD may be applied to designing a new product or improving the design of the existing product. After the WHATs have been finalized, the QFD team has to identify how these requirements will be met. They have to identify one or more technical requirements that will facilitate satisfying one or more customer requirements identified as above. Here again, the technical requirements could be organized as primary, secondary or tertiary. A tree diagram will help in this case. Let us try to identify the technical requirements that would enable meeting customer requirements in the case of the example of the clinical lab. Let us also assume that our QFD team is working on improving the existing processes of the services of the clinical laboratory. The technical requirements are given in Table 16.2:

Table 16.2 Technical Requirements of the Clinical Laboratory

- Good training
- Good equipment maintenance
- Adequate resources
- Good ambience (temperature, aesthetics, etc.)

The QFD team identifies the measurable characteristics of the product or process, which will help in meeting the customer requirements. Since our example is a service, we identified process parameters. The technical requirements are to be entered in the ceiling marked 2 in Fig. 16.2.

HOWs are the list of what the organization can measure and control in order to ensure that it is able to satisfy the customers requirements. These entries are typically parameters for which a method of measurement and a measurable target can be established. The HOWs are also quality characteristics or design requirements.

3. Inter-Relationship Matrix between WHATs and HOWs

The voice of the customers is arranged in rows and the voice of the organization in columns. It is time now for QFD team to capture the relationships between WHATs and HOWs, i.e. customer requirements and measurable process characteristics or technical requirements. Process or product characteristics which will satisfy each of the customer requirements are to be entered in the inter-relationship matrix. There may be different levels of relationships between each WHAT and HOW. This may be depicted using different symbols as shown in Fig. 16.4.

Degree of relationships between WHATs and HOWs

◉	Strong relationship
○	Medium relationship
△	Weak relationship
Empty	No relationship

Figure 16.4 Degree of Relationships between WHATs and HOWs

The inter-relationship matrix is to be entered in the box 3 in Fig. 16.2. Therefore, in this phase, the QFD team captures the degree of relationships between WHATs and HOWs.

The inter-relationship matrix for our example is shown in Fig. 16.5:

Sl.No.		Good Training	Good equipment maintenance	Adequate resources	Good ambience
1	Accurate reports	◉	○		
2	Quick turn around	○	◉	△	
3	Reasonable cost				
4	No delay at counter			◉	
5	Friendly technicians	◉		△	
6	Friendly customer service	◉		△	

Figure 16.5 Version1: Inter-relationship Matrix for Clinical Laboratory

Filling the matrix involves discussions and consensus building within the QFD team and can be very time consuming. This can be achieved at optimal time by:

- Concentrating on key relationships
- Minimizing the number of requirements

WHATs vs. HOWs is a relationship matrix, which correlates what the customer wants from a product or service and how the company can meet those requirements. It is the core matrix of QFD. Here, the relationship between WHATs and HOWs are indicated through symbols. Usually a four-level relationship such as strong, medium, weak and none are indicated at the cross-sections of each WHATs and HOWs.

A strong relationship indicates that the HOW is an excellent measure of the corresponding WHAT. Similarly a weak relationship indicates that the HOW gives some indication of whether the WHAT will be achieved.

Analysis of Inter-relationship Matrix

(1) Empty row Let us look at Fig. 16.5. The row number three is empty meaning that none of the technical requirements satisfies this requirement. This means that this requirement cannot be satisfied with the identified measures. We need to brainstorm again and find additional technical requirements to meet this requirement of the customer. Reasonable cost can be achieved through the following:

- Reduced wastes
- Improved quality

These are to be added to the technical requirements.

(2) Empty column We also find an empty column (column four) namely good ambience. The technical requirements should relate product or service requirements. This is only a requirement of the user and hence not very important for house of quality. Hence this column can be deleted since such requirements make the house of quality cumbersome.

(3) Row with no strong relationship It is difficult to meet the customer requirement without at least one strong relationship in every row. Our matrix satisfies this requirement.

(4) Row with too many relationships If a row contains too many relationships it could be a requirement pertaining to reliability, safety or cost. Such items should be removed from the house of quality and should be dealt with separately. In our matrix, this problem does not arise.

(5) Column with too many relationships If it is so the technical requirements may be a reliability, safety or cost item. This may be removed from the house of quality and dealt with separately. We don't have such a column.

(6) Too many weak relationships The technical requirements should relate strongly with at least one customer requirement. Otherwise, we have to develop a clearer technical requirement. Our example matrix does not violate this rule. Now, let us redraw the inter-relationship matrix for our example.

The inter-relationship matrix for our example is shown in Fig. 16.6:

Sl. No.	Customer Requirements	Technical Requirements				
		Training	Equipment maintenance	Resources	Reduced wastes	Improved quality
1	Accurate reports	⊙	○			⊙
2	Quick turn around		⊙	△	△	
3	Reasonable cost				⊙	○
4	No delay at counter			⊙		
5	Friendly technicians	⊙		△		
6	Friendly customer service	⊙		△		

Figure 16.6 Version 2: Inter-relationship Matrix for a Clinical Lab

4. Technical Correlation Matrix—Inter-relationship between HOWs

Each technical requirement (TR) should be compared with every other technical requirement. Improving one requirement may lead to the following:

- Improvement in another
- Deterioration of another

Hence it is important to study the inter-relationships between the HOWs. The relationships between the HOWs can be further qualified as given below:

- Strong positive (++)
- Positive (+)
- Strong negative(– –)
- Negative (–)

We can use symbols as given within bracket to identify the relationship between the technical requirements. These relationships are to be given in the roof marked 4 in the diagram. Let us now construct the roof for our example of house of quality.

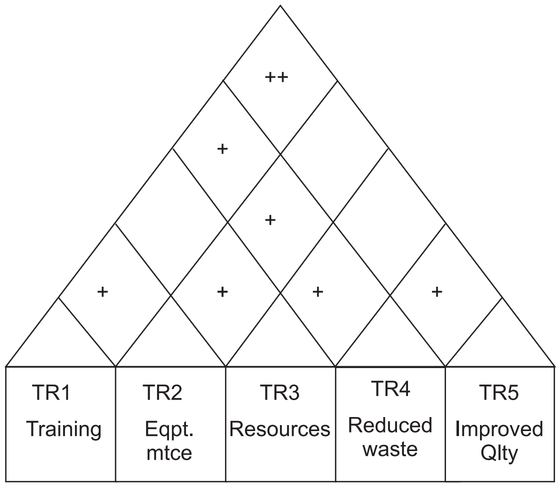


Figure 16.7 Relationships between HOWs

We start from TR1. We have to see the effect of improving TR1 and other TRs. In our case, improving TR1 improves positively TR2 and TR4 and strongly positively TR5. This is indicated accordingly. Then, we compare TR2 with TR3, TR4 and TR5 and finally TR4 with TR5. TR2 has positive relationship with TR3 and TR4. Similarly, TR3 and TR4 and TR4 and TR5 have positive relationships. We place the appropriate symbols in the square connecting the two TRs when we traverse from one TR to the other TR. The roof is constructed in this manner. The conflicting TRs are to be noted. We did not have any in our example. But, if there are any, they call for trade-off in design. This has to be discussed not only by the QFD team but also, at the highest level in the organization and resolved. QFD team may not be able to handle this problem.

The roof helps us to capture the tradeoffs between the different design requirements. If two design requirements help each other to move in their desired direction of improvement, then they are rated as being positively related. If on the contrary, if improving one HOW has a negative impact on another HOW, then they are negatively related. The quantum of aiding determines whether it is strongly positive or positive. Similarly, the quantum of adverse effect can also be determined and the strongly negative or negative relationship can be captured.

5. Planning Matrix—Customer Competitive Assessment and Prioritized Customer Requirements

This matrix is entered on the right side wall marked 5 in Fig. 16.2.

Competitive Benchmarking

In this step, we have to measure the current performance of our own products against each requirement. We have to also benchmark competitors products and services of the same kind. The competitive benchmarking involves the following steps:

- Identify competitors
- Carry out reverse engineering of competitors' products
- Finalize common set of customer requirements through benchmarking
- Measure performance of competitors' products or services against the same customer requirements

- Rate competitors' products against the same

The performance measurement of the product or service should be based on customers' perception. The performance has to be ranked on a scale of one to five, 1 being the worst or not at all satisfied and 5 being excellent meaning that the customer is delighted. The performance against the various requirements can also be graphically illustrated. This has been plotted for the clinical lab.

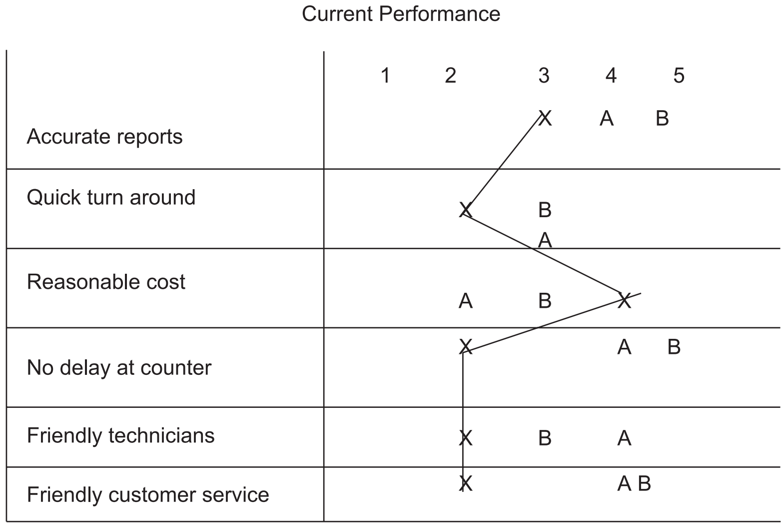


Figure 16.8 Competitive Benchmarking for Clinical Labs

Legend

5 – best

X – our performance

A – Performance of services of Competitor A

B – Performance of services of Competitor B

The above diagram clearly brings out the strengths and weakness of the organization with regard to its competitors. The organization's performance is shown in the form of a line diagram connecting X_s corresponding to their performance levels. The performance levels of competitors A and B are marked with A_s and B_s respectively.

Prioritized Customer Requirements

The competitive benchmarking is a simple comparison of performances against each requirement of the customer. We can now arrive at a more detailed assessment of prioritized customer requirements for each of the parameters quantitatively.

(a) Importance to customer We ordered the requirements from one to six depending upon the priority of the customers. For this exercise, we have to give marks to each requirement depending on its importance to customers. The highest marks or rating is five and the lowest is one. This is relative importance of the requirements of the product or service from the customer perspective. We can choose a wider scale say one to ten, if required. More than one requirement can get the same rating. The QFD team assigns ratings to the requirements. This has to be entered in the column degree of importance to customer. Figure 16. 8 is further extended to contain additional data pertaining to prioritized customer requirements. It is shown in Fig. 16.9. Look at the column for "degree of importance to customers". Accuracy of reports is the most important and gets a rating of five, cost is of medium important and hence gets a rating of three, friendly customer service and friendly technician are least important and hence both get a rating of one.

The customer requirement namely WHATs are prioritized based on the factors mentioned:

- Relative importance of each WHAT to the customers
- Current and future status of the product or service in comparison with the competitors
- Importance of each WHAT to the sales strategy

		Our service	Service of A	Services of B	Degree of importance to customer	Target value	Scale up factor	Sales point	Absolute weight
Accurate reports		3	4	5	5	5	1.7	2	17
Quick turn around		2	3	3	4	3	1.5	2	12
Reasonable Cost		4	2	3	3	4	1	1.5	4.5
No Delay at counter		2	4	5	2	4	2	1	4
Friendly technician		2	4	3	1	3	1.5	1	1.5
Friendly customer service		2	4	4	1	3	1.5	1	1.5

Figure 16.9 Prioritized Customer Requirements

(b) Target value for customer requirements We can also assign target values for customer requirements taking into account the following:

- Current performance
- Importance to customer
- Competitors performance

For instance, we propose to improve accuracy of reports from three to five, but retain the cost at the same level at four, etc. Look at the corresponding column in Fig. 16.9 for target values.

(c) Scale up factor It is the ratio of target value to the current performance rating of the product or service against each customer requirements. We have to scale up twice with regard to "no delay at counter" requirement. Look at the corresponding column in Fig. 16.9.

(d) Sales point The sale point is the value from 1.0 to 2.0. This indicates how much meeting each customer requirements can be used for marketing for increased sale of the product or service. The index indicates the level of attraction of each customer requirement for selling the product or service. The highest sale points are in quick turn around and accurate reports, which get a value of 2. This is indicated in the sale point column of Fig. 16.9.

(e) Absolute weight The absolute weight of each customer perceived requirements is a product of the three quantities as given below:

Absolute weight = Importance to customer × scale up factor × sales point.
The complete planning matrix for our example of a clinical lab including absolute weight is given in Fig. 16.9.
Figure 16.9 finally leads to the prioritized customer requirements. The most important requirements are:

1. Accurate reports
2. Quick turn around

The next important requirements are:

1. Reasonable cost
2. No delay at counter

Thus, we have now finalized the prioritized customer requirements. Now we will arrive at the prioritized technical requirements.

6. Prioritized Technical Requirements

(a) Technical Competitive Benchmarking Now, measure the performance of our product or services and that of the same competitors and plot them at region 6. This is below the inter-relationship matrix. Again 5 denotes the best performance and one 1 worst. The technical competitive assessment for the clinical laboratory is given below:

X : Ours
A : Competitor A
B : Competitor B

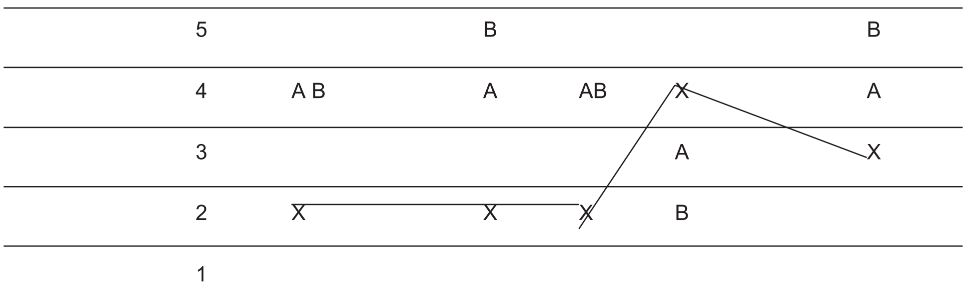


Figure 16.10 Technical Competitive Assessment for a Clinical Laboratory

Thus, benchmarking is used extensively in QFD. In the first place, we benchmarked the performance of our product against competitors' products in terms of customers, stated and implied needs. Now we have benchmarked our product in terms of technical requirements. These two are different. The first one is in the language of the customer and the second one is in our language of technical specifications.

Both the competitive assessments will have some relationship. If customer requirements and technical requirements are strongly related, there will also be a relationship between their competitive assessments. For instance, the clinical lab is known for reasonable costs. The customer requirements of reasonable costs are strongly related to reduced wastes. Thus, in both the technical and competitive assessment the lab is better than its competitors. If the correlation is missing, then something is wrong and needs analysis. This may be due to a wrong judgement somewhere. This could be used as a checklist.

(b) Absolute weight for technical requirements We look at the inter-relationship matrix. We assign the following marks for the level of relationship.

◉ Strong = 9

○ Medium = 3

△ Small = 1

Now, we look at the column corresponding to the degree of importance to customer in the planning matrix and then multiply the corresponding degree of importance to customer with degree of relationship index as above. We start at the first row on the top and traverse from top to bottom. We multiply only when there is a relation. If there is more than one relationship in the column, we multiply the marks corresponding to the degree of importance to customer with marks for relationship index and keep adding till all the rows are covered for the particular technical requirement. The total importance of weighting is written below the matrix against absolute weight for the column. It is illustrated in Fig. 16.11:

Customer Requirements	Training	Equipment Maintenance	Adequate Resources	Reduced Wastes	Improved Quality		
Accurate reports	◉	○			◉	5	17
Quick turn around		◉	△	△		4	12
Reasonable cost				◉	○	3	4.5
No delay at counter			◉			2	4
Friendly technician	◉		△			1	1.5
Friendly customer service	◉		△			1	1.5
Absolute weight	63	51	24	28	48		
Relative weight	180	159	51	52.5	166.5		
Competitor A	4	4	4	3	4		
Competitor B	4	5	4	3	5		
Our performance	2	2	2	4	3		
Target	5	4	3	4	4		
						Degree of importance to the customer	Absolute weight

Figure 16.11 Prioritized Technical Requirements

The detailed calculations for each column are given below:
Calculation of absolute weight

Training	$= 5 \times 9 + 1 \times 9 + 1 \times 9$	$= 63$
Equipment Maintenance	$= 5 \times 3 + 4$ ´ 9	$= 51$
Adequate Resources	$= 4 \times 1 + 2 \times 9 + 1 \times 1 + 1 \times 1$	$= 24$
Reduced Waste	$= 4 \times 1 + 3 \times 9$	$= 31$
Improved Quality	$= 5 \times 9 + 3 \times 3$	$= 54$

(c) Relative weight The weightage for each technical requirement can be obtained by using the following steps:

Multiply the marks for relationship index if any, with the corresponding absolute weight for the particular customer requirement given in Fig. 16.9, which are reproduced in Fig. 16.11 for convenience. Here, instead of importance to customer, we multiply the relationship index with the absolute weight. Each column starts from the top row and traverse below as in the previous case of finding absolute weight. If there is a relationship, multiply the index of the relationship with the corresponding absolute weight. It is shown below for each column:

Calculation of relative weight

Training	$= 9 \times 17 + 9 \times 1.5 + 9 \times 1.5$	$= 180$
Equipment Maintenance	$= 3 \times 17 + 9 \times 12$	$= 159$
Adequate Resources	$= 1 \times 12 + 9 \times 4 + 1 \times 1.5 + 1 \times 1.5$	$= 51$
Reduced Waste	$= 1 \times 12 + 9 \times 4.5$	$= 52.5$
Improved Quality	$= 9 \times 17 + 3 \times 45$	$= 166.5$

The values are entered in the row corresponding to the relative weight.

The relative weight takes into consideration the sales point and scale up factor. Hence, it may be more relevant than the corresponding absolute weight of the technical requirements from the customer perspective.

The above brings out the relative importance. A Pareto chart can be plotted to understand a few vital areas for improvements. To satisfy the customers the clinical laboratory of our example has to attend to the following on priority:

- Training of employees
- Quality of service
- Equipment maintenance

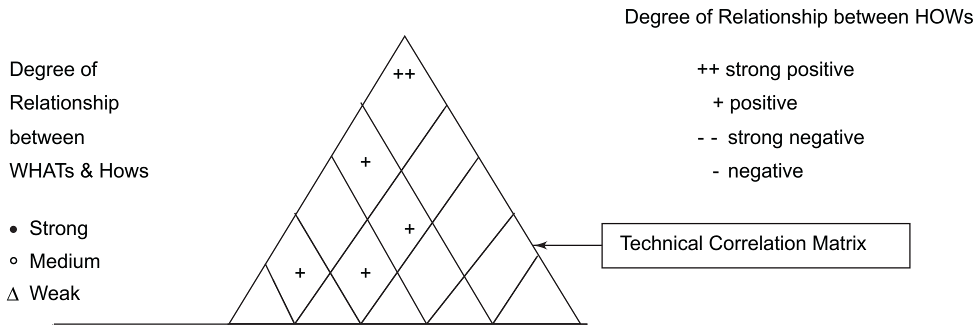
Thus, the house of quality brings out the relative importance of technical requirements to satisfy the customers.

(d) Target value for technical requirements The target value is for the technical requirements. The QFD team considering all the above decides where they want the company to be. The current levels of performance and target values of technical requirements are shown in Fig. 16.11.

The technical requirements namely HOWs should be measurable parameters. If they are appropriately controlled they will guarantee that one or more WHATs will be satisfied. This also requires defining the HOWs clearly. The QFD team could develop the target values for HOWs by using brainstorming and use of tools such as an affinity diagram.

CONSTRUCT HOUSE OF QUALITY

Now, all the six parts of the house of quality can be integrated. It is shown in Fig. 16.12. However, in actual practice, the diagram can be developed on a big sheet of paper. Each part is finalized and added to the house gradually.



Customer requirements /(WHATs) — Technical Requirements HOWs — Planning Matrix — Prioritized customer requirements

Customer Requirements	Training	Equipment Maintenance	Adequate Resources	Reduced Wastes	Improved Quality	Our service	Service of A	Service of B	Degree of importance to customer	Target value	Scale up factor	Sales Point	Absolute weight
Accurate reports	•	∘			•	3	4	5	5	5	1.7	2	17
Quick turn around		•	Δ	Δ		2	3	3	4	3	1.5	2	12
Reasonable cost				•	∘	4	2	3	3	4	1	1.5	4.5
No delay at counter			•			2	4	5	2	4	2	1	4
Friendly technicians	•		Δ			2	4	3	1	3	1.5	1	1.5
Friendly customer service	•		Δ			2	4	4	1	3	1.5	1	1.5

Inter-relationship Matrix between WHATs & HOWs

	Training	Equipment Maintenance	Adequate Resources	Reduced Wastes	Improved Quality
Competitor A	4	4	4	3	4
Competitor B	4	5	4	3	5
Our Performance	2	2	2	4	3
Target	5	4	3	4	4
Absolute weight	63	51	24	28	48
Relative weight	180	159	51	52.5	166.5

Prioritized technical requirements

Figure 16.12 House of Quality for Clinical Laboratory

Notice that benchmarking is essential to compare the organization's current level of performance with competitors in terms of customer requirements as well as technical requirements. QFD results in arriving at prioritization of technical requirements in an objective manner and as a consensus in the QFD team.

CASE STUDY 1

House of Quality for Electronic Power Supply

During a workshop for an organization, manufacturing electronic power supplies, a house of quality for one of their products was constructed and is shown in Fig. 16.13.

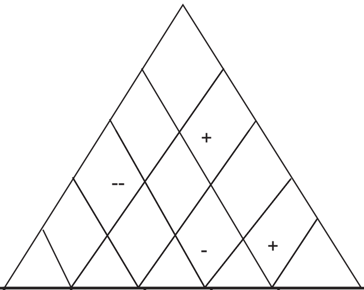
Wednesday, March 17, 2004

Degree of Relationship between HOWs

++ strong positive
+ positive
- strong negative
- negative

Degree of Relationship between WHATs & HOWs

- ● strong
- ○ medium
- Δ weak



Customer requirements (WHATs) / Technical Requirements –HOWs	T/0 Ranges	Charger Quality	Look & feel	Serviceability	Safety		Present	Comp. A	Comp. B	Future	Scale up Factor	Sales Point	Absolute Weight	Importance Rating
Reliable & Safe		○		Δ	●		7	5	7	7	1	2	20	10
Reasonable Cost	○	●	○	○	●		4	9	3	3	1.5	2	27	9
Better Quality of Output	●	Δ			○		6	7	8	8	1.5	1	12	8
Better Service Quality				●			5	10	6	6	2	2	24	6
Rugged					●		5	6	6	6	1	2	15	5
Ease of Use			○	○	Δ		7	7	5	5	1	1	3	3

Prioritized customer requirements

	T/0 Ranges	Charger Quality	Look & feel	Serviceability	Safety
Competitor A	9	8	6	5	7
Competitor B	10	4	8	8	6
Our Performance	9	5	6	7	9
Target	10	8	9	7	9
Absolute weight	99	119	36	100	243
Relative weight	189	315	90	327	597

Prioritized technical Requirements

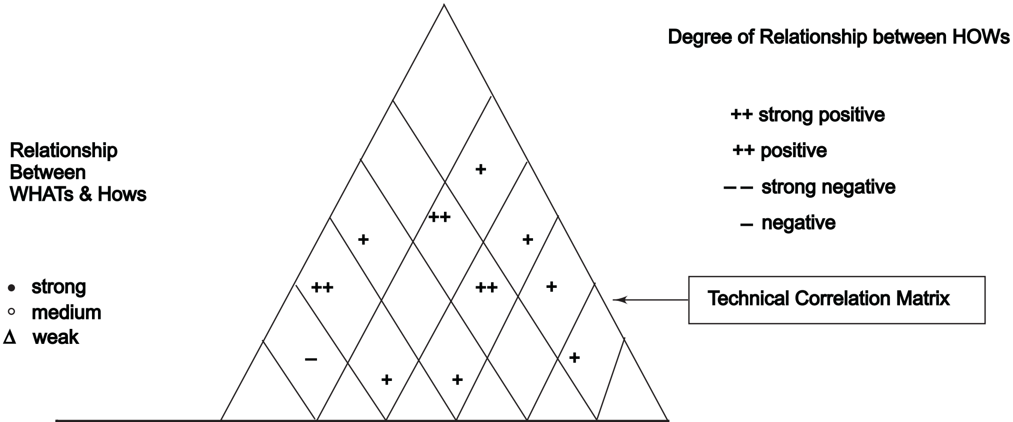
Figure 16.13 House of Quality for Electronic Power Supply

The participants of the workshop included designers of the product as well as members from other sections including 6 sigma black belts. The participants felt that the final numbers in the house of quality reflect the correct position with regard to their product and gives the right direction for improvement.

CASE STUDY 2

House of Quality for EDTC, Chennai

Senior executives under the leadership of the author functioned as a team to build house of quality for ETDC, Chennai. The completed house of quality for ETDC is given below:



Customer requirements (WHATs)

Planning Matrix

Technical Requirements - HOWs	Promptness of Service	Effective Contract	Customer Satisfaction	Maintenance of Equipment	Error Free Report	Adequate Resoures	Service A	Service B	Our Performance	Imp. to customer	Target value	Scale up factor	Sales point	Absolute weight
Quick turn around	•	○	○	○		°	3	4	4	10	5	1.25	2	25
Competitive cost		Δ	○	Δ			5	5	3	8	3	1	1.5	12
Accreditation				Δ		○	5	5	5	8	5	1	1.5	12
Quality of reports	○	○	○		•	○	3	4	4	7	5	1.2 5	1.8	15.75
Quick response	○		○			○	2	3	3	5	4	1.3	1.5	9.75
One stop solution						•	3	5	3	3	3	1	1.5	4.5

Prioritized customer requirements

Inter -relationship Matrix between WHATs & HOWs

	Promptness of Service	Effective Contract	Customer Satisfaction	Maintenance of Equipment	Error Free Report	Adequate Resoures
Competitor A	2	2	3	3	2	2
Competitor B	3	3	4	4	3	5
Our Performance	4	3	3	4	3	3
Target	5	4	4	4	4	4
Absolute weight	156	59	90	46	63	117
Relative weight	360	146	187.5	99	142	228

Prioritized technical Requirements

Figure 16.14 House of Quality of ETDC, Chennai

The house of quality gave the organization, the prioritized technical requirements, which is deducible from relative weight. The topmost requirement is promptness of service followed by adequate resources. The team through a consensus decision-making process arrived at this. Since the team finalized it, ownership of the decision by the team will be beyond doubt. Thus, QFD aids an organization to arrive at priorities to improve the processes.

ITERATIVE QFD

The process of QFD can be further extended. In the first iteration, we found WHATs and HOWs. The HOWs are the technical requirements. In the second iteration of QFD, the HOWs can be treated as WHATs, i.e. customer requirements and detailed technical requirements can be found. These are the new HOWs, which will be very close to the transfer for actual implementation. This process is illustrated below:

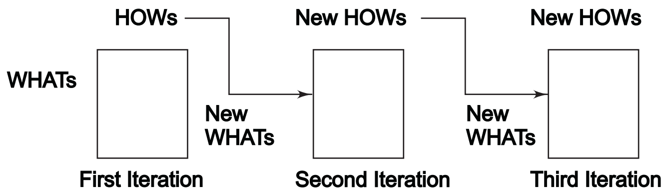


Figure 16.15 Iterative QFD

Thus, QFD can be used to identify the activities or tasks required to fulfill the customer's requirements, the voice of the customer.

ORGANIZATIONS USING QFD

The list of organizations, which use QFD methodology, will be endless. But some of the well-known names that presented papers on using QFD are:

3M
AT&T
Boeing
EDS
Ford
General Motors
HP
IBM
Hughes Aircraft
Jet Propulsion Laboratory
Kodak
Lockheed Martin
Motorola
NASA
Nokia
Raytheon
Texas Instruments

Toshiba
Visteon
Xerox and many other *Fortune 500* companies in USA.

QFD has been used in all the sectors of industry. Some of them are:

- Aerospace
- Manufacturing
- Software
- Telecom
- IT
- Chemical and Pharmaceutical
- Defence
- Government
- R&D
- Transport
- Space agencies, etc.

TIPS FOR SUCCESS OF QFD

QFD is also called another Quality Management System (QMS). It is so important that there is a dedicated institute for QFD (refer "references on the web" at the end of the chapter for the URL of the institute). Some tips for success of QFD are:

- A consultant is needed to guide through at least the first few projects
- The activity should be a formal activity and every member should take part, fully prepared
- The meetings should be planned at regular intervals for shorter duration so as to get the best out of this exercise through maintaining focus
- Elicitation and recording customer requirements is key to successes. In the area of software development the Unified Modeling Language (UML) diagrams are used to capture the requirements. Similar techniques should be adopted to gather all the stated and unstated requirements of the customer.
- The new seven management tools should be applied at various stages to get better results.
- Belief that "we don't know all the requirement of the customers" will lead to success.

SUMMARY

QFD is different from other quality initiatives in the following manner:

(1) It brings out both the spoken and unspoken customer requirements.
(2) It focuses on positive quality aspects such as usability, reasonable cost, etc.
(3) It enables prioritization of customer requirements as well as technical requirements of the products and services.

The other quality initiatives address negative quality aspects such as reducing defects, cycle time, etc.

QFD is a structured approach for defining both the spoken and unspoken needs of customers and translating them into specific product and process improvements. This is also an analytical tool and brings out relative importance of customer requirements and thereby specific product / process improvements clearly and unambiguously. This tool was also developed in Japan, but is now used all over the world. QFD results in dramatic improvements such as reduction of development time by 50 per cent, reduced overall costs, time to market and above all large improvements in customer satisfaction. It also facilitates teamwork and involvement of people, which are TQM principles.

House of quality is the primary tool of QFD. The house of quality for a product or process consists of six constituents of the house as given below:

(1) WHAT – the requirements of customers.
(2) HOW – the technical requirements for the product or process to meet the above.
(3) Inter-relationship matrix, bringing out the degree of relationship between each customer requirements and the technical requirements.
(4) Technical correlation matrix between the HOWs as a roof of house of quality.
(5) Prioritized customer requirements including the comparison of the product or process with that of the competitors using benchmarking, target values for the new design for each customer requirements, sales point of each requirements and absolute weight which gives the relative importance of each customer requirements
(6) Prioritized technical requirements consist of:
   - Current performance against each technical parameter vis-à-vis to its competitors arrived through competitive benchmarking
   - Target value for each parameter in the new design
   - Absolute weight and relative weight for each parameter by linking with importance to the customer

In order to arrive at specific activities to be undertaken to meet customer needs, the QFD process can be repeated with HOWs of the first iteration as WHATs in the second iteration. The specific detailed technical requirements can now be identified and stated as new HOWs. In this manner, the QFD technique can be exploited as product and process planning matrix for success of the organization.

QFD is exploited by many *Fortune 500* companies due to its benefits and for building the process and products for the future. Competitive benchmarking is essential to arrive at the targets for the performance of the product against each customer requirement. Similarly, to arrive at targets for the technical requirements of the product, benchmarking technique should be used. An organization will be successful only if the new product design target is derived from the house of quality. Benchmarking plays an important role for successful QFD that will lead to the products that will be successful in the market.

REVIEW QUESTIONS

I. Choose the most appropriate answer

1. QFD team may consist of
   (a) Marketing persons (b) Designer
   (c) QA (d) All the above
2. Benefits of QFD includes
   (a) Consensus building and better coordination (b) Increase company's efficiency
   (c) Cutting costs (d) All the above

3. The voice of the customer includes
   (a) Customer's unspoken requirements (b) Technical requirements
   (c) Prioritized technical requirements (d) None of the above
4. WHATs include
   (a) Stated customer requirements (b) Unstated customer requirements
   (c) Important requirements to customers (d) All the above
5. The voice of the organization includes
   (a) Technical requirements (b) HOWs
   (c) Product performance requirements (d) All the above
   (e) None of the above
6. Degree of relationship between WHATs and HOWs is contained in
   (a) Roof (b) Bottom
   (c) Inter-relationship diagram (d) None of the above
7. Father of QFD is
   (a) Deming (b) Taguchi
   (c) Yoji Akao (d) None of the above
8. Technical correlation matrix is
   (a) Relationship between HOWs (b) Relationship between WHATs
   (c) Prioritized technical requirements (d) None of the above

II. True or False

(1) QFD can be used for process improvement
(2) QFD is a graphical tool
(3) House of quality is a primary tool in QFD
(4) Voice of customer can be captured better in QFD than other tools
(5) Seven management tools will be useful for QFD
(6) Targets are to be computed by QFD team both for customer requirements and technical requirements
(7) Targets can be graphically expressed
(8) Absolute weight for customer requirements depends on the importance of each customer requirements
(9) Prioritized technical requirements takes into account the absolute weight corresponding to customer requirements
(10) Absolute weight and relative weight will be equal for each technical requirements

III Practice Problems

1. For an institution, who wants to apply QFD for design of a course, carry out the following.
   (a) Find out thorough discussions with your friends of the WHATs.
   (b) Identify the technical requirements that will satisfy the customer requirements.
   (c) Develop a relationship matrix between WHATs and HOWs.
   (d) Develop inter-relationship between HOWs.
   (e) By choosing the importance of each customer requirement and assuming that this course is to be sold to a software organization and assuming that there are two better competitors for the course, develop customer competitive assessment, target value, scale up factor, sales point and absolute weight for the customer requirements.

(f) For the above, develop prioritized technical requirements consisting of the following:
  (i) Target value
  (ii) Absolute and relative weight
(g) Using all the above, develop a house of quality

2. Repeat the above problem in respect of a restaurant.

IV. Explain briefly

(1) The voice of the customer
(2) Benefits of QFD
(3) Requirements elicitation
(4) WHATs, HOWs, relationship matrix
(5) Technical correlation matrix
(6) Prioritized customer requirements
(7) Prioritized technical requirements
(8) QFD and benchmarking
(9) Four Phase approach of American Supplier Institute
(Hint: Get more details from the web.)

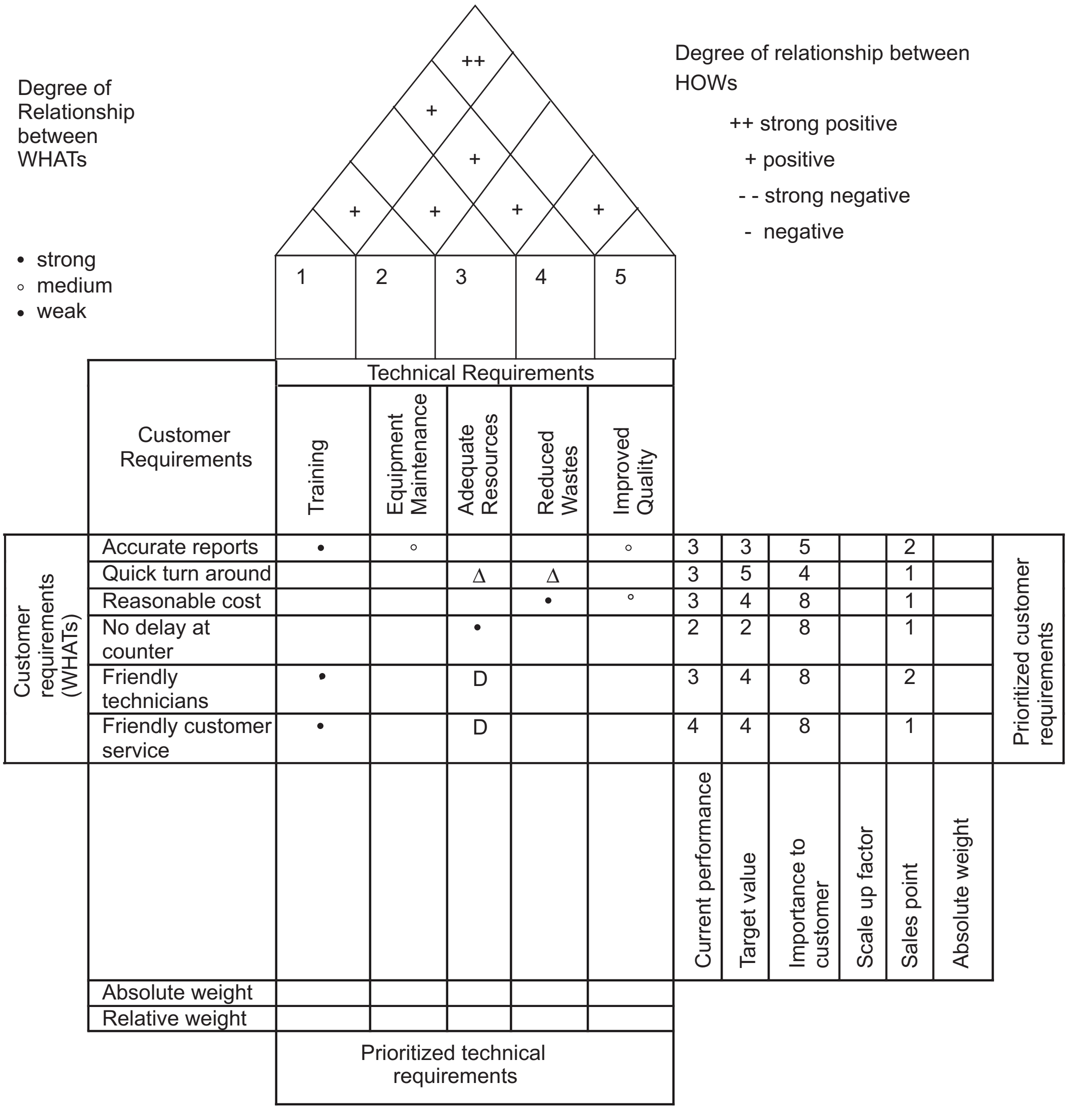
V. Fill up the blanks in following Tables / Figures

1.

Customer Requirements	Training	Equipment Maintenance	Adequate Resources	Reduced Wastes	Improved Quality		
Accurate reports	◉	○			◉	15	10
Quick turn around		◉	△	△		9	10
Reasonable cost				◉	○	8	8
No delay at counter			◉			6	6
Friendly technician	◉		△			4	4
Friendly customer service	◉		△			2	2
Absolute weight Relative weight							
						Degree of importance to the customer	Absolute weight

Prioritized Technical Requirements

2.



House of Quality

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Chapter 17

Taguchi's Robust Design

Success in business requires training, discipline and hard work. But if you're not frightened by these things, the opportunities are just as great today as they ever were.

—David Rockefeller

INTRODUCTION

The concept of minimizing losses was also born in Japan due to their specific need. It is an island with limited natural resources. They have to add value to imported materials and export products with maximum added value. Low loss in a process is as good as adding efficiency to a process. In the modern age, no society can afford to have quality losses. Thus, every industry must understand quality loss function evolved by the Japanese Quality Guru, Taguchi and minimize losses. Traditionally, the emphasis for achievement of quality was through inspection. Taguchi methodology provides new approach to quality. Taguchi advocated optimization of product and process, prior to actual production. His strategy pushes back the quality and reliability issues to the design stage. His method has been found to result in efficient techniques to design product and testing them prior to entering the production phase. Thus, Taguchi impressed upon improving designs, which costs less in comparison with all other costs of making a product, but has a bigger impact on the price of the product. Brenda Reichelderfer of ITT industries after their benchmarking survey of many leading companies reported that "design directly influences more than 70% of the product life cycle cost; companies with high product development effectiveness have earnings three times the average earnings"[1].

Robust design method is central to improving engineering productivity. Pioneered by Dr Genichi Taguchi after the end of the Second World War, the method has evolved over the last five decades. Many companies around the world have saved hundreds of millions of dollars by using the method in diverse industries such as automobiles, telecommunications, electronics, software, etc. Thus Taguchi's techniques are important ingredients of TQM. In this chapter, we will discuss about quality loss, signal to noise ratio, design of experiments and orthogonal arrays.

MEASURE OF QUALITY

Recall our discussions about specification limits and statistical control limits in Chapter 12. A product or service has specifications. The specification specifies limits, Upper Specification Limits (USL) and/or Lower Specification Limits (LSL) for product or process characteristics. For instance, an incubator has a specification of 37 °C ± 1 °C for temperature inside. The USL is 38 °C and LSL is 36 °C. The user of the incubator will be satisfied if the temperature of the device remains within the tolerance limits. If we plot the satisfaction level of the user with the temperature, in this example, it will be as given in Fig. 17.1.

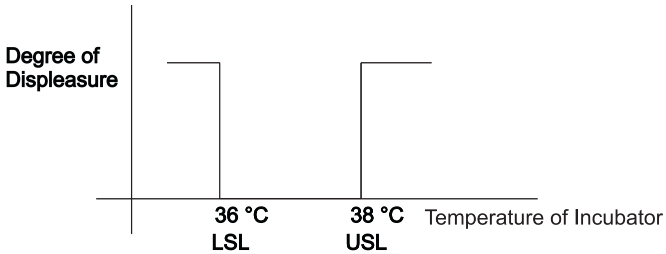

Figure 17.1 Satisfaction Level of the User

Quality was traditionally viewed as a step function as shown in Fig. 17.1. The above figure assumes that the incubator is uniformly good if the temperature lies between LSL and USL. It depicts two situations, product is good or bad, quality is good or bad, user is fully satisfied or not.

This was the assumption till Genichi Taguchi disproved the above understanding. Taguchi was born in 1924. He is a Japanese telecom engineer who mastered statistics and the author of a concept called Design Of Experiments (DOE). He learnt much of the experiment design techniques and use of orthogonal arrays from Japanese Statistician Matosaburo Masuyama. Japanese companies including Toyota Motors began applying his methods, since 1950s. In 1954-55, Taguchi was a visiting Professor at the Indian Statistical Institute, Kolkatta, where he met renowned statisticians R A Fisher and Shewhart. He won the Deming Award for individuals four times, in the years 1951, 1953, 1960 and 1984, which is a rare achievement. His methods including signal to noise ratio, quality loss function and orthogonal arrays were used in Japan since the 1950s with a lot of success. His teachings were initially used for improvement of production processes and later for improvement of product design. USA noticed his contribution for improvement of product design and manufacturing processes in the early 1980s.

TRADITIONAL VIEW OF QUALITY

Taguchi developed the concept of quality loss function. In contrast to the Western countries, Taguchi works in terms of quality loss rather than quality. He used loss function to measure quality. The loss function is defined as "loss imparted by the product to the society, from the time the product is shipped". This loss includes not only the loss to the company through the cost of rework or scrap, maintenance cost and warranty claims, but also the cost to the customers through poor product performance, down-time due to equipment failure and poor reliability. The loss function establishes a financial measure (in terms of $s lost) of the customer's dissatisfaction with a product's performance as it deviates from the target value. We call the central value as τ (tau). Figure 17.2 gives the traditional view about quality loss. It assumes that the product is uniformly good between the specification limits. The Y-axis indicates the degree of displeasure of the customer or $s lost. The process performance is indicated in the bell shaped curve.

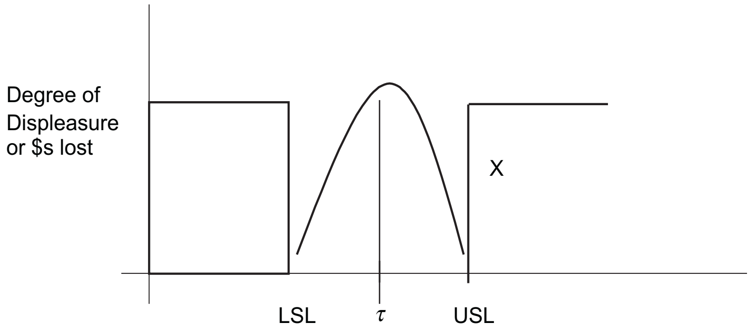

Figure 17.2 Traditional View of Quality Loss

In the case of the incubator example, the target value is the central value or mean of 37 °C. We know from SPC that the process and product characteristics will vary due to random causes and we were satisfied when the process or product performs well within the USL and LSL as depicted in Fig. 17.2. But, the customer may not be satisfied. Taguchi proved that the customer becomes increasingly dissatisfied as the performance deviates farther away from the target value τ. He calls the uncontrolled sources of variations, which we were happy with, lie within the specification limits, as noise factors. Thus, both the mean μ (or target τ) as well as variations are critical measure of quality.

Let us analyze further about the customer dissatisfaction and process variation. There could be another situation as indicated by Y in Fig. 17.3.

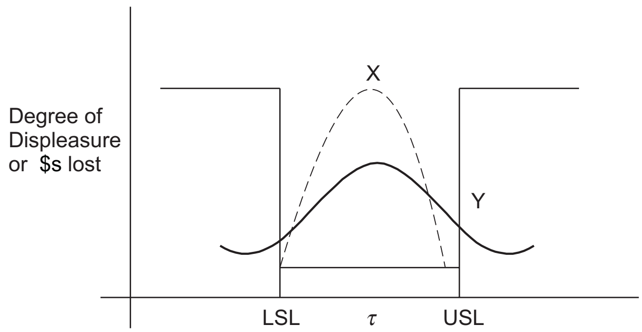

Figure 17.3 Traditional View of Quality Loss

The frequency distribution X was what we saw in Fig. 17.2. The process variation does not cross the specification limits. Whereas although the mean is τ in the case of Y also, it exceeds the specification limits. Both the traditional QA experts and those who use Taguchi's technique will agree that X is better than Y, since the averages are same, but the dispersion is more in the case of Y.

TAGUCHI'S LOSS FUNCTION

Taguchi views that the customer becomes increasingly dissatisfied as performance of the product or process moves away from the target τ. He suggests a quadratic curve to represent customer dissatisfaction with a process or product's performance. The quadratic curve is called quadratic loss function as shown in Fig. 17.4.

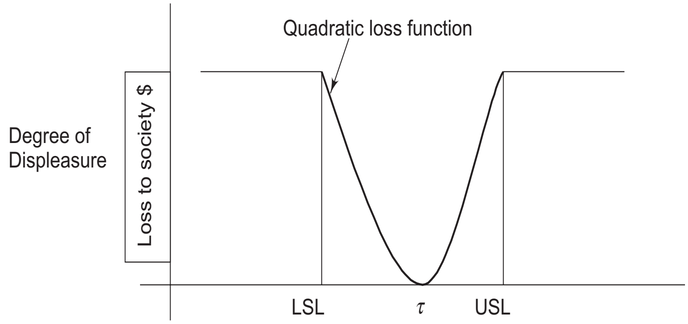

Figure 17.4 Taguchi's Loss Function

The quadratic loss function is also centered on the target τ. As the performance moves away from the target, there are losses. Therefore producing within specification limits is not good enough. The premise of loss function is that at some point as a process moves away from the target value, there is a corresponding decrease in the quality. This quality loss may be difficult to discern by the customer, but eventually it reaches a threshold where a complaint is made or the customer is dissatisfied. The ideal quality defined by Taguchi "is that quality which customers would experience when product performs on target every time the product is used under all intended operating conditions throughout its intended life without causing harmful side effects to the society".

The cost of product consists of two elements as given below:

- Unit manufacturing cost—cost incurred on manufacturing the product including design cost, material cost, manufacturing cost, depreciation of machinery, etc. These are the costs incurred before delivery to the customer. A low manufacturing cost satisfies the producer.
- Quality loss—cost incurred on the product after delivery to customer including cost of operating product (energy, environmental control like temperature / humidity control and cost of repairs). A low quality loss satisfies the customer.

The financial loss due to variation is called societal loss. It is approximately proportional to the square of the deviation from the target. Thus, quality loss occurs even when the product performs within the specification limits, but away from the target. Taguchi's loss function recognizes the customer's desire to have products that are consistent and producer's drive to control manufacturing cost. The goal of quality loss function is to reduce the societal loss.

Types of Loss Functions

Loss functions enable calculations of social loss, when products deviate from the target value. Taguchi developed many loss functions with different equations—to suit different applications. There are three types of loss functions as given below:

- Nominal-the–best
- Lower-the-better
- Higher-the-better

Each one of them is suitable for a class of applications. We will now look at their applications.

Nominal-the-best This loss function is applicable to those parameters, which have a central value, and allowable tolerance on either side as discussed in the previous section. The target τ is not necessarily the average process performance, but it is the choice of the customers. It is that value with which majority of customers will be satisfied. It may not be directly derivable. The quadratic loss function in the case of nominal-the-best is given by:

$$\text{Loss} = K\,(Y - \tau)^2$$

Where Loss = cost incurred as performance deviates from the customer's target value.

$$Y = \text{actual performance}$$

$$\tau = \text{target value}$$

$$K = \frac{\$}{\Delta^2} \quad \text{where } \Delta = \text{USL} - \tau \text{ or } \tau - \text{LSL}$$

K is also called quality loss coefficient. Let us look at an example to understand this types of loss function.

Example 17.1

An oil bath manufacturer has set the specifications as 100 ± 6 °C for the baths sold by them. The average repair cost was found to be \$ 360. Find out the loss when the oil bath functions as 102 °C and 104 °C and then at 100 °C.

Δ Permitted deviation = 6 °C

$$K = \frac{\$}{\Delta^2} = \frac{360}{36} = 10$$

$$\begin{aligned} \text{Loss at } 102\text{ °C} &= 10\,(102 - 100)^2 \\ &= 10\,(4) = \$\,40 \\ \text{Loss at } 104\text{ °C} &= 10\,(104 - 100)^2 \\ &= \$\,160 \\ \text{Loss at } 100\text{ °C} &= 10\,(100 - 100) = 0 \end{aligned}$$

Thus the loss is zero, when the product performs on target. It increase when there are deviations. The societal loss increase is proportional to the quantum of deviation. Taguchi's concept can be used in QFD for technical benchmarking. The loss function provides a comprehensive metric for benchmarking. When we wish to calculate quality in case of QFD, we can even use a value of $K = 1$, because we are interested in relative performance of the product with respect to competitors' products. Let us look at one more example.

Example 17.2

A TV manufacturer identified colour sensitivity as one of the critical factors. What will be the loss when the receiver operates at $\mu + 1\ \sigma$, $\mu + 2\ \sigma$ and $\mu + 3\ \sigma$ given that $\tau = \mu$ and $\sigma = 1$ db.

Loss at $\mu + 1\ \sigma$

$$\begin{aligned} \text{Loss} &= K\,(Y - 1)^2 \\ &= 1\,(0 - 1)^2 \\ &= 1 \end{aligned}$$

Loss at $\mu + 2\ \sigma$ = $(0 - 2)^2 = 4$

Loss at 3 σ will be 9

Average loss The examples discussed above considered only one sample. But in manufacturing a large number of products are made. Hence, we can modify the loss function to address manufacturing situations. In such cases, we have to calculate average quality loss.

$$\text{Average loss} = K\{\sigma^2 + (y \text{ bar} - \tau)^2\}$$

$$\text{Where } K = \$ / \Delta$$

This means τ is not the same as y bar (the mean value of the parameter). It is the target value from the customers' perspective. Mean is determined by the process, but τ is determined by the customer.

Let us take an example.

Example 17.3

Find out the average quality loss for a process manufacturing resistors.

$$\text{Mean} = 10 \quad \tau = 11$$

$$\sigma = 1 \qquad K = 1$$

Substituting, we get:

$$\text{Average loss} = 1\{1^2 + (10\text{–}11)^2\}$$

$$= \{1 + 1\} = 2$$

Calculating the average loss permits a design team to consider the cost benefit analysis of alternate designs. In order to bring down the average quality loss we have to do the following:

- Adjusting the mean to approach τ by process control
- Reducing the variations

The average loss function is useful when the organization intends to control one or more of the product characteristic such as voltage, weight, or temperature in a process.

Since σ^2 is, difficult to estimate, sample variance, s^2, can be used in the average loss calculations. The above loss function is general loss function for Nominal-the-best situation. The loss function may not give exact losses, but certainly can be used in design of experiments to adjust the process. The goal should be to reduce variance continually and make process mean coincide with τ. There are some more loss functions to suit specific needs. We will look at them now.

Smaller-the-better This is useful, for instance, in many day-to-day applications such as:

- Waiting time for a bus
- Waiting time in a restaurant, etc.

Here the target will be ideally zero. The loss function is shown in Fig. 17.5.

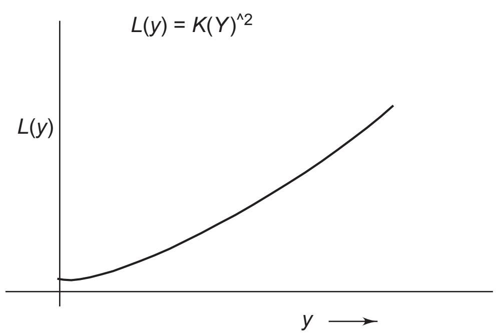

Figure 17.5 Loss Function for Smaller-the-Better

This can be appropriate for defects in software products too.

The above equation applies for a single value. But, in manufacturing there will be a number of values of the same parameter due to large number of items produced. In such cases we calculate average loss function. The average loss for a process in this case will be

Average Loss = $K\ \{(y \text{ bar})\ ^{\wedge 2} + \sigma^2\}$

Higher-the-better While nominal the best is applicable to product characteristics that have a central value and ± tolerances, in the case, where ideal target is zero such as delay at various places, smaller the better was most appropriate. Higher the better is apt when more energy or more power is more suitable or there is no upper tolerance limit. This may be applicable to power generating stations, power generated by an engine etc. The shape of the loss function is given in Fig. 17.6.

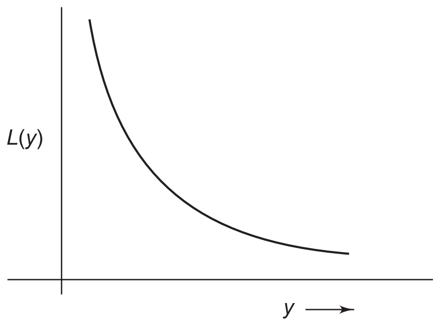

Figure 17.6 Loss Function for Higher-the-Better

The loss in this case is as follows.

$L\ (y) = \ K\ (1/y)^{\wedge 2}$

Average loss in case of production of multiple products will be

Loss = $K\,[1\ /\ y\ ^{\wedge 2}\ ] \times [1 + (3\ \sigma^2/\,y\ ^{\wedge 2})]$

This above three types of loss functions will serve most of the applications.

SIGNAL TO NOISE RATIO

We know that, the central value (μ) of a process may also vary due to random causes. Hence it cannot be assumed to be static. Taguchi methodology is fundamentally a prototype method that enables the designer to identify the optimal settings to produce a robust product, which can survive manufacturing, time after time, piece after piece, in order to provide the functionality required by the customer. Optimizing a product means not only getting its quality characteristics on target, but also minimizing variability away from the target. A product design or manufacturing process that is insensitive to uncontrolled variations improves the quality of a product or service and reduces loss. Traditional method of quantifying variation was standard deviation. Taguchi developed his own metric and called it as signal to noise ratio. Taguchi calls the uncontrollable variations as the noise. The term was already in use in Taguchi's original field of Electronics and Communications Engineering. The contribution of Taguchi, is the use of signal to noise ratio to choose the control setting that minimizes the sensitivity to noise, which is nothing but random variations or common cause variations. This is based on the ratio of wanted to unwanted energy transformations between the input and output sides of a process or a product. The signal is the wanted energy and noise is the unwanted energy. Noise factors can be contributed during manufacturing as well as usage. A microwave oven is affected by external noise such as the number of times the door was opened, wrong operation of the door, etc. The noise generated by the manufacturing process is called internal noise and that generated during the operation is called external noise. The noise factors cause loss to society by shifting the central value.

Signal to noise ratio indicates the quantum of loss. In a process, the target value is the signal and the deviations from it are the noises. Thus, the ratio of the mean to the standard deviation is a simple measure of signal to noise ratio. The signal to noise ratio for the three types of loss functions are given below:

1. Nominal-the-best

Where $S/N_{NB} = 10 \log_{10} \times [(y^2/\sigma^2) - (1/n)]$

$\overline{Y}$ = mean

σ = standard deviation

n = No. of trials

Example 17.4

A process performance is given below:

$\mu = 10$ $\sigma = 1$ $n = 10$

Find out signal to noise ratio for nominal the best loss function.

$$S/N_{NB} = 10 \log (100/1 - 1/10)$$
$$= 10 \log .99$$
$$= 19.9563$$

2. Higher-the-better

The signal to noise ratio of this function is

$$S/N_{HB} - 10 \log_{10} [1/n \sum_{i=1}^{n} 1/y_i^2]$$

Where n = no of readings or trials

y = value at the i_{th} trial.

Let us look at an example to understand the above.

Example 17.5

Find out the signal to noise of the mileage of Maruti car, which gave mileage as given below:

Trial	1	2	3	4
Mileage Km / litre	20	21	21	19

$$\sum_{i=1}^{4} 1/y_i^2 = 1/20^2 + 1/21^2 + 1/21^2 + 1/19^2$$
$$= 0.00981$$

$$S/N_{HB} = -10 \log_{10} [¼ \times 0.00981]$$
$$= 26.104 \text{ db}$$

3. Smaller-the-better

The signal to noise ratio for this type is given by

$$S/N_{SB} = -10 \log_{10} \left(\sum_{i=l}^{n} y^2/n \right)$$

Example 17.6

Radiated emission of three samples of PCs in a lot are give below:

– 40, – 40, – 40

Find out the signal to noise ratio of

$$S/N_{SB} = -10 \log_{10} [1/3 (-40^2 + (-40)^2 + (-40)^2]$$
$$= -32.04 \text{ db}$$

Taguchi Philosophy

Deming's major contribution was to convince the organizations to improve quality of the products through statistical control of the processes. Taguchi built further on this. He provided a complete system for improving and maintaining product and process quality at the lowest cost, in the shortest possible time. Taguchi provides methodology for:

- Evaluating quality
- Improving quality and reducing cost
- Monitor and maintain quality

Evaluating Quality

Quality improvement is the most effective way of achieving a simultaneous increase of sales and cost reduction. This was also the theme of Deming's chain reaction. Therefore, quality evaluation must address:

- Evaluate quality in the entire product life cylcle
- Intent of engineering objectives and customer response to a product function
- Quality in terms of ideal product function and include effect of costs of not meeting customer expectation. Taguchi has given two quality evaluators namely quality loss function (QLF) & Signal to noise Ratio. Both measure variability. Quality loss function converts it into $. Quality loss function is a tool for finding balance between the cost and quality that can increase profit. It can be used in design and production phases. Signal to noise ratio measures stability or reliability of performance in the face of uncontrollable factors on the factory floor and actual use.

Improving Quality and Reducing Costs (Off-line QC)

Taguchi's Quality Engineering (QE) uses designed experiments to improve product and process quality. The organization has to design products and processes to reduce variability, around the target value at the lowest cost in the shortest time. The organization has to design product/process nominal values, their tolerances, in such a way that cost and quality can be optimized. The organization should design products that reduce loss.

Taguchi methods for QE are a system for achieving engineering objectives, i.e., for reducing loss and improving profit. For this purpose it addresses:

- System design
- Parameter design
- Tolerance design

System Design Conceptual design stage is in which scientific and engineering expertise is applied. The approach is to compare alternate designs and select an optimal one. Benchmarking and QFD are useful at this stage.

Parameter Design Numerous variables affect system performance. They are categorized from an engineering point of view into control factors-engineer is free to set the values of these variables. Others will be uncontrollable (noise factor); these are down stream variables that cause function variation. Recall our discussion in Chapter 13 on CNX diagram.

Goal of parameter design is not to find and remove these causes of variation, but to find that combination of control factor settings that allow system to achieve its ideal function and remain insensitive to effects of noise factors. This allows us to develop a design with high stability and reliability.

Stability of performance in the face of noise function is called robustness. Experimentation is done by orthogonal array designs to be discussed in the later sections. The objective of experimentation in parameter design is to reduce loss by increasing robustness. The signal to noise ratio evaluates robustness of selected control factors.

Tolerance Design Designed experiments are used to find impact of each factor on variability. QLF is applied to evaluate impact of factors with respect to cost and trade off between cost and quality characteristics that can be economically tightened and upgraded.

Most important task at this stage is the selection of quality characteristics that reflects engineering function of a product or process.

Monitor and Maintain Quality (On-line QC)

To maintain benefits of off line improvements, on-line QC methods were proposed by Taguchi, utilizing QLF.

On-line reduction in variability comes from inspection, measurement and adjustment of equipment and process parameter levels. These have associated costs. Taguchi's on-line system takes these costs into account to determine how often a product characteristic or a process parameter should be measured and adjusted and what the optimal adjustment limits should be.

To sum up, Taguchi methods outlines quality engineering that provides relevant indices for evaluating and improving quality, offline for efficient design of low cost robust products and cost driven on-line methods for maintaining improved quality in production.

EXPERIMENT

Experiments are carried out to improve the quality of a process and product. Experiment can be defined as a test or series of tests in which preplanned changes are made to the input variables of a process or system in order to observe and identify changes in the output response. The experiments involve changing a control variable and observing its effect on the response variable. This change is purposeful and aimed at finding whether it improves the characteristics of the process or product. For instance, for soldering a given component on a given printed circuit board, the duration of soldering is an input variable and quality of soldering is the output response. We may change the input variable of the process, namely the duration of soldering and observe its effect on the quality of soldering. That is a simple experiment. Statistics helps in carrying out experiments systematically. Statistically designed experiments (SDE) are useful for planning and carrying out experiments and analyzing the results and deriving objective conclusions. This is where Taguchi came in. SDE applications include the following:

- New product design
- New process design
- Service design
- Process, product and service improvement

Recall out discussions pertaining to CNX diagram in Chapter 13. it is also a usage of design of experiments. We discussed four factors as given below:

- Constants C, which can't be changed in the process
- Uncontrollable factors, also called Noise N
- Controllable factors which we called X
- Response Y.

Experiment means changing values of Xs in a systematic manner and measuring or observing Y.

Uncontrollable factors There are three types of uncontrollable factors as given below:

(i) Known factors, but the organization doesn't want to control, may be because of high costs involved. For instance, the temperature variations, which increase the length of rails.
(ii) Known factors, but cannot be controlled such as climatic variations in a paddy field.
(iii) Unknown factors that could not be identified clearly.

Objective of Experiments

The following are the objectives of design of experiments in a commercial organization:

- Determining the X variables, which have maximum influence on the response (Y)
- Determining where to set the influential Xs, so that response Y is always almost near the target value
- Determining where to set the Xs, so that variability in Y is small
- Determining where to set Xs, so that the effect of uncontrollable variables and noise variables are minimized.

Making changes in the control variables and observing its effect on the output response is known as design of experiments (DOE). Design of experiment requires identification of response variables or output variables (Y) and all possible control variables (X) and their ranges. Then the experimenter has to formulate a table listing all combinations of X variables. The output response has to be noted for each combination of input variables as shown in Table 17.1.

Table 17.1

Run No.	X_1	X_2	X_3	…	X_n	*Output Y*
1						
2						
3						

Efficient experiment means that we optimize the resources. We know the permissible range of *Xs*. For instance, one of the *X*s is humidity, which may have a range say 30% RH to 70% RH (RH-Relative Humidity). It may be ideal to carry out the experiment by changing 1% at a time. But, the best accuracy for achievable humidity may be 5%. Therefore, it is waste of resources to repeat the experiment by changing humidity by 1% at a time.

The experimenter also knows the effect of change of each parameter (*X*). Therefore, he may decide to carry out the experiment at two levels namely high and low. High means (60% RH to 70% RH) and low means (30% RH to 40% RH). These two ranges are called levels. In some experiments, change of humidity may also have a bigger impact. It may be necessary to carry out the experiments at intervals of say 10% RH. In such a case, we will have four levels of RH as given in Table 17.2.

Table 17.2 Indication of levels

Level	*Range of Humidity*
1	30% RH to 40% RH
2	40% RH to 50% RH
3	50% RH to 60% RH
4	60% RH to 70% RH

Taguchi uses a concept called matrix experiment using orthogonal arrays. A matrix experiment consists of a set of experiments, where we change the settings of the various product or process parameters. Each row represents an experiment. DOE essentially consists of identifying the number of experiments, the number of parameters, number of levels and the sequence of experiments. Example levels are described in Table 17.2. Humidity is the parameter in the above example. The sequence is from top to bottom.

Orthogonal Arrays

The word "design" in DOE implies a formal layout of the experiments that contains information about how many tests are carried out and combination of factors included in the study. Orthogonal arrays are employed to study the effect of several control factors. Taguchi codified them in such a way that an engineer automatically has a route to the minimum number of prototypes necessary for experimentation. The numbers are kept deliberately small without losing confidence in the experiments. Orthogonal arrays are used in design of experiments to set design and process parameters so as to reduce the losses.

For instance, we may like to simulate varying environments and would like to evaluate the product performance in different environments. This will give us a realistic data about the real world variance of the products. Assume that we would like to vary the following parameters, to study their effects on the product:

- Temperature (T)
- Humidity (H)
- Pressure (P)

We decide to experiment only at high and low values of the above three parameters. This means that there are two levels and three parameters. Let us represent high value of any of the above three parameters by 1 and low value by –1. Then, we have to test the product in eight possible combinations of the parameters as given in Table 17.3.

Table 17.3 All Possible Combinations

T	*H*	*P*
1	1	1
1	1	–1
1	–1	1
1	–1	–1
–1	1	1
–1	1	–1
–1	–1	1
–1	–1	–1

T: Temperature
H: Humidity
P: Pressure
1: High
–1: Low

Traditionally, we have been testing the products under all the eight possible combinations of T, H and P as in the Table 17.3. This is called full factorial orthogonal array. Taguchi has suggested orthogonal arrays to reduce the number of experiments, but at the same time not losing the required confidence about the results of the experiment. The orthogonal array uses a special subset of the combinations. Due to the balanced nature of the combinations the effect of the missing combination can still be predicted. For instance, the orthogonal array for the above eight combinations is given in Table 17.4.

Table 17.4 Special Subset

Run	*T*	*H*	*P*
1	1	1	1
2	1	–1	–1
3	–1	1	–1
4	–1	–1	1

The Table 17.4 is called fractional factorial orthogonal array. Thus, it is enough if we study the variance in the above four combinations of temperature, humidity and pressure.

The above orthogonal array is called $L_4\ 2^3$

Where 4 – number of combinations in the orthogonal array or runs.

2 – levels (High and low named +1 and –1 respectively)

3 – factors (T, H, P)

Example 17.7

No. of factors = 4

Number of levels = 3

We will then get 3^4

= 81 arrays without optimization. But Taguchi's orthogonal array contains nine combinations as given in Table 17.5:

Number of parameter = 4

Number of levels of each parameter = 3

Optimized number of runs = 9

Table 17.5 $L_9(3^4)$

Run	*Parameters*			
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Thus, orthogonal arrays are quite useful in reducing the experiment time, efforts and costs.

Orthogonal arrays are balanced Study the orthogonal array $L_8(2^7)$, which is given in Table 17.6.

Table 17.6 $L_8(2^7)$ Orthogonal Array

Expt. No.	*Column*						
	A	*B*	*C*	*D*	*E*	*F*	*G*
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

This is called OA-8. 8 in the designation represents the number of rows. Two indicate 2 levels and 7 indicates seven parameters. This way, one can understand the nomenclature of the orthogonal array.

One has to select orthogonal arrays, depending on the number of parameters and the number of levels. Orthogonal means balance. The orthogonal array enables balancing of the experimental design.

Analysis of the OA-8 indicates that there are four level 1s and four levels 2s for each parameter. There are four level 1s for factor A. Corresponding to this, there are two level 1s and two level 2s in all other factors B to G. Similarly, there are four level 2s in any of the factors. Corresponding to them, there are two level 1s and two level 2s in all other factors. That's how the orthogonal arrays are balanced. No doubt, for full factorial orthogonal array, the balancing is automatic. However, even for partial factorial orthogonal arrays, the balance is ensured. That's why these arrays are called balanced orthogonal array, which enable balanced experimental design.

Some more examples of balanced orthogonal arrays are given in Table 17.7, which can be used depending on the needs.

Table 17.7 $L_8(2^7)$

Experiment Number	*Column*						
	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
1	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Full factorial in the case of $L_8(2^7)$ will consist of 128 rows. However, the optimized orthogonal array contains only eight rows, which is depicted in Table 17.8.

Table 17.8 $L_9(3^4)$

Experiment Number	*Column*			
	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	2	1	2	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Full factorial of $L_9(3^4)$ will consist of 81 rows. However, the optimized fractional factorial consists of only nine experiments saving a lot of cost.

Thus, the orthogonal array is quite handy for optimizing the number of experiments. Their balanced nature helps in achieving full confidence as that of full factorial orthogonal arrays. The orthogonal arrays also provide the sequence of experiments, making the job of the experimenter easy. Now, orthogonal arrays are finding wide use in all the sectors including the software sector for testing of software products. The orthogonal arrays have now become a part of Taguchi's design of experiments.

Design of Experiments

Taguchi advocates systematic approach for design of experiments and analyzing the results. A methodology for the same is shown in Fig. 17.7.

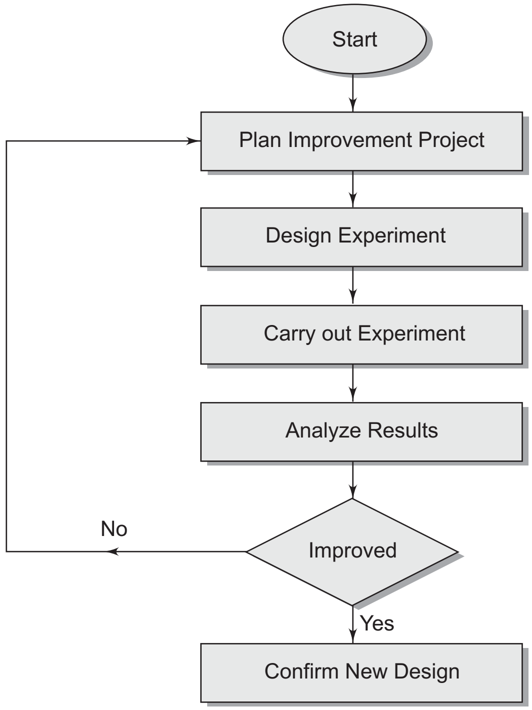

Figure 17.7 Design of Experiments

The diagram itself is self-explanatory. During the planning phase, the team identifies the parameter of the response (*Y*) to be improved. It also identifies the control variables. For instance, it may be desirable to check the operation of equipment say from 200°C to 300°C. It means one can take any number of points and change the temperature from lower to higher. However, this will be very expensive. Hence, usually two or three levels are chosen. For instance, 200°C can be one level and 300 °C can be another level. If a more detailed investigation is called for, then one can have three levels, i.e. 200°C, 250 °C and 300 °C. In the above case, the temperature is the parameter. The levels are 200 °C, 250 °C and 300 °C. The levels can be indicated as 1,2 and 3. If there are only two levels like 200 °C and 300 °C, then 200 °C can be given a name –1 and 300 °C can be given a name of +1.

If the process improves, then the design or redesign is confirmed and the process is set at the new identified levels for the factors. If not, another experiment is designed. Each run in consists of different combinations of levels for each factor. All runs in the designed experiment are carried out and results are noted. The best result, i.e. where there is an improvement to the process is noted.

Taguchi's method can be applied for improving an existing design or carrying out a new design through experiments. The objective of Taguchi's robust design is to develop a robust product which will not be affected by environmental or noise factors.

To summarize, the various phases of statistically designed experiments are:

- Statement of the problem
- Choice of factors, levels and ranges
- Selection of response variable
- Choice of experimental design
- Performing experiment
- Statistical analysis of data
- Conclusion and recommendations

Let us look at a case study. This real life case study will give a clear picture about design of experiments.

CASE STUDY

Statistical Tools for Process Improvement

Applying DOE to Microwave Popcorn[1]

Design of experiments identifies which factors matter and which ones don't, as well as helping find optimal setting.

By Mark J. Anderson and Hank P. Anderson

Look it hot enough, not too long, and a little bit off the floor of the oven. And preheating the oven by heating a glass of water for 1 min. has no effect. Don't even bother.

Those were the conclusions we made from applying the Design of Experiments (DOE) technique to the problem of preparing microwave popcorn. The study was conducted at home, using a common microwave oven designed for the consumer market. Since the study examined something with which everyone has some experience, it provides a good example for understanding how to apply DOE in adjusting process industry recipes. In particular, cooking microwave popcorn demonstrated how DOE helps in applying the Pareto principle. In other words, it helps to identify what Juran calls the vital few factors from among the trivial many.

Table 1 Factors and Levels

Factor	*Low* (–)	*High* (+)
Price	Generic	Brand
Time	4 min.	6 min
Power	Medium	High
Preheat	No	Yes
Elevate	No	Yes

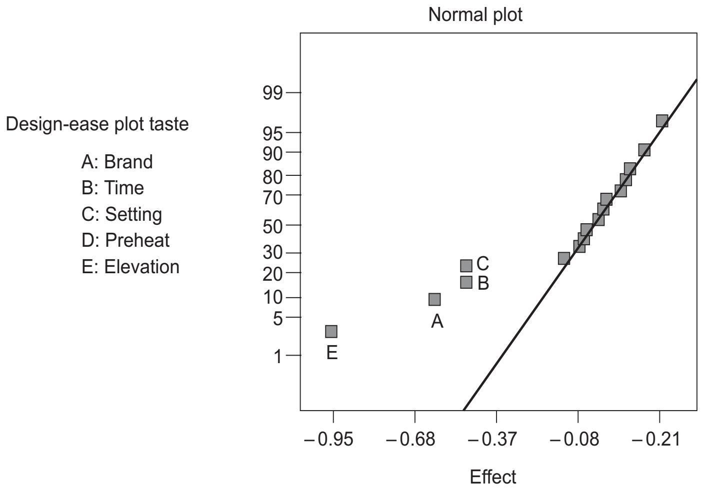

Figure 1 Analysis of Unpopped Kernels

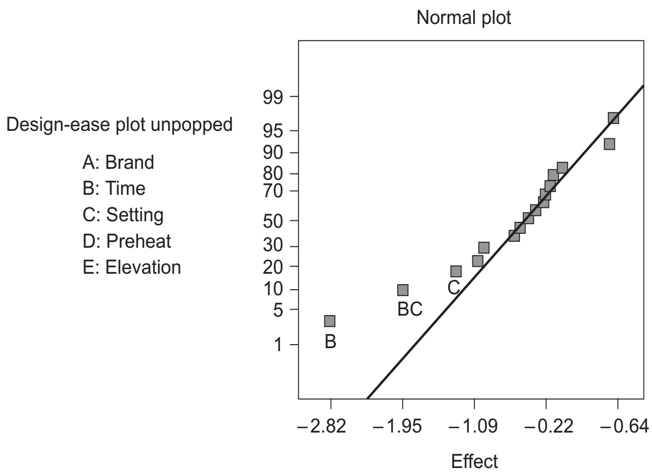

Figure 2 Analysis of Taste

Independent variables

To begin, a brainstorming session was help to identify all possible factors that could be studied as independent variables. For this study, five major factors were selected from a broader range of ideas. The five factors were brand, cooking time, microwave oven temperature, preheat time and tray elevation.

The idea for the study grew out of the last two factors. A quick study of microwave popcorn instructions at the local supermarket showed that all packages pretty much say the same thing. The instructions advise that the consumer perform a range-finding operation, cooking the popcorn pouch for 2–5 min. on a high setting until the rate of popping subsides to an interval of about one pop every three seconds.

Two unusual instructions caught our attention. One involved in having the microwave bag resting on a microwave-safe rack at about the centre of the chamber, as opposed to resting it on the floor of the oven. The second involved the preheating step. One of these unusual factors did influence the results, the other didn't.

Our study was designed around a two-level factorial model. Some of the factors were by their nature discrete and binary; others were continuous. All variables had only two values. To limit the continuous variables, range-finding trials were conducted to set low and high levels for each of the experiments.

During some of the range-finding runs, the popcorn was seriously over-cooked. We found that a kitchen filled with was a small price to pay for the education gained.

The brand factor was selected based on the central intent of the study, to determine if there is a strong correlation between the quality of the finished product and the price of the package on the grocery store shelf. The brands tested were selected to contrast a nationally distributed big-name brand against a local grocery store (generic) brand of microwave popcorn. The national brand was purchased at $1.79 per package, the generic brand for $1.25 per package. (A complete listing of the two-level factors can be found in Table 1.)

The instructions on one package of popcorn that we had tired suggested that using a preheating step could increase the yield of the cooking process. If the occurrence of corn that remains unpopped (we call these *bullets*) is high, the instructions suggested that operating the oven with a glass of water inside for a period of one minute can increase the yield.

A statistically desirable array of combinations of the low and high levels was built, for a total of 16 runs, half the total number (32) of combinations possible. Such a fractional factorial design is sufficient to learn all that we needed to know about popping popcorn. In fact, making more runs would not add to our knowledge. It is not necessary to run all 32 combinations to study the interactions between factors. The runs were randomized to protect the study against lurking variables—such as changes in the environment—that could otherwise confound the study. To simplify the administration of such a study, we used a Design-Ease® software for design of experiments. It handled randomizing the samples and the statistical analysis.

Table 2 shows the standard ("Std") array for five factors and 16 experiments. It also shows the run order and observed responses. To estimate pure error, two repeat runs were planned. These extra experiments were meant to be run at mid-level (coded as zero) of the time factor, with the other factors fixed at low (–) or high (+). However, the runs were not executed as planned. Also, one run in the standard array was botched and another one was missed. The software accommodated these accidental variations, and they had no impact on the results.

Table 2 Array of factors and responses

Std	*Run*	*A*	*B*	*C*	*D*	*E*	*Bullets*	*Taste*
1	12	–1	–1	–1	–1	1	1.5	7.5
2	9	1	–1	–1	–1	–1	1.4	8.0
3	6	–1	1	–1	–1	–1	1.9	9.0
4	18	1	1	–1	–1	1	0.6	6.5
5	1	–1	–1	1	–1	–1	1.8	7.0
6	14	1	–1	1	–1	1	0.3	7.5
7	7	–1	1	1	–1	1	0.2	2.5
8	5	1	1	1	–1	–1	0.9	1.0
9	17	–1	–1	–1	1	–1	1.7	7.0
10	15	1	–1	–1	1	1	0.8	6.0

(Contd)

Std	*Run*	*A*	*B*	*C*	*D*	*E*	*Bullets*	*Taste*
11	3	–1	1	–1	1	1	0.6	4.5
12	16	1	1	–1	1	–1	0.9	4.0
13	4	–1	–1	1	1	1	0.6	9.0
14	13	1	–1	1	1	–1	1.3	7.5
15	NA	–1	1	1	1	–1	Missing	—
16	NA	1	1	1	1	1	Missing	—
×	2	–1	–1	–1	1	–1	3.2	8.5
×	8	1	0	1	1	1	0.1	4.0
×	11	1	0	1	–1	–1	0.8	5.0
×	10	–1	0	1	1	–1	1.6	5.5

Response analysis

To measure the effects of the variable factors in each run, three response factors were considered. First the unpopped kernels (bullets) were weighted and the weight was recorded. Likewise, burnt popcorn was collected from each sample run and weighted. However, this response turned out to be unreliable.

The third response–taste—was subjective, but finding people willing to serve on a judging panel was not difficult in this case. Taste evaluations were recorded using a scale from 1–10, with 10 being high or good. Observed values ranged from 1.0 to 9.0.

Observations from the 18 runs were then entered in the Design-Ease package. The software calculated the effect each independent variable and combination of variables had on the responses.

What the yield told us…

The software automatically produced a graph, called the normal plot of effects that helped isolated the factors that were key to determining the yield—the percentage of unpopped bullets. Figures 1 and 2 show the main effects and two-factor interactions for the two measurable responses. The trivial many factors, which had no influence, fall on a straight line near the zero effect level.

One of these factors was the preheating step (D). Preheating thus had no impact on the responses. This is an important outcome because it means that we don't have to wait an extra minute for the popcorn.

The four remaining factors (brand, temperature and elevation) significantly affected the bullets (see Figure 1). Residual analysis by design ease revealed the possibility that run two was an outlier for bullets. This experiment produced an unusually low amount of popcorn, but since no special cause could be attributed to this, and it did not greatly affect the findings, it's included in the results.

Figure 2 shows the normal plot of effects for the taste response. It reveals a highly significant interaction between time (B) and power (C). The biggest effect comes from the time alone, but its impact depends on the level of power. As the interaction plot in Figure 3 shows, when the time was limited to its low-level of 4 minutes, the predicted taste responses were roughly equal, around 7.5. (The points fall within the 95% confidence "least significant difference" bars displayed by the software). With time set at its high (+) level of 6 minutes, however, the taste response varies significantly depending on other factors in this case, the temperature or setting of the microwave oven. When set on high, enough of the popcorn burned to pull the taste response value down to under 2. Set on medium high, taste response dropped some-what less to around 6.

With this information, we feel-that preheating the microwave oven is a waste of time. On the other hand, elevating the pouch in the oven is a good idea. No matter how powerful your home oven is, cooking microwave popcorn at a high setting and for a shorter rather than a longer time probably produces a tastier result.

The results also suggest that a name brand performs better than a generic one, although our tests covered only the two brands. Clearly, more investigation is called for before changing one's brand preference. As a result of this study, however, we were able to reduce the presence of bullets or unpopped kernels by 80 percent, a significant gain in yield.

In addition to possibly making a home movie or sports viewing more enjoyable, this study was intended as a learning opportunity for all participants. When talking about process improvement, this is the kind of analysis that has to be done to make breakthrough changes. Looking at one factor at a time in a traditional approach will not work. DOE provides the tools to uncover special causes.

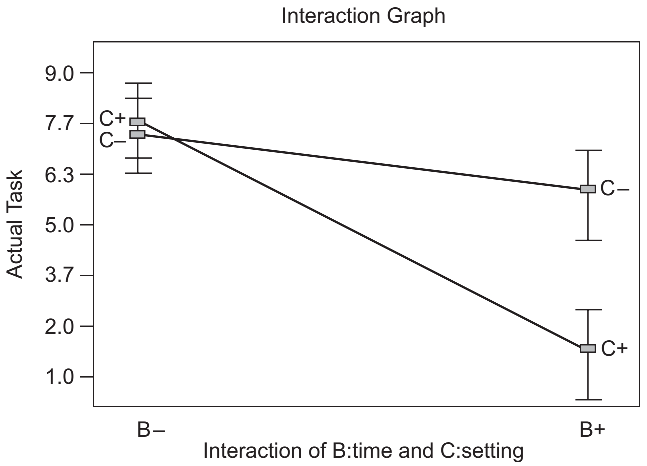

Figure 3 Interaction of Time vs Heat on Taste

Follow-up Study Reveals More Secrets for Making Popcorn

Our DOE on microwave popcorn unintentionally turned out to be a destructive test. The heat and smoke generated at the upper limits of time and power degraded the chamber to a point where we decided it might be best to get a new machine. We purchased a more powerful and sophisticated microwave that included a pre-programmed setting for popcorn. Not content to leave things be, we did a follow-up factorial at plus and minus times around the factory setting (factor C), and two additional factors: prechilling the bag (A), and putting it on a wind-up carousel (B). We did all the combinations plus four centerpoints on time for a total of eight runs.

We thought the carousel (factor B) would distribute the microwaves more evenly, but as can be seen in Figure 4, it caused a significant increase in bullets, perhaps because it absorbs energy. Increasing the time caused a small but significant reduction in bullets. However, this was counteracted by a reduction in taste (see Figure 5). Prechilling did not significantly impact either the bullets or the taste, so it's unnecessary. As a result of this study, we decided to use the factory setting for popcorn and no carousel.

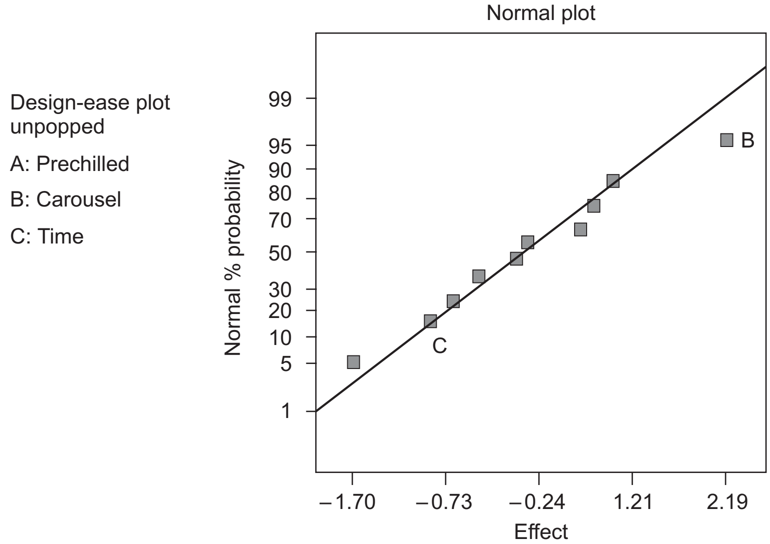

Figure 4 Follow-up DOE—Effects on Bullets

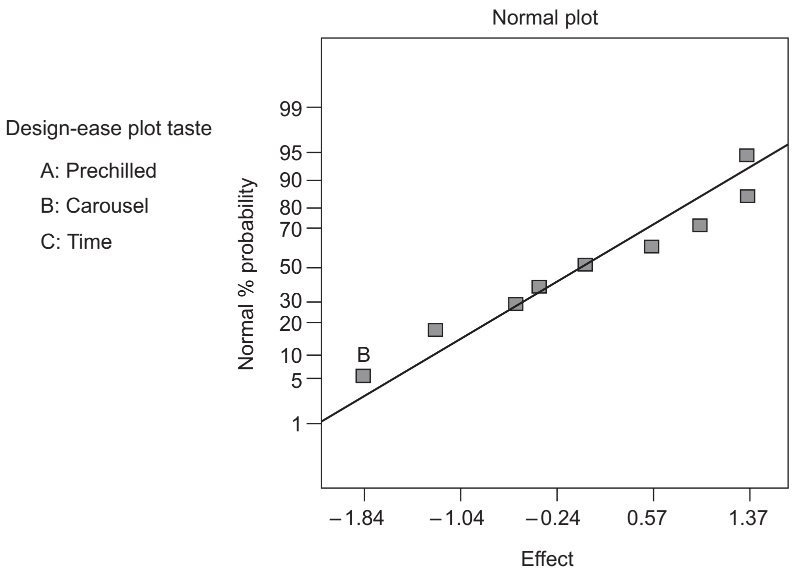

Figure 5 Follow-up DOE—Effects on Taste

SUMMARY

Quality should be measured by the deviation from a specified target value, rather than by conformance to tolerance limits. It should be realized that quality cannot be ensured through inspection but must be built in through appropriate design of process and product. Through proper design of a system the process can be made insensitive to variations.

We discussed in chapter 12 that if the variations in the process are due to random causes and if they are within the 3 σ limits, we concluded that the process is under statistical limits. The processes should perform at the target value τ to minimize societal losses. Any variation, even within the limits, is a quality loss. The cost of quality loss is expressed in the form of a quadratic equation. There are three types of loss functions:

- Nominal-the-best (NB)
- Smaller-the-better (SB)
- Higher-the-better (HB)

The processes with a central value and tolerance limits on both sides can use the NB to calculate the loss. If we have to calculate the loss based on number of observations, then we use average loss.

No one wants to wait for a bus or train or at the cinema theatre or restaurant. In such cases, we want the target value for waiting to be zero. The loss function suitable is smaller the better.

We want the battery of a car or in a walkman to give maximum life. Therefore, in such situations we can use, higher-the-better loss function. The equation for each one of the loss functions are accordingly different.

The variations are noise and the mean value is the signal. Signal to noise ratio is another measure of quality loss. We saw three different formulae for calculating signal to noise ratio in each of the three cases.

Robust design needs experiments. We usually control more than two variables such as temperature, humidity, input voltage, etc. while experimenting. We also keep the variables at set levels—not at all possible values of the variables. Even when we restrict the number of levels, the various combinations of test conditions become too large. In order to save time and efforts, Taguchi, the developer of quality loss function and S / N ratio, has also formulated optimal arrays called orthogonal arrays for various combinations of levels as well as parameters. These are useful for design of experiments for reducing quality losses. By setting the parameters at optimal levels, the design can be made robust to changes in production, operation and environmental conditions. Thus, Taguchi's robust design techniques are aimed at reducing societal loss to the minimum.

REVIEW QUESTIONS

I Choose the most appropriate answers.

1. Taguchi's techniques were initially developed in
   (a) Japan (b) UK
   (c) USA (d) None of the above

2. Quality loss function equation is
   (a) Linear (b) Logarithmic
   (c) Quadratic (d) None of the above
3. Signal to noise ratio is a
   (a) Linear function (b) Logarithmic function
   (c) Exponential function (e) None of the above
4. Loss in travel time from one place to another can be captured using
   (a) HB (b) SB
   (c) NB (e) All the above
5. Losses in votes can be best captured by
   (a) HB (b) SB
   (c) NB (e) None of the above

II. True or False

1. When a process performs within the statistical limits there is no loss
2. τ is always equal to mean.
3. τ is determined by customer
4. Signal to noise ratio is also an indicator of quality loss
5. Average loss is applicable only to NB
6. Orthogonal array minimizes the number of experiments
7. Step function is the appropriate quality loss function
8. Loss function is also used in QFD.
9. Loss function is a comprehensive measure of quality
10. Taguchi's loss function recognizes the customer's desire
11. In the loss function of a cinema theatre NB is appropriate.

III. Solve the following problems

1. Find out the quality loss for equipment at 102 °C and 104 °C given that

$$\tau = 100\ °C$$
$$\Delta = 3$$
$$K = \$\ 100$$

2. Find out the average quality loss given that

$$K = 100$$
$$\sigma = 1.5$$
$$\bar{y} = 100$$
$$\text{target value} = 102$$

3 Find out average quality loss for a microwave oven as per details given below:

$$K = 100$$
$$\text{Target value} = 600\ °C$$

Four readings taken when the oven was set at 200 °C were:
201, 203, 202, 202

4. The values of the power output of a public address system in decibels are:
   100, 101, 99, 98, 102
   $K = 1$
   Find out the average loss. Justify the reasons for choosing the type of loss function.
5. List out all possible experiments when there are four variables (parameters) and three levels for each variable.
6. The frequency of a radio transmitter was recorded as given below: (All figures are in kHz)
   610.0, 610.1, 610.2, 610.0, 610.1
   Find out the signal to noise ratio.
7. The mileage in km/litre of a two-wheeler was recorded as given below in five trials:
   85, 90, 82, 88, 78
   Find out quality loss and signal to noise ratio,
8. The pollution levels recorded in mg of a city are:
   120.1, 90.1, 125.2, 85.7
   Find out the quality loss and the signal to noise ratio.

IV. Explain briefly

1. Relation between signal to noise ratio and quality loss
2. Target value
3. Application of three types of quality losses
4. Orthogonal arrays
5. Signal to noise ratio of the three types of loss functions.

Reference

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Chapter 18

Total Productive Maintenance

The squeaking wheel doesn't always get the grease,
Sometimes it gets replaced.

—Vic Gold

INTRODUCTION

Maintenance of plant and machinery deserves importance since idle or defective machinery means loss of money. In developing countries a large number of equipment lie idle, due to want of spares or lack of competent persons to repair the items or the cost of repair is comparable with a new replacement. Since maintenance requires specific skills in troubleshooting and the operators don't have skills to maintain or repair the equipment on their own, some organizations have separate maintenance departments. In such cases the operators of the machinery don't care about maintenance leading to more down time of the equipment. Unless the equipment is always in proper working conditions, the organization will undergo losses. Total Productive Maintenance (TPM) was also evolved in Japan to take care of this important aspect of business. Increased productivity is the hallmark of TPM and hence TPM is a part of TQM since the former has a bigger role to play in satisfying customers and shareholders of an organization.

GOAL OF TOTAL PRODUCTIVE MAINTENANCE (TPM)

The goal of TPM is continuous improvement in up time of the equipment by harnessing the skills of every employee leading to the growth of the organization. The goal is to involve every employee in upkeep of plant and machinery. The measure of TPM is the actual percentage of time the equipment was used for regular production. An interesting observation is "Equipment does not need lunch or tea or dinner breaks; only the men need it". It is not a joke, but is a hidden truth that whenever operators take all these breaks, the equipment is also idle. If these break hours can be utilized then an organization will increase the productivity by 10% and profits will also increase correspondingly.

Total Productive Maintenance (TPM) is a modern maintenance strategy aimed at more profits. Philosophically, TPM resembles Total Quality Management (TQM) in several aspects, such as:

- Total commitment to the program by top management is essential
- Employees must be empowered to initiate timely corrective and preventive actions
- Since it is a long term and ongoing process, one has to wait for the results
- Changes in employee mind-set are essential for success

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. It is no longer simply squeezed in whenever there is a break in material flow. The goal is to hold emergency and unscheduled maintenance to a minimum by planned and effective maintenance.

Let us understand some terms used in the maintenance arena.

PREVENTIVE MAINTENANCE

"Prevention is better than cure". TPM calls for planned maintenance to avoid breakdown of the plant and machinery. Preventive maintenance is a set of maintenance actions that are required to be carried out by trained employees to prevent failures and increase the life of the equipment.

Preventive maintenance is classified into two types:

- Periodic maintenance
- Predictive maintenance

Periodic Maintenance

The periodic maintenance is scheduled on the following basis:

- Daily maintenance
- Weekly maintenance
- Monthly maintenance
- Annual maintenance

Daily Maintenance Simple preventive actions such as cleaning, applying lubricants, tightening parts, visual examination, etc. is carried out before an operator starts his work in a day. It could be on every shift basis or a daily basis. The operator of the machine carries out daily maintenance. Any abnormality noticed during maintenance should be brought to the notice of the foreman.

It may be easier to explain the concepts of periodic maintenance using an automobile as an example. Daily maintenance is cleaning and dusting the exterior and interior of the car. Checking that fuel, lubricants and charge of the battery are sufficient (as indicated by the respective meters) is adequate for daily maintenance.

Weekly Maintenance This is more detailed and time consuming than the daily maintenance. In some cases, some parameters of the machinery such as pressure, temperature may be measured.

In the case of an automobile, the weekly maintenance includes checking the air pressure of the tyres, checking electrical system, etc. The indications such as the level of brake oil, etc. are to be checked on a weekly basis.

Monthly Maintenance On a scheduled date, monthly maintenance is to be carried out. One problem with maintenance is that it gets lower priority. Hence there should be commitment at all levels so as not to skip maintenance. The monthly maintenance of automobile may include checking the condition of battery through measurements. Monthly maintenance may call for tuning of the engine and checking emission levels, etc.

Annual Maintenance A shut down of the plant has to be planned to carry out complete overhaul of the plant and machinery. This is a major maintenance activity to be carried out by the maintenance technicians. A part, which is likely to fail in the future, should be replaced although residual life may be still left in it. The idea is that by carrying out periodic maintenance, we reduce equipment down time.

Predictive Maintenance

Here the organization makes a prediction of the equipment failure, using date and statistics. On the contrary, periodic maintenance is carrying out routine maintenance on scheduled dates to prevent failure, which is a time-based maintenance. In the predictive maintenance, the life of the equipment or sub-system are determined or predicted based on the current status as revealed by an inspection or diagnosis using special tools. Predictive maintenance is condition-based maintenance. An on-ine system can be designed to monitor the condition of the equipment. Appropriate corrective action is taken so that any breakdown is prevented just in time.

Breakdown Maintenance

The goal of TPM is to eliminate or at least minimize the breakdown of the equipment. However, if it happens it has to be repaired and brought back to working condition at the earliest. Such breakdown affects productivity and cause losses to the organization. This is called breakdown maintenance.

HISTORY OF TPM

The origin of TPM can be traced back to the year 1951, when preventive maintenance concept was introduced in Japan. Nippon Denso was the first organization to introduce plant-wide preventive maintenance in the 1960's. Nippon Denso was a major supplier to Toyota Motors. TPM was added as a new element of Toyota Production System (TPS). The existing elements of TPS were:

- Total Quality Control (TQC)
- Just In Time (JIT)
- Total Employees Involvement (TEI)

The secret of Japanese TPM was not known to the west till the publication of two text books on TPM by Seiichi Nakajima in the year 1988. Then, the missing link, TPM for world class equipment performance was noted and many companies adopted it since the 1990's. Thus, TPM is a relatively new concept in the industrial world.

Nippon Denso also decided later, that the operators will carry out routine maintenance and specialized maintenance group will only take up essential and complex maintenance tasks. The routine maintenance by operators was called autonomous maintenance. Maintenance staff carried out modifications to equipment. Thus, the entire organization was involved in maintenance, justifying the word "Total" in TPM.

USE OF 5S

The Japanese 5S tools are deployed to increase the productive time. Remember that productive time is not the same as equipment uptime. Because, the equipment may be up but waiting for material from the vendor or the previous internal supplier. Therefore, JIT and TQM are both important to maximize the productive time. Use of 5S certainly improves the productive time.

Quality circles are used to find ways to improve the productive time. The suggestions from quality circles not only address the equipment up time, but also the entire organization. The productive time of the equipment depends on many factors. A simple situation in a factory is given in Fig. 18.1.

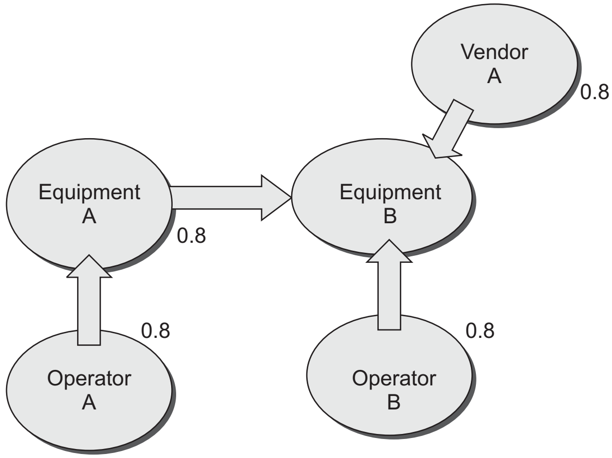


Figure 18.1 A Simple Situation in a Factory

Operator B operates the equipment B. The equipment can operate only if it has received items from equipment A as well as vendor A. Assume that all of them are operating with 80 per cent efficiency. Then the productive time of equipment B or efficiency of the process at equipment B is not 80 per cent, but $0.8 \times 0.8 \times 0.8 \times 0.8 \times 0.8 = 0.32768$ per cent.

Of course that is the worst-case efficiency, but it can happen. That is the reason for the adoption of TPM so that the entire organization is involved in high throughput of the entire process.

OVERALL EQUIPMENT EFFICIENCY (OEE)

To understand OEE, we need to understand some new terms.

MTBF

Mean Time Between Failures (MTBF) is an indicator of reliability of a product. The unit of MTBF is hours. If item A has MTBF of 10,000 hours and item B has 8,000 hours, then, item A has higher reliability. Higher the MTBF, better is the reliability.

MTTR

This is the average time to repair an item when it becomes defective. Mean Time To Repair (MTTR) is a measure of maintainability. Dependability of an equipment (for performance) depends as ARM.

A → Availability
R → Reliability
M → Maintainability

Availability is the proportion of time the machine is available for use out of the total time available. It can be calculated using the other two factor of ARM as:

A = (MTBF – MTTR) / MTBF

Example 18.1

The MTBF of a lathe is 1000 hrs. Its MTTR is 10 hrs. Find out availability?

$$A = \frac{\text{MTBF} - \text{MTTR}}{\text{MTBF}} = \frac{1000 - 10}{1000}$$

$$= 0.99 \text{ or } 99\%$$

Example 18.2

A drilling machine should be available for at least 99.99 per cent of the time. If average time taken for repairs is one hour, what should be its MTBF?

$$A = \frac{\text{MTBF} - \text{MTTR}}{\text{MTBF}} = 1 - \frac{\text{MTTR}}{\text{MTBF}}$$

$$0.999 = 1 - \frac{1}{\text{MTBF}}$$

$$\frac{1}{\text{MTBF}} = 0.001$$

$$\text{MTBF} = \frac{1}{0.001} = 1000 \text{ hrs}$$

PERFORMANCE EFFICIENCY

The performance efficiency depends on two factors

- Rate efficiency
- Speed efficiency

Rate Efficiency (RE)

The organization plans for a particular production time subtracting planned down time from the total time available. The planned down time occurs due to the following:

- Maintenance
- Machine set up time
- Authorized tea and lunch breaks, etc.

The unplanned down time occurs due to the following:

- Sudden breakdown
- Non-receipt of material
- Late coming of the concerned operator or operator of the feeder process

Therefore, rate efficiency is the ratio of actual cycle time achieved to the total cycle time possible.

Speed Efficiency (SE)

Due to many reasons the machine operates at lower speed affecting the production.

Performance Efficiency (PE)

$$\text{PE} = \text{RE} \times \text{SE}$$

QUALITY RATE

It is nothing but yield. The non-conformities affect the yield.

$$\text{The quality rate } (Q) = \frac{\text{Number of good parts produced}}{\text{Total produced}}$$

Thus, the Overall Equipment Efficiency (OEE) is determined by three factors as given below:

- Availability (A)
- Performance Efficiency (PE)
- Quality Rate (Q)

$$\text{OEE} = A \times \text{PE} \times Q$$

The availability we calculated in the previous examples is the theoretical availability assuming that there is no other cause that causes non-availability of the equipment. The causes of non-availability are preventive maintenance and other hold up time. Therefore, practical availability can be calculated as:

$$A = \frac{P - NA}{P}$$

$$P = \text{planned operating time}$$

$$NA = \text{Time not available due to various reasons}$$

Let us look at examples to understand OEE.

Example 18.3

A plant is operating on a three-shift basis.

Time not available due to various reasons including preventive maintenance = 21 hours per week. The unit produced 10,000 pieces of the item in a week, which contained 100 defectives. The machine was operated at 80 per cent of its capacity on an average. The capability of the process is to produce 11,000 pieces per week. Calculate the overall equipment efficiency?

$$A = \frac{P - NA}{P} = \frac{(7 \times 24) - 21}{7 \times 24}$$

$$= 147/168 = 7/8$$

$$\text{RE} = \frac{10000}{11000}$$

$$\text{SE} = 0.8$$

$$\text{PE} = \text{RE} \times \text{SE}$$

$$= 10/11 \times 0.8 = 8/11$$

$$Q = \text{No. of good items produced / Total}$$

$$= 10{,}000 - 100 / 10{,}000 = 0.99$$

$$\text{OEE} = A \times \text{PE} \times Q$$

$$= 7/8 \times 8/11 \times 0.99$$

$$= 0.63 \text{ or } 63\%$$

When organizations measures OEE for the first time they may get a figure of 40 to 50 per cent. This will give them a shock. If they implement TPM the figure can be increased to as high as 95 per cent.

STEPS TO INCREASE OVERALL EQUIPMENT EFFICIENCY

The eight pillars of TPM, identified by the Japanese, help in improving the OEE. The pillars are shown in Fig. 18.2.

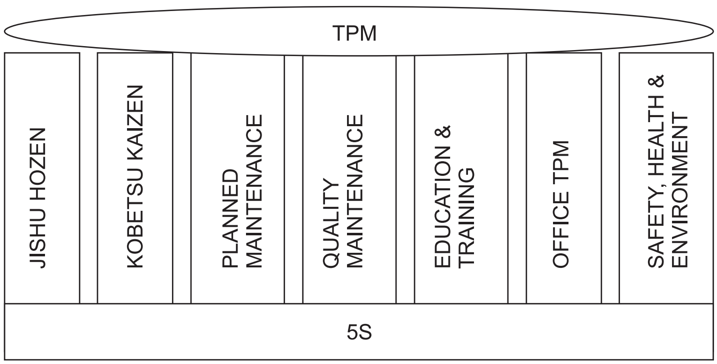


Figure 18.2 8 Pillars of TPM

Now let us discuss the 8 pillars of TPM, which will help in increasing OEE briefly.

Pillar 1—5S

All the 5Ss are to be used to reduce down time of plant and machinery as well as to improve OEE.

Pillar 2—Jishu Hozen (Autonomous Maintenance) (JHAM)

The organization should enable the operators to take responsibility for routine maintenance tasks and participate in improvement activities pertaining to TPM, in addition to their routine duties. This is the most difficult task since this requires changing mindset of the operators. This step can be achieved through training, coaching, rewards and awards. If every operator carries out the assigned routine maintenance correctly, it will dramatically improve down time of plant and machinery. The JHAM is aimed at the following:

1. Uninterrupted operation of equipment
2. Flexible operators who operate and carry out routine maintenance
3. Eliminating defects at source through active employee participation

Typical JHAM targets could be:

1. Reduce oil consumption by 40% in one year
2. Reduce cycle time by 30% in one year

Steps in JHAM

1. Train the employees.
2. Initial cleanup of machines.
3. Take counter measures
4. Fix tentative JH standards
5. General inspection
6. Autonomous inspection
7. Standardization and
8. Autonomous management.

Each of the above mentioned steps are discussed briefly.

1. **Train the employees**
   Train the employees about TPM, its advantages, JHAM advantages and steps in JHAM.
2. **Initial cleanup of machines**
   - Supervisor and technicians should fix a date for implementing clean up
   - Arrange all the items needed for cleaning
   - On the scheduled date, employees should clean the equipment completely with the guidance of the maintenance department.
   - Dust, stains, oils and grease have to be removed.
   - Oil leakage, loose wires, unfastened nuts and bolts and worn out parts are to be attended to during cleaning.
   - After cleanup problems are categorized and suitably tagged. White tags indicate problems, which can be solved by operators. Pink tag is placed where the aid of maintenance department is needed.
   - Contents of the tag are transferred to a register.
3. **Counter measures**
   - This is about measures to be taken to enable ease of maintenance.
   - To prevent wear out of machine parts, necessary action must be taken.
   - Machine parts should be modified to prevent accumulation of dirt and dust.
4. **Tentative standard**
   - JHAM schedule has to be made and followed strictly.
   - Schedule should be made regarding cleaning, inspection and lubrication and it should include details like when, what and how.
5. **General inspection**
   - The employees are trained in disciplines like pneumatics, electrical, hydraulics, lubricant and coolant, drives, bolts, nuts and safety. This is necessary to improve the technical skills of the employees and to use inspection manuals correctly.
   - After acquiring this new knowledge the employees should share this with others.
   - By acquiring this new technical knowledge, the operators are now well aware of machine parts.
6. **Autonomous inspection**
   - New methods of cleaning and lubricating are used.
   - Each employee prepares his own autonomous chart / schedule in consultation with the supervisor.

- Parts, which have never given any problem, or part, which don't need any inspection, are removed from list based on experience.
- Inspection that is made in preventive maintenance is included in JHAM.
- The frequency of cleanup and inspection is reduced based on experience.

7. **Standardization**
   - In this step the surroundings of machinery are organized. Necessary items should be organized, such that searching time is reduced.
   - Work environment is modified so that there is no difficulty in getting any item.
   - Everybody should follow the work instructions strictly.
   - Necessary spares for equipments are planned and procured.
8. **Autonomous Management**
   - OEE and other TPM targets achieved through *kaizen*.

Pillar 3—KOBETSU KAIZEN (KK)

The 16 major losses in an organization[1] are given in Table 18.1.

Table 18.1 16 major losses in an organization

Loss	*Category*
1. Breakdown loss 2. Set up / adjustment losses 3. Cutting blade loss 4. Start up loss 5. Minor stoppage / Idling loss. 6. Speed loss-operating at low speeds. 7. Defect / rework loss 8. Scheduled downtime loss	Loses that impede equipment efficiency
9. Management loss 10. Operating motion loss 11. Line organization loss 12. Logistic loss 13. Measurement and adjustment loss	Loses that impede human work efficiency
14. Energy loss 15. Die, jig and tool breakage loss 16. Yield loss	Loses that impede effective use of production resources

KK focused equipment improvements reduces and finally eliminates these losses. KK should be aimed at improving the efficiency in utilization of the following:

- Equipment
- Operator
- Material
- Energy

Cross-functional teams comprising of employees in production, maintenance engineering and operators should take up KK projects to minimize equipment losses.

Pillar 4—Planned Maintenance (PM)

This pillar aims at planned maintenance such as periodic maintenance and predictive maintenance to enable the following:

- Zero equipment breakdown
- Improve reliability and maintainability of equipment
- Reduce maintenance costs
- Ensure availability of spares at all times

Pillar 5—Quality Maintenance (QM)

QM activities are aimed at setting equipment conditions that will facilitate production of quality products. QM is aimed at the following:

1. Defect free conditions and control of equipment.
2. Provide support to quality assurance.
3. Focus on prevention of defects at source.
4. Focus on poka-yoke (mistake proofing system).
5. In-line detection and segregation of defects.
6. Effective implementation of operator quality assurance.

Paka–Yoke Pake-yoke is using methods or automatic devices to avoid human error. Shigeo Shingo, a Japanese engineer who developed TPS, developed it. This approach for mistake proofing is based an the following:

1. Prediction that a defect is likely to occur and giving a warning.
2. Stopping the process after recognizing that a defect has occurred.

The paka-yoke techniques are simple, but based on creative thinking. For instance, the number of drilling operations that takes place in a printed circuit board can be counted in a device. It should give an alarm when the PCB is removed without drilling the correct number of holes. This will help in improving quality. This is an example of paka-yoke technique. These techniques are generally inexpensive.

Mistake-proofing techniques are simple. Some examples will illustrate this concept.

Problem:	Letters intended to one customer was inserted in an envelope addressed to another.
Mistake-proofing solution:	Use window envelopes.

Pillar 6—Training

This pillar focuses on improvement of knowledge, skills and techniques of the multi-skilled revitalized work force.

Pillar 7—Office TPM

Office TPM is aimed at improving quality, productivity and efficiency in the administrative functions and identifying and eliminating losses. This includes analyzing processes and procedures towards increased office automation. Office TPM should eliminate twelve major losses as given below:

1. Processing loss
2. Cost loss including in areas such as procurement, accounts, marketing and sales leading to high inventories

3. Communication loss
4. Idle loss
5. Set-up loss
6. Accuracy loss
7. Office equipment breakdown
8. Communication channel breakdown, telephone and fax lines
9. Time spent on retrieval of information
10. Non availability of correct on-line stock status
11. Customer complaints due to logistics
12. Expenses on emergency dispatches/purchases

Pillar 8—Safety Health and Environment

This should enable zero accident, zero health problems and zero fire accidents.

THE RESULTS OF TPM

Ford, Eastman Kodak, Dana Corp., Allen Bradley and Harley Davidson are just a few of the companies that have implemented TPM successfully. All report an increase in productivity using TPM. Kodak reported that a $5 million investment resulted in a $16 million increase in profits, which could be traced and directly contributed to implementing a TPM program[2]. Texas Instruments reported increased production figures of upto 80 per cent in some areas. The TPM companies reported reduction in down time, reduced spare parts inventory, and increased on-time deliveries.

CASE STUDY 1

Total Productive Maintenance Case Study[3]

MRC Bearings' TPM Journey

In 1996 MRC Bearings, a unionized aerospace industry supplier, recognized it had a problem. They were behind on their orders. Their customers were pushing for shorter lead times and cost reductions.

Approximately 80 per cent of their maintenance hours were dedicated to emergency work orders. In October 1997, over 1660 hours were consumed by unplanned maintenance in just one area. Ten months later that number fell to less than 30 hours. That's over a 98 per cent decrease.

In another area they were able to achieve almost a 99 per cent decrease in the number of unplanned maintenance hours in an eight-month period. Greg Folts, Manager of Continuous Improvement at MRC attributes their remarkable success to having a hardworking, dedicated maintenance team and implementing a Total Productive Maintenance (TPM) program.

"We started slow, beginning with a small area that was critical to our process but was experiencing chronic problems", said Folts. "At first, a lot of people were skeptical and not really interested in getting involved with TPM", he said. "We had a core of people who were excited about TPM and we enlisted the help of people outside of our organization to work with us", Folts said. MRC worked with Preston Ingalls, President of Marshall Institute, to organize their TPM efforts. He continued, "Preston helped us get started, but he was also our best cheerleader. He got our folks fired up about TPM". One of MRC's customers, Pratt-Whitney, also supported their efforts by facilitating MRC's first TPM event and sharing their TPM practices with MRC.

MRC began with a week-long TPM event. Folts explained they would begin by cleaning, inspecting, lubricating, and performing corrective work on a piece of machinery. Once a machine was cleaned, it would be painted. At first, people were reluctant to participate in TPM events. As time went on, people began to notice what improvements were being accomplished under the TPM events. “In fact, the same people that were hesitating in the beginning were suddenly asking when their machine would be scheduled for a TPM event,” Folts said.

Rick Staples, an electrician that has been involved with TPM since it’s inception said, “The physical changes are easy to see. Our machines are more reliable, the area is cleaner and have a lot more pleasant atmosphere to work in.

MRC formed Equipment Improvement Teams (EITs) to work on resolving equipment-related issues. Folts credits the EITs with a success that was critical in their adoption of TPM.

After the initial success, followed by eight TPM events, MRC expanded their TPM efforts to their second facility. They created a TPM Steering Committee at their second site and also created a policy group to coordinate the efforts of both the facilities. The President of MRC Bearings, Bengt Nilsson joined the policy group as an active member. “Having the company president working with us to drive TPM sent a clear message to everyone that this was not just another flavor of the month program”, said Folts.

Don Russell was then solicited to assist in driving the process as the TPM coordinator. “We have been very fortunate to have a fantastic support from both the management as well as our U.A.W. union personnel,” said Russell. In a recent MRC company newsletter, President Nilsson is pictured shoulder to shoulder with the TPM area coordinators. TPM at MRC has been described as one of the most successful co-management programs ever started at MRC. Mr. Nilsson said, “I am very pleased and proud of how the whole organization, after the initial skepticism and hesitation, enthusiastically embraced the TPM concept. It is of utmost importance to have reliable and well maintained machinery in order to serve our customers well and to get on-time deliveries. A well developed TPM program is one of the cornerstones in our drive for manufacturing excellence.”

MRC trained ten TPM area coordinators who are dedicated to TPM one week each month. These TPM coordinators organize TPM events in their areas, also lead EITs, and make sure the process keeps working. MRC has begun to create full-time TPM teams.

Folts and Russell attribute their success in implementing TPM to seven things. Russell said, “We realized early on that we couldn’t do it all. So we identified a few areas that we felt were key, we did those things, and we did them well”. The areas that MRC focused on were:

Preventive Maintenance

1. Putting predictive maintenance process in place (i.e. vibration analysis equipment)
2. Cleaning the machines, resulting in inspection
3. Creating standards on the equipment cleaning, lubrication, and daily checks
4. Collecting data on downtime
5. Creating equipment improvement teams
6. Creating TPM area coordinators

Folts said, “We learned that training is a key to being successful with TPM. We did some initial TPM awareness training for the organization, about one week of training for the operators, and some for the mechanics. But, looking back we could have had quicker success if we had done more training.” Folts also credits their success to the support of their management, the U.A.W. union, the hard work of the people at MRC, involvement of Marshall Institute, and the support of their customers. “Ultimately this is a people issue and we are lucky to have the right people involved,” he said.

Thinking back about the initial resistance to TPM, Don Russell laughs and says, "At first a lot of folks here defined TPM as 'Totally Painted Machines'. Now I can say we all define TPM as 'Taking Pride in our Machines'."

CASE STUDY 2

TPM initiative of Essar Engineering – Moulded Rubber Components Manufacturing[4]

The Company:
Essar Engineering and Food Products Pvt. Ltd., is pioneering auto component manufacturing and moulded rubber parts manufacturing company. The auto component division is located at Chennai and rubber parts manufacturing division is located at Mayiladudurai, Tamil Nadu, India. Both the divisions of Essar are certified to ISO 9001:2000 and the rubber part division is presently implementing Total Productive Maintenance (TPM).
The Process:
The moulded rubber component manufacturing company having the process of raw material procurement and mixing the products as per the requirement in a mixing mill to form a compound. The compound is then moulded in a moulding press with the help of moulds to form the required shape. Trimming process is carried out to remove the extra material and finally all the products are checked 100 per cent by visual inspection before the product is packed and dispatched.
Present Level:
Since the company is certified to ISO 9001:2000, the top management has a clear overview of the processes. Department objectives were also set and the process measures were reviewed during the management review meetings conducted once in three months.
Kick-off:
The top management decided to improve on the organization's overall performance by implementing TPM. The Managing Director kicked off TPM on 2nd January 2004. During the occasion, Mr. Suresh Kumar, Managing Director and CEO briefed that by implementing TPM, the company aims at becoming world class in all areas of its activity.

He brought out the following during his kick-off meeting:
Aim of TPM:
To restructure the corporate culture through improvement of human resources and plant equipment.
Improving Human Resource:
Educate and foster employees so that they can respond to the needs of existing requirement

- Operator—Ability to perform "Jishu-Hozen"
- Maintenance Man—Ability to perform high-quality maintenance
- Production In charge – Ability to execute maintenance-free equipment plan

Improving Plant Equipment:

- Attain efficiency through revamping of the existing equipment

TPM Consultant conducted introductory training program and targets and action plans were discussed and decided during the meeting. The TPM Consultant highlighted the following requirements for practicing TPM:

- To set a goal to maximize equipment efficiency (overall efficiency)
- By establishing a total system for preventive maintenance for the entire life of equipment
- Participation by all departments, including equipment planning, operating and maintenance departments.
- Involving all personnel, including top personnel to first-line operators.
- For promoting preventive maintenance by motivation management, namely, by autonomous small-group activities.

The following targets were set:

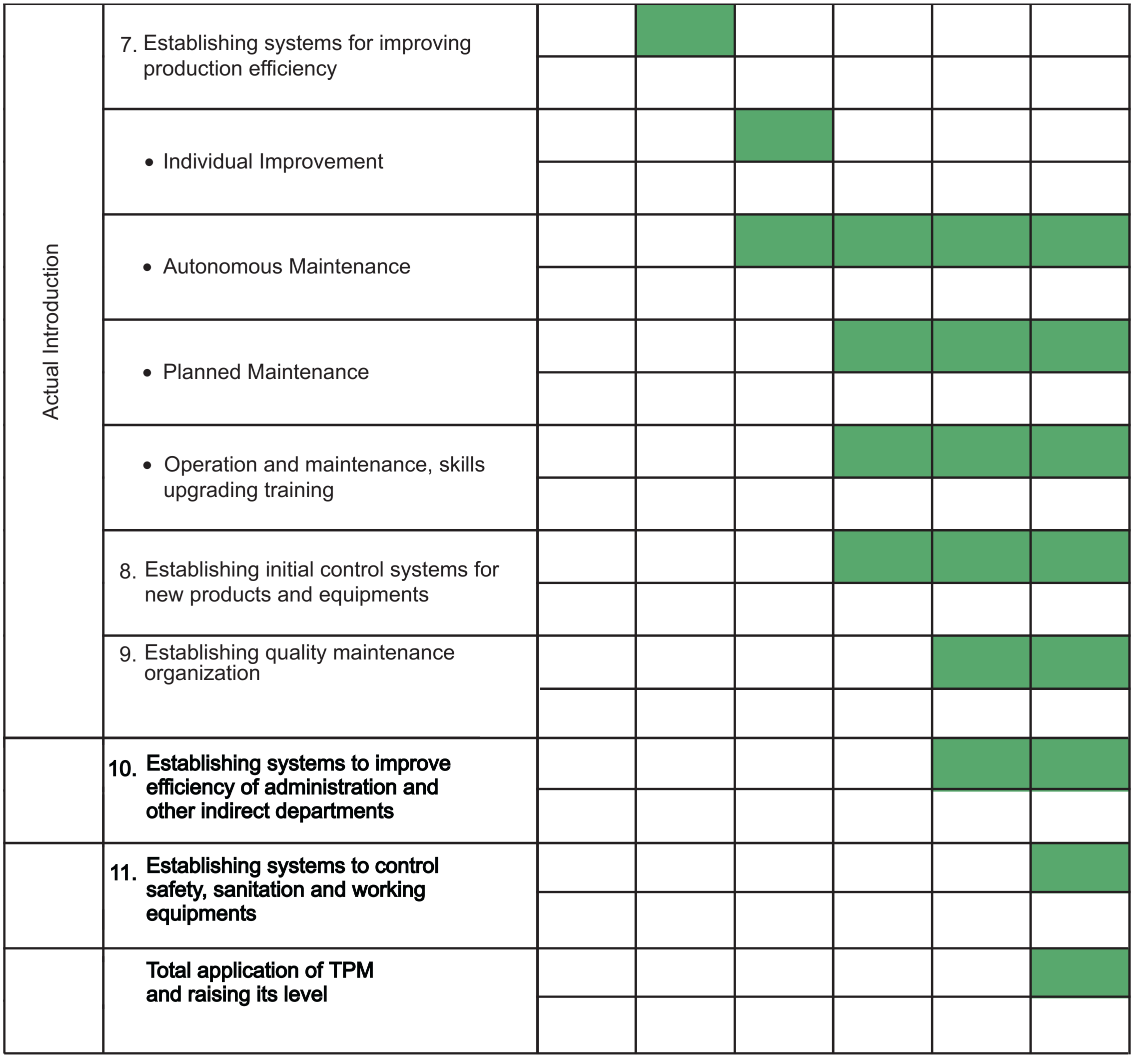
#	*Parameter*	*Present Level*	*Initial Target Level*	*Improvement Target Level*
1	Reduction in equipment failure	25 Hr / Month	5 Hr / Month	0 Hr / month
2	Overall Equipment Effectiveness	54 %	65 %	78 %
3	Improvement in productivity	70 %	80 %	90 %
4	Reduction of rework	1%	2000 PPM	500 PPM
5	Number of *kaizens* (employees suggestion)	DNA	10 / month	50 /month

Policy for TPM was set and the same were affixed in an identity card of all the employees and distributed to all.

Detailed action plan was prepared for deployment of TPM. The same were discussed and explained to all the employees.

Stage	*Steps*	*Month I*	*Month II*	*Month III*	*Month IV*	*Month V*	*Month VI*
Preparations for Introduction	1. Declaration by top management to introduce TPM						
	2. Introductory training and campaign for TPM						
	3. Establishing TPM promotion organization						
	4. Setting basic principles and target for TPM						
	5. Creation of master plan for establishing TPM						
Introduction	6. Kick-off of TPM						

(*Contd.*)



Action Carried out:

1. PM Circle was formed and PM Leader was fixed for each team.
2. Teams were identified to look into the seven major losses of the equipment.
   a. Loss on account of breakdown
   b. Loss on account of change-over and adjustment
   c. Loss on account of tool-change
   d. Loss on account of start-up
   e. Loss on account of minor stoppages
   f. Loss on account of reduced speed
   g. Loss on account of defects and repairs

The losses were measured for a period of one month and data relating to the same were summarized and a Pareto chart was drawn.

#	*Type of Loss*	*Breakdown Hours*
1	Loss on breakdown	50 Hrs
2	Loss on change – over and adjustment	20 Hrs
3	Loss on tool change	36 Hrs
4	Loss on start-up	15 Hrs
5	Loss on minor stoppages	43 Hrs
6	Loss on reduced speed	10 Hrs
7	Loss on defects and repairs	10 Hrs

The equipment losses were calculated and countermeasures for chronic losses were studied.

Following are the steps that were followed to achieve Zero-Breakdown:

1. Uncover all hidden defects which are the basic cause of breakdown.
2. Maintaining basic conditions
3. Adhering to operating conditions
4. Restoring deterioration
5. Improving the skill / expertise

Small Group Activity (SGA) was formed and *kaizens* were initiated in all the areas. Each team was motivated to be successful in all the area of *kaizens*. About 10 *kaizens* were received in the first 20 days and were towards productivity improvement and quality improvement. Suggestion box were placed in all appropriate places and best suggestion were rewarded.

Individual Improvement:

Training was imparted to acquire four important skills for all operators.

1. To have the capability of judging an abnormality
2. To take an immediate speedy correct measures
3. Quantitative fixation for determining standards
4. Follow the rules in letter and spirit, once decided.

Self-Initiated Maintenance:

Operators and all appropriate personnel carrying out production were trained to initiate self-maintenance of their responsible machines

Individual Improvements:

Each operator and other production related personnel were trained for the following whenever a breakdown occurs:

1. Why the breakdown has occurred?
2. How and what are the causes for breakdown?
3. Investigation and facts related to breakdown
4. Corrective measures to avoid recurrence

Effectiveness of TPM

TPM activities were measured and data related to all set targets were monitored.

The effectiveness that were evidenced after six months were the following:

P		Productivity improvement	1.5 – 2 times
	•	Reduction in number of sporadic failures	1/10 to 1/250
	•	Equipment operating	1.5 – 2 times
Q		Reduction in product defects	1/10
		Reduction in customer claims	1/4
C		Reduction in maintenance cost	30%
D		Increase in delivery performance	30%
S		Reduction in accident and elimination of pollution	50%
M		Increase in number of employee suggestions	5 – 10 Times

Intangible Effects of TPM

- After introduction of autonomous maintenance activity, operators take care of machines by themselves without being ordered to
- With achievement of zero breakdowns and zero defects, operators get new confidence in their own abilities
- Workplaces that used to be covered with oil and chips are now so clean and pleasant that they are almost unrecognizable
- Improved image of the company, leading to the possibility of increased orders.

SUMMARY

Maintenance of plant and machinery is as important as TQM, rather it is also a TQM strategy. Periodic maintenance and predictive maintenance are preventive maintenance activities. These are carried out to prevent breakdown maintenance. TPM is a modern maintenance program. The TPM is aimed at increasing production while improving employee morale and job satisfaction. A Japanese company Nippon Denso, which is a major supplier to Toyota Motors, developed TPM. This was added as one of the four elements of Toyota production system, the others being TQC, JIT and TEI. The overall equipment efficiency (OEE) is the product of availability, performance efficiency and quality rate. The improvement in OEE will result in direct profit. Thus, it is essential to improve OEE. Japanese suggested 8 Pillars to OEE as given below:

- JHAM
- KK
- PM

- QM
- Education and training
- Office TPM
- Safety, Health & Environment
- 5S

Practicing TPM by using the 8 pillars results in dramatic improvements in the organization, although it is not a cakewalk. Thus, TPM is one of the essential techniques to be adopted by every organization.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. TPM is
   (a) TQM (b) TQC
   (c) Preventive maintenance (d) None of the above
2. Toyota Production System elements include
   (a) JIT (b) TPM
   (c) TEI (d) All the above
3. Availability is
   (a) MTTR / MTBF (b) MTBF–MTTR
   (c) 1 – MTTR/MTBF (d) All the above
4. 16 major losses include
   (a) Speed (b) Logistic
   (c) Yield (d) All the above
5. 12 major losses of office TPM include
   (a) Accuracy (b) Set up
   (c) Processing loss (d) All the above

II. Say True or False

1. TPM is similar to TQM.
2. TPM is only about reducing down time of equipment.
3. TPM requires worker participation.
4. Preventive maintenance reduces equipment breakdown.
5. SHAM mean involving operators for maintenance.
6. KK reduces major losses.
7. 5S is one of the pillars of TPM.
8. Predictive maintenance is based on data.
9. Daily maintenance is not required.
10. Quality loss also decides OEE.
11. OEE should be 0 per cent.
12. Paka-yoke is applying sophisticated automation for mistake proofing.
13. TPM is aimed at reducing 16 losses of office TPM.

14. Cross functional teams are required for TPM.
15. TPM is everyone's responsibility in the organization.
16. TPM does not increase profits.

III. Match the following

JISHU HOZEN	Mistake proofing
KK	Speed efficiency
Office TPM	Autonomous maintenance
Performance Efficiency	12 losses
Planned Maintenance	Predictive maintenance
Paka-yoke	16 losses

IV. Explain briefly

1. Organization's 16 major losses.
2. 12 losses associated with office.
3. Applying 5S for TPM (use the concepts learnt in Chapter 8)
4. Preventive maintenance.
5. History of TPM.
6. OEE.
7. 8 Pillars of TPM.
8. JHAM.
9. Kobetsu Kaizen.
10. Paka -yoke.
11. TPM results.

V. Find overall equipment efficiency in the following cases

1. Plant is operating in three shifts. Data for 28 days are given below:
   Time not available due to various reasons is 84 hours
   - Produced 40,000 items
   - No. of defectives 400
   - Operating speed 80%
   - Capability of the process 44,000 pieces in 28 days
2. Data same as above, but speed increased to 90 per cent. Find out OEE
3. Find out OEE if the speed is increased to 95 per cent in the above case.
4. Find out OEE in the following case:
   Plant operating on a three shift basis.
   Data for a week is given below:
   - Time not available 21 hours
   - Units produced 10,000 pieces
   - No. of defectives 2000 pieces
   - Machine operated at 90% speed
   - Capability of process is to produce 11,000 pieces

5. Find out OEE if in problem Δ above, if the no. of defectives get reduced to zero.
6. Compare result of problems 4 and 5 and comment on it.

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Chapter 19

Failure Mode and Effects Analysis (FMEA)

Hard work pays!

INTRODUCTION

TQM strategy for success of organizations is to design in quality and reliability in the products or services early in the development cycle. Failure Mode and Effects Analysis (FMEA) is a methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome these issues, thereby enhancing reliability through design. FMEA is a bottom up approach. It is used to identify the potential failure modes on the parts or components, determine their effect on the operation of the product, and identify actions to mitigate the failures. A crucial step is anticipating what might go wrong with a product due to failure of its parts. While anticipating, every failure mode of every component may not be possible, the development team should formulate a comprehensive list of potential failure modes.

The early and consistent use of FMEAs in the design process allows the engineer to design out failures and produce reliable, safe, and quality products that will lead to customer delight. FMEA also captures historical information on failure analysis for use by the design teams in the future.

RELIABILITY

In Chapter 1, we identified reliability as one of the dimensions of quality of a product or service. The buyer expects that the product or service will satisfy the requirements for quite sometime or a specified period of time, say 10 years. The measure of the probability of the item satisfying the customers at a given time 't' is described by the term reliability. Thus, reliability is quite an important characteristic of any product. Reliability can be defined as:

> *"Reliability of an entity is defined as the probability that a product or a system will perform its intended functions for a specified period of time, under the stated operating conditions".*

Thus, reliability is a measure of the ability of a product to function as intended at a given time. It is time dependent. Since reliability of any product at any given time is a probability, it will be equal to or less than 1.

BATHTUB CURVE

Most of the industrial products depict the human failure pattern as given in Fig. 19.1.

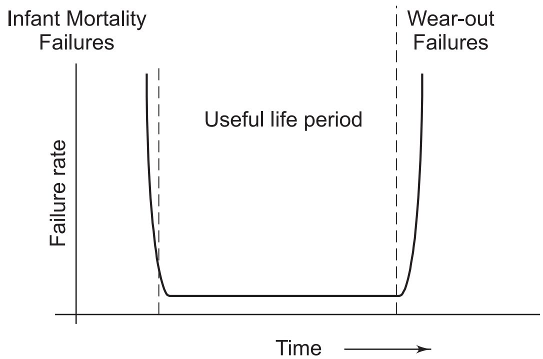

Figure 19.1 Failure Rate Curve

A bathtub curve is a graph of failure rate over time. There are three regions in the graph. The region 1 is called infant mortality failure region. As we know, the failure is relatively high during the infant stages even in human beings. Similar phenomena can be expected in every manufactured product. The region 3 is called wear-out period. During the wear-out period, since the product's life has been utilized fully due to wear and tear, product fails rapidly. The period in between, i.e. region 2 is called useful life period of the product. This could be even of the order of 20 years for electronic products or 10 years for an automobile product. The shape of the curve may also vary with type of the product. The products when sold should have crossed the infant mortality period, which is achieved by the industries through burn-in tests or stress screening. Smart manufacturers remove those products, which could fail due to infant mortality and deliver the products in the useful life period where we expect fewer defects. These defects will be due to random causes. Region 2 is also called constant failure rate region since the failure rate will be nearly constant.

Probability Density Function (PDF)

Reliability is a probability of survival of a product. The survival or success of a product can be characterized by a random variable. There are two types of random variables as given below:

- Continuous
- Discrete

A function $f(x)$ is said to be the probability density function of a continuous random variable x, if x takes any value from –infinity to + infinity such that

$$f(x) >= 0 \text{ and integral of } f(x)\, dx = 1.$$

Normal distribution, exponential distribution, etc. are examples of probability density functions of continuous random variable. The probability density function for an exponential distribution is given in Fig. 19.2.

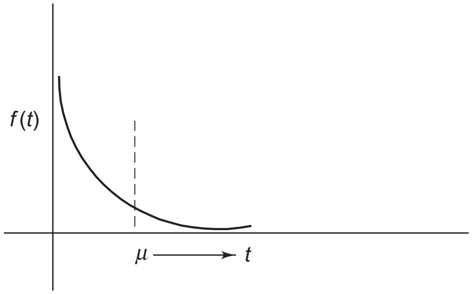

Figure 19.2 Exponential Probability Density Function

The pdf of the above exponential distribution can be expressed as:

$$f(t) = \lambda e^{-\lambda t}$$

where $\lambda = 1/\mu$

and μ is the mean.

In the reliability context, we can call μ as the mean time between failures and λ as the failure rate.

Hazard Function

The hazard function is a measure of tendency of a product failure. If the value of the hazard function is high, then the probability of failure will be greater. The hazard function of an exponential distribution is shown in Fig. 19.3.

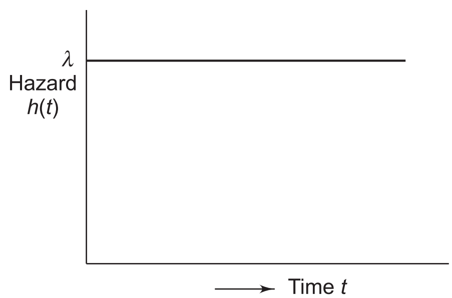

Figure 19.3 Hazard Function for Exponential Distribution

$h(t) = \lambda$ and it is a constant in the case of exponential probability distribution.

Reliability Equation

The reliability can be mathematically described as:

$$R(t) = f(t)/h(t)$$

where $f(t)$ is the probability density function and $h(t)$ is the hazard function. All the three of them vary with time.

We know that in the case of exponential pdf

$$f(t) = \lambda e^{-\lambda t}$$

$$h(t) = 1$$

Therefore,

$$R(t) = e^{-\lambda t}$$

$$\lambda = \text{failure rate or hazard rate}$$

$$\lambda = 1/\mu$$

A plot of reliability with time when the failure pattern follows exponential distribution will appear as given in Fig. 19.4:

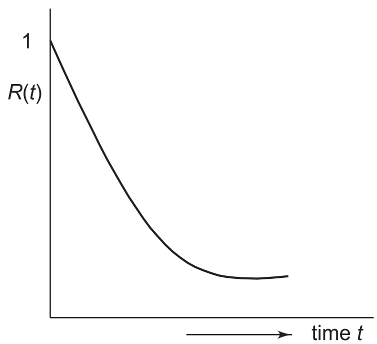

Figure 19.4 Reliability

μ is also called θ. μ represents the mean time between failures. Since the exponential distribution describes constant failure rate, it can be linked to our bathtub curve. Exponential distribution represents the constant failure rate region in the curve. It is an important assumption for FMEA of electronic products. Essentially, $R(t)$ in our example refers to the instantaneous reliability at any time. Reliability is the probability of the equipment functioning satisfactorily. At time $t = 0$, the reliability that is the probability of the equipment functioning satisfactorily is 1. This is clearly depicted in Fig. 19.4.

As time increases, the reliability goes down. As time goes to infinity, the reliability = 0.

Let us take an example to understand reliability. We will assume that the probability of success follows exponential distribution.

Example 19.1

Given λ = failure rate = 0.0001 per hour. Find out the reliability of the product at 1000 hours and 10,000 hours.

At 1000 hours

$$R(1000) = e^{-\lambda t}$$

$$= e^{-0.0001 \times 1000}$$

$$= e^{-0.1}$$

$$= 0.90483$$

$$\text{At time } t = 10{,}000 \text{ hours}$$

$$R\,(10{,}000) = e^{-0.0001 \times 10000}$$

$$= e^{-1}$$

$$= 0.37$$

Thus, the reliability at 10,000 hours is lower than the reliability at 1000 hours. This has to be expected.

Failure Rate

We know that hazard rate is the same as failure rate. Failure rate indicates the number of failures per unit time. In the case of an exponential distribution, the failure rate is constant. This is expressed as λ. Failure during constant failure rate is due to random causes or chance causes. Hence, it is also called chance failures.

FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

Let us look at some related definitions first:

Failure Cause The physical, chemical, metallurgical, design defects, quality defects or other processes, which are the basic reasons for failure or which can initiate the physical process by which deterioration leads to a failure.

Failure Mode It is the observed result of failure. It is the way in which a failure is observed. Failure mode describes the way the failure occurs.

For instance, open circuit and short circuit are electrical failure modes. Rusting, breaking, etc. are also failure modes.

Failure Effect FMEA is all about studying the effect of failure of components or parts of the system. For instance, it is the study of the effect failure of carburetor on the car or the effect of failure of a pulley on a crane. The FMEA can be described as shown in Fig. 19.5:

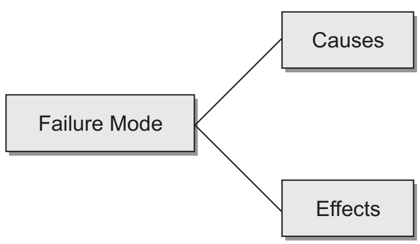

Figure 19.5 FMEA in a Nutshell

FMEA is the study of consequences of a failure mode on the operation, function or status of a system or equipment.

FMEA

FMEA is defined as *"a systematic group of activities intended to: (a) Recognize and evaluate the potential failure of a product/process and the effects of that failure, (b) Identify actions that could eliminate or reduce the chance of the occurence of potential failure"*.

Failure mode indicates the modes of failures of a part or sub-assembly. The effect indicates the effect of failure of a part in any of the modes, on a system. Therefore, FMEA is intended to identify failures of parts or components, which have significant consequences on the system in which it is used. For instance, a fan is mounted using a bracket fixed to a hook in the ceiling. If we analyze what are the failure modes of the bracket and list out the consequences we will be able to conclude correct analysis of the various failure modes. Any failure due to any of the modes may affect the system performance adversely. The FMEA is useful for studying the failure modes, failure causes and their effects on the system as well as taking appropriate preventive actions. It is a reliability evaluation / design technique and it examines the potential failure modes within a product or a system. In order to determine the effects on the equipment each potential failure mode is classified according to its impact on the mission success (successful operation of the system) as well as personnel and equipment safety. FMEA can be carried out qualitatively as well as quantitatively. The FMEA is an advanced technique for review of designs by considering the failure modes of various components, their causes and the effect of these failures on the systems or products on which these components are used. Thus, it will lead to eliminating the weaknesses of design as well as improving the reliability of the products.

Purpose of FMEA

The purpose of FMEA are:

- Enables structured analysis of the design for identifying potential failure modes
- The FMEA examines the potential failure modes, which have a high likelihood of occurrence
- Each failure mode is analyzed to find out their causes
- Develop product or process requirements that minimize the likelihood of those failures
- Ensure that any failure that could occur will not injure or seriously impact the user
- Helps in preparing for unavoidable failures and thus increases the competitiveness for maintenance of the product

The designer should minimize the causes that will lead to the failure of the components in the particular mode. The designer should also take action to minimize the effect of the failure of the component in the given mode on the system.

Benefits of FMEA

The benefits of FMEA are:

- Minimizes late changes and associated costs since FMEA will be earned out right at the design stage
- Identifies failure modes which will have a significant impact
- Identifies the causes of failures and minimizes them
- Helps in redesigning to reduce the effect of the failures
- Improves product reliability, maintainability and availability of the system
- Increases customer satisfaction
- Prioritize product / process deficiencies for improvement

- Emphasizes problem prevention
- Provides information on the following:
  - Maintainability analysis
  - Safety analysis
  - Survivability
  - Vulnerability
  - Logistics support analysis
  - Maintenance plan analysis
  - Risk analysis
  - Failure detection
  - Failure isolation

Types of FMEA

There are five types of FMEA as given below:

- System—focuses on global system functions
- Design—focuses on components and subsystems
- Process—focuses on manufacturing and assembly processes
- Service—focuses on service functions
- Software—focuses on software functions

Design FMEA The design FMEA is an analytical technique used by FMEA teams to ensure that to the extent possible, potential failure modes and their causes / mechanisms are considered and addressed before the design is frozen. The hierarchy of the system has to be understood before taking up the task. A simple hierarchy is given in Fig. 19.6.

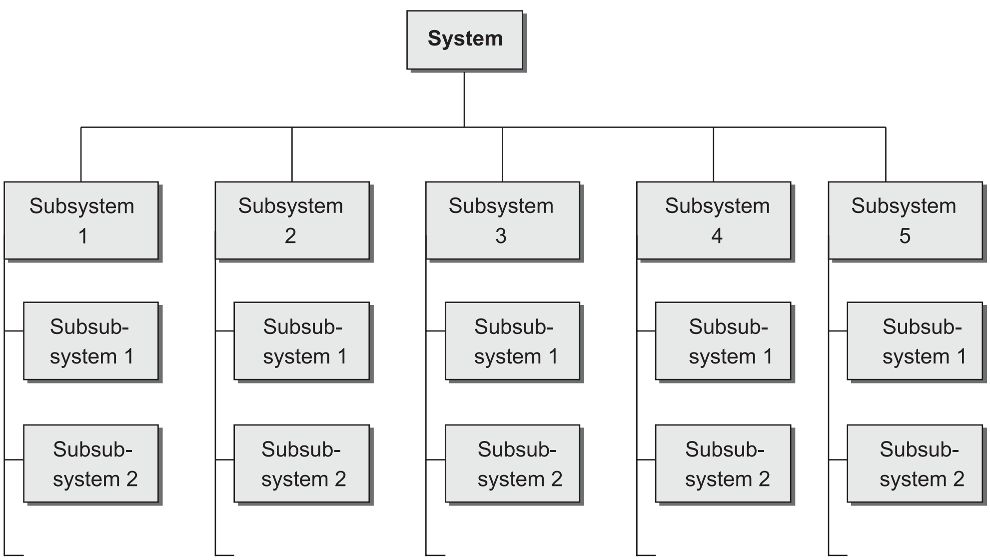

Figure 19.6 Hierarchy of systems

FMEA Reference Manual for an Automotive Industry American Society of Quality (ASQ) and AIAG task force brought out in addition to QS 9000, a set of related documents. One of them is Failure Mode and Effects Analysis (FMEA) Reference Manual. This document has been revised and the 3rd edition[1] was issued in July 2001. This document gives guidelines for design and process FMEA, which are applicable to the automotive industries. The FMEA reference manual gives the process sequence for FMEA.

FMEA Team Since FMEA is an advanced technique and also a complex task, a competent team has to be constituted to carry out FMEA of each design or process. Design knowledge (Process knowledge in the case of Process FMEA) and reliability knowledge are the essential pre-requisites to be a member of FMEA team. The duly authorized FMEA team with a facilitator carries out design or process FMEA.

FMEA RISK PRIORITY NUMBER (RPN) TECHNIQUE

The QS 9000 standards brought out a technique for FMEA based on RPN number. This is a quantitative technique. It helps in finding out the risk and action plan for reducing the risk. We will look at the RPN method popularized by the automobile industry.

Risk Priority Number (RPN)

The risk priority number is the product of the severity (S) of the effect of a failure, probability of occurrence (O), and ease of detection (D) rankings for each failure mode of each part or component.

$$\text{RPN} = (S) \times (O) \times (D)$$

The FMEA team assigns a number up to 10 for each of the above for each failure mode. If the severity is the least it gets 1 and if too severe it gets 10. Similarly, if probability of occurrence is almost nil the team assigns a value of 1 and 10 if it is too high. If the detection is too simple, detection gets a rank of 1 and if it is too difficult to detect, it gets a value of 10. The higher the product, the RPN, more risky is the corresponding failure mode.

The essential tasks to be carried out in FMEA are:

- Determine the functions of design or process, its features or requirements

Once the above step is completed, the team can determine the following:

(i) What can go wrong is the potential failure mode of the parts or components
(ii) Once the failure modes are identified, the FMEA team determines the effects of the failures. Depending on how bad could be the severity of the effect, the team assigns a severity number.
(iii) The causes of failure can be arrived at by the team for each failure mode
(iv) Once the causes are identified, the team has to determine how they can prevent the failure causes and how they can be detected
(v) The ease of detection determines the detection number.
(vi) How often it happens determines the ranking for the probability of occurrence or occurrence number.
(vii) The risk priority number is the product of the numbers for severity, occurrence and detection
(viii) Once the RPN number is arrived at and if it is high, the FMEA team has to suggest an action plan for the following:
    - Design changes
    - Process changes
    - Changes to procedures, etc.

FMEA RPN Procedure

A 15-step procedure for carrying out FMEA by the RPN methodology is described below. We will take an example of a fan assembly to explain the procedure.

Centre For Reliability (CFR), India has developed a software tool for FMEA called CFR-FMEA RPN. The tool facilitates carrying out FMEA as per QS 9000 requirements. Let us use the tool to carry out FMEA of a fan system and explain the FMEA procedure side by side.

Step 1 **Define the product/process and its functions**, for which FMEA has to be carried out. The FMEA team should understand the design of the product as well as the functions of each sub-assembly. It is also important to document both the intentional and unintentional use of the product.

Step 2 **Construct the reliability block diagram of the product/process**. This diagram should bring out clearly the block diagram of the system under analysis from the reliability perspective. The diagram should show major components or process steps as blocks connected together by lines, which will indicate how the components or the process steps are related. The diagram should bring out the logical relationships of the components and establish its structure around which the FMEA can be developed. The FMEA team should establish a coding system to identify system elements.

The reliability block diagram of a fan assembly, whose FMEA we are going to carry out, is given in Fig. 19.7 below:

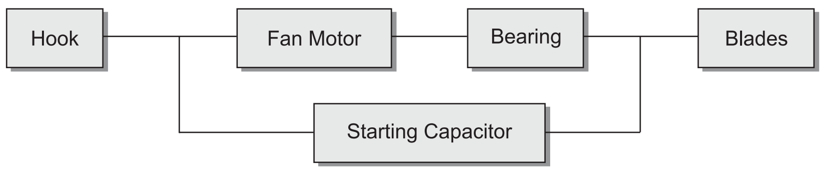

Figure 19.7 Reliability Block Diagram

Step 3 **Complete the header on the FMEA worksheet.** It can be entered in the tool directly. The team has to enter the details as per the format provided with the tool. The header consists of a number of items. Some of them are described below:

- System (Name): Ceiling fan
- FMEA NUMBER (Reference) Document No.: This is a unique document number for the analysis of the specific system. It is used for tracking purposes: 1
- SUBSYSTEM: ELECTRICAL

The details for our example are filled up and shown in Table 19.1.

Step 4 **List the part along with its functions** in column 1 — The block diagram drawn in Table 19.1 should be used to list the items in a product or functions in a process, one by one. If the items are components, then they are to be listed in a logical manner under the subsystem / assembly based on the block diagram. For instance, the fan assembly contains two subsystems namely, electrical and mechanical. The parts in each subsystem are listed together.

Table 19.1 Potential Failure Mode and Effects Analysis

System	: Ceiling Fan	Sorted by (RPN)	FMEA NUMBER	:	1
Subsystem	: Electrical		FMEA Date	:	11/3/2004
Design Responsibility	: Jambu		Key Date	:	11/3/2004
Model Years	: 2001-02		Prepared by	:	Jambu

SEV = Severity; OCC = Occurrence; DET = Detection

Component Details/ Function	*Potential Failure Mode*	*Potential Effect(s) of Failure*	*SEV*	*CLASS*	*Potential Cause(s)*	*OCC*	*Current Design Controls Prevention*	*Current Design Controls Detection*	*DET*	*RPN*	*Recomm-ended Action(s) Including Life testing for 128 days*	*Responsibility & Target Completion Date*	*Action Results*				
													Action Taken	*SEV*	*OCC*	*DET*	*RPN*
Electrical																	
CI-Capacitor Starting fan	Shorted	External Electrical Circuit will be affected.	8	N	Short circuit	2	Nil	Nil	8	128	Carryout Type test Including Life testing for 128 days	Anil 11-04-2004	Capacitor type changed after analysis	8	1	8	64
C1-Capacitor Starting fan	Opened	Fan will not start	6	N	Excessive voltage	5	Nil	Nil	1	30	Carry out type test including life test for 128 days.	Anil 11-09-2004	Capacitor type changed after analysis	6	1	1	6
M01-Motor Gives force for Rotation of the Blades.	Coil burnt	Fan not rotating	5	N	Short Circuit	2	Nil	Nil	8	80	No action		Nil	5	2	8	80
Mechanical																	
H1–Hook Holds the fan and mounted on the roof	Broken	Fan failing at unex-pected time	10	N	Contamin-ation	5	Nil	Nil	5	250	Carry out corrosion test.	Jambu 12-04-2004	Use galvani-zed steel	10	1	5	50
BR1–bearing Couples the fan motor to the fixed assembly.	Out of adjustment	Speed variation	4	N	Improper alignment	5	Nil	Nil	4	80	No action for the present		Nil	4	5	4	80

SEV = Severity; OCC = Occurence; DET = Detection

REPORT GENERATED BY: CFR-FMEA –SOFTWARE PACKAGE

In the first column, pertaining to electrical subsystem, the following details pertaining to component details and its functions appear:

Component Details	C1–capacitor
Function	Starting fan

The first component for analysis is a capacitor called C1 in the electrical subsystem. The function of the capacitor is to start the fan.

Step 5 **Identify potential failure modes** — At this step, identify the potential failure modes for each component in each one of the block, or sub-assembly of a system.

Potential failure mode is a manner in which a component or a sub-system can potentially fail to meet or deliver the intended function. The potential failure mode can cause failure in the higher-level sub-system or system or it can affect another component in the same level of hierarchy. To identify the potential failure modes it may be useful to review the type of failures that happened in the past and carry out brainstorming. Some failure modes in vehicles are given below:

- Cracked
- Loosened
- Fractured
- Disengages too fast
- Intermittent signal
- EMC / RFI
- Deformed
- Leaking
- Oxidized
- Does not transmit torque
- Corrosion
- Electrical short circuit
- Electrical open circuit
- Torque fatigue
- Deformation

Each failure should be listed in technical terms. Failure mode should be listed for each item. The failure modes for a fan assembly are listed in Table 19.1. For instance, in the first row "shorted" is the potential failure mode. And in the third row "coil burnt" is the failure mode.

Step 6 **Potential Effects of Failure**

It is defined as effects of a part on each of its failure modes on the function of the system as perceived by the customer. It describes the failure in terms of what the customer might notice or experience. It can be internal customer or the ultimate end-user. Typical failure effects could be as follows:

- Noise
- Erratic operation
- Poor appearance
- Unstable
- Intermittent operation
- Inoperative

- Unpleasant odor
- Operation impaired
- Regulatory non-compliance
- Degraded performance
- Noise

The effects of each significant failure mode of each component has to be analyzed. Look at Table 19.1 in column 3. In our example, in the first row, we have stated "external electrical circuit will be affected" and in the second row we have stated "fan will not start". These are all failure effects of the respective failure modes.

Step 7 **Assign severity number for the effect** — A numerical ranking has to be given for the severity of the effect. A common industry practice is to use 1 to represent no effect and 10 to indicate very severe effect. The failure in each one of the failure modes may have varying severity level from catastrophic to simple. Severity of each one of these effects are to be analyzed. For instance, in our example in Table 19.1, the first row contains severity of 8 and the third row 5.

Step 8 **Classification —** This column is used to highlight high priority failure modes. This column can be used to classify any special product characteristics for components, subsystems, etc. that may require additional design or process control. For instance, critical, major, significant, etc. are some of the classifications. In our example, we have put N indicating nil.

Step 9 **Potential causes**

Now we have to identify the causes for each failure mode.

Potential cause of failure is defined as an indication of a design weakness, the consequence of which is the failure mode. The cause / mechanism should be listed as concisely and completely as possible so that corrective action can be aimed at pertinent causes.

Typical failure causes are given below:

- Incorrect material specified
- Over-stressing
- Insufficient lubrication capability
- Inadequate maintenance instructions
- Incorrect algorithm
- Improper maintenance instructions
- Improper software specifications
- Improper surface finish specifications
- Inadequate travel specification
- Excessive heat
- Improper tolerance specified

In addition, there could be typical failure mechanisms for some components or sub-system. Some of the failure mechanisms are given below:

- Fatigue
- Material instability
- Creep
- Wear
- Corrosion

- Chemical oxidation
- Electro migration

Look at column 6 of Table 19.1 to identify the potential failure causes of the parts of the fan assembly.

Step 10 **Probability of occurrence** — A numerical rank should be assigned to each cause that indicates how likely that cause will occur. 1 represents that the cause is not occurring and 10 represents that the cause is very likely to occur. Look at Table 19.1. The FMEA team has found that excessive voltage is more likely to occur and has given a rank of 5. It has found that short circuit is less likely to occur and hence given a rank of 2.

Step 11 **Identify current controls (design/process)** — The team has to list the prevention, design verification or other verification activities that have been completed. These activities are aimed at assuring the design adequacy for the failure mode and failure cause. These are the mechanisms that prevent the cause of the failure mode from occurring. Column No. 8 is to indicate the current controls for prevention and column No. 9 is to document the current design controls for detection. Since, in our example, there are no design controls currently, the team has indicated nil in both the columns.

Step 12 **Determine the likelihood of detection** — Detection is an assessment of the likelihood that the current controls will detect the cause of the failure mode or the failure mode itself. Based on the current controls, the likelihood of detection is to be entered in column No. 10. 1 in this column represents very easy to detect and 10 represents not at all possible to detect or no design control exists for detection. Look at Table 19.1. The probability of detection of various failures of components in the fan assembly vary from 1 to 8.

Step 13 **Assign Risk Priority Number** — Risk Priority Number is the product of the three factors as given below:

RPN = Severity × Probability of occurrence × Detection

The RPN is used to prioritize the items that require additional quality planning. The RPN number is indicated in column 11.

Step 14 **Determine the recommended actions** — In order to minimize the effects, the corrective actions are to be brainstormed and identified and documented in this step. Column No.12 gives the recommended actions, column No.13 gives the responsibility and target completion date.

Step 15 **Estimate the new ranks** — After the actions have been taken, the new numbers for the three factors are to be assigned. These are given in the next column. Thus, the corrective actions have reduced the RPN numbers wherever required.

Complete analysis comprising the above steps is to be documented as a FMEA report as given in Table 19.1.

The design FMEA aids in design process in reducing the risk of failures by the following tasks:

- Enabling objective evaluation of the design including functional requirements and design alternatives
- Considering the potential failure modes and their effects on the system, in the design process
- Providing additional information to aid in planning of thorough and efficient design, development and validation programs
- Bringing out a ranked list of potential failure modes according to their effects on the user, equipment, etc. thus enabling the prioritized system for design improvements

- Providing a format for recommending and tracking the contingency measures for reducing the risk

The design FMEA has to be updated constantly. It should be initiated before the design process and continued till the design is in use.

Process FMEA

The process FMEA is applied to improving the process in contrast with the design in DFMEA. The purpose is to ensure that the potential failure modes and the associated causes/mechanisms are considered and addressed in the appropriate form. The process FMEA addresses production operations. The potential process FMEA results in the following:

- Identifies the process functions
- Identifies potential product and process-related failure modes
- Assesses the effects of the potential failures on the customer
- Identifies the potential manufacturing or assembly process failure causes
- Identifies process variables on which to focus process controls for occurrence reduction or detection of the failure conditions
- Develops a ranked list of potential failure modes, thus establishing a priority system for preventive/corrective action considerations
- Documents the RPN of the manufacturing or assembly process

The format, approach, etc. of process FMEA are the same as design FMEA. However, the object is different in this case.

FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS (FMECA)

FMEA RPN is more popular in the automobile industry. However, FMECA is popular in the electronics and allied industries. FMECA consists of two parts as given below:

- Failure Mode Effects Analysis
- Criticality Analysis

In the following, the FMECA as per the international standards on the subject will be discussed.

Criticality Analysis (CA)

When the CA is combined with FMEA, the task is called Failure Mode Effects and Criticality Analysis. The FMEA worksheet can be transferred to FMECA worksheet. CA is a quantitative analysis. CA leads us to calculate what is known as failure mode criticality number (C_m).

$$C_m = \beta \alpha \lambda_p t$$

Where C_m = Failure mode criticality

β = Probability of mission loss or system not functioning

i.e. the system failure or not carrying out intended functions.

α = Failure mode ratio

λ_p = Failure rate of the component or part in number of failures per hour of operation.

t = Duration of applicable mission phase, i.e. period up to which the system is to operate. It is expressed in hours or numbers of operating cycles.

MIL –STD –1629 and IEC 812 are standards applicable for carrying out FMECA. A component may have one or more failure modes. For instance a rectifier diode has the following failure modes and corresponding probabilities of failures which is called failure mode ratio, as indicated in Table 19.2.

Table 19.2 Failure Modes of Rectifier Diode

Failure mode	*Probability* (α)
Short	0.51
Open	0.29
Parameter change	0.20

The data is reproduced from FMD - 91 document of Reliability Analysis Centre, USA. The diode has three failure modes and the corresponding probabilities of their occurrence are indicated. The FMECA team (team which carries out FMECA) should get this data from the data books available or use their failure analysis data to get the correct numbers. The sum of all the three probabilities is 1. α represents the fraction of the part failure rate (λ_p) related to the particular failure mode.

Failure mode distribution, namely α may not be available for specific part number. But the generic failure mode distribution is available from the following sources.

- Rome Laboratory Study of Part Failure Modes, L.J. Gubbins
- MIL-HDBK-338, "Electronic Reliability Design Handbook"
- RADC Non-electronic Reliability Notebook
- Naval Avionics Center Standard entitled "FMECA"
- Reliability and Maintainability in Perspective, D.J. Smith
- European Space Agency (ESA) Specification

Probability of Mission Loss (β) For each failure mode we have to calculate β. It is defined as the failure effect probability. The β values are based on the FMECA team's assessment as to the conditional probability that the anticipated loss of mission or failure of system will occur. It is the conditional probability since we assess the probability of the loss on the condition that the failure mode occurs. This subjective assessment of the FMECA team has to be converted into β value. MIL-STD 1629 gives the guidance for β value as given in Table 19.3.

Table 19.3 Typical Failure Effect Probabilities

Failure mode	*Probability* (β)
Sure loss	1.00
Probable loss	> 0.10 to < 1.00
Possible loss	> 0 to 0.10
No effect	0

The failure effects are brainstormed and a consensus arrived as to which of the four possibilities exist with reference to a particular failure mode.

Failure Rate (λ_p) The failure rate data for each part has to be calculated based on field failures. Alternately it can be taken from the handbook MIL–HDBK – 217 F "Reliability Prediction of Electronic Equipment". It is a good source for this data.

Let us look at some examples.

Example 19.1

For the rectifier diode, calculate the failure mode criticality number in each of the mode given that:

Failure rate = 0.123×10^{-6}

Operating time = 43,800 hours

Failure effect probability = 1 in all modes

Solution

$$C_m = \beta\, \alpha\, \lambda_p\, t$$

Diode Short mode

$$C_m = 1 \times 0.51 \times 0.123 \times 10^{-6} \times 43800$$
$$= 2.747 \times 10^{-3}$$

Open Mode

$$C_m = 1 \times 0.29 \times 0.123 \times 10^{-6} \times 43800$$
$$= 1.562 \times 10^{-3}$$

Parameter change

$$C_m = 1 \times 0.20 \times 0.123 \times 10^{-6} \times 43800$$
$$= 1.077 \times 10^{-3}$$

Severity Class Severity refers to the effects of each of the failure modes on the system. The severity of the effect is classified into four categories as given in Table 19.4.

Table 19.4 Severity Class

Description	*Category*	*Mishap Definition*
Catastrophic	1	Death or system loss
Critical	2	Severe injury, severe occupational illness, or major system damage
Marginal	3	Minor injury, minor occupational illness, or minor system damage
Negligible	4	Less than minor injury, occupational illness, or system damage

Item Criticality Item criticality is used in criticality analysis. In the above example, we calculated the criticality number in each one of the failure modes of the rectifier diode. Item criticality for an item is the sum of criticality numbers of the item in various failure modes resulting in the same severity levels of the effects:

or

Cr (of a part at each severity level of effect)

$Cr = \Sigma\, Cm$

Cr = Criticality number for a part

Cm = Individual criticality numbers for the various failure modes having the same severity level.

Example 19.2

In the above example, if the severity levels associated with the failures are given below:

Failure mode	*Severity level*
Short	1
Open	2
Parameter change	3

Find out *Cr* of the rectifier diode.

Solution

Since each failure mode leads to a different severity level

Cr for short = 2.747×10^{-3}

Cr for open = 1.562×10^{-3}

Parameter change = 1.077×10^{-3}

Example 19.3

In the above example, if short produces severity level 1 and the other two-severity level 3, find out *Cr*.

Solution

Level 1 $Cr = 2.747 \times 10^{-3}$

Level 3 $Cr = Cr \text{ open} + Cr \text{ parameter variation}$

$= (1.562 + 1.077)\, 10^{-3}$

$= 2.639 \times 10^{-3}$

CRITICALITY MATRIX

A criticality matrix is plotted with *Cr* in the Y-axis (logarithmic scale) and severity classification on the X-axis as shown.

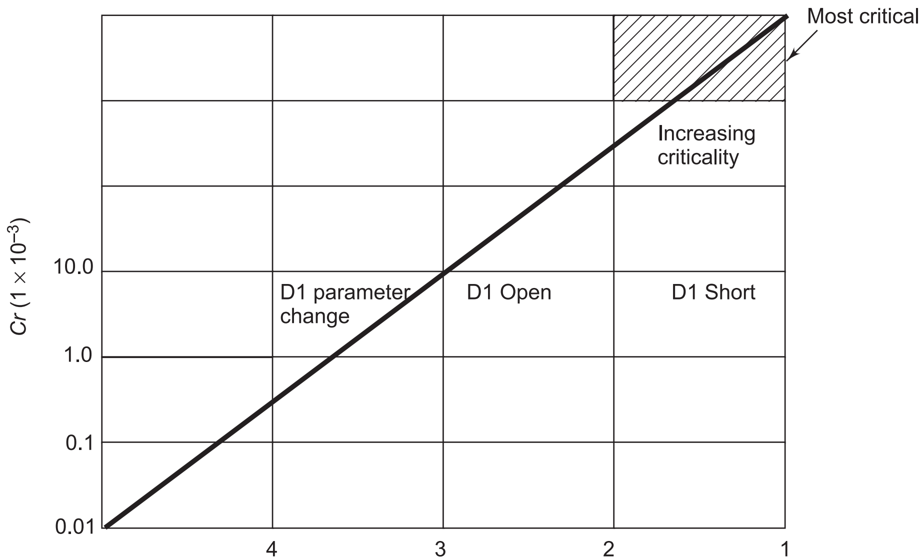

Figure 19.8 Criticality Matrix

We have plotted the above as per data in Example 19.2. The part number of rectifier diode is D1. Y-axis represents *Cr*, the plotting is only that of *Cm*. The above is an example of criticality matrix.

As we move towards the right and up, the criticality increases as shown in Fig. 19.8. Thus, the three failure modes of rectifier diode results in moderate criticality.

CASE STUDY

Case 1: FMECA for Rectifier Circuit

Let us use the FMECA technique to learn and carry out FMECA analysis for the following electronic circuit.

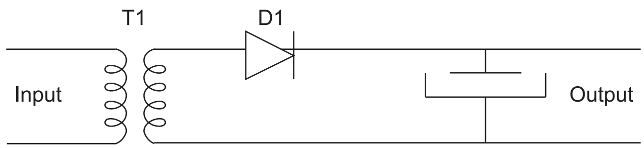

Figure 1

The above is a rectifier circuit used in a radio receiver.

The FMECA analysis needs two tasks:

(i) FMEA analysis

(ii) Criticality analysis

The second task is to be carried out after completion of the first one. The first task is called task 101 and second task 102. CFR Failure Mode tool was used for this task. The results of the FMECA are given in Table 1 and 2. Look at Table 1.The first row is for FMEA of the capacitor C1 in the circuit. There are three modes of failure of C1. We study effect of each failure mode and arrive at a severity class.

Now we carry out criticality analysis leading to finding C_m and part criticality number C_r as given in Table 2. The severity as per Table 1 is used here. A criticality matrix can also be plotted using the data. It helps in taking action for reducing criticality of failures.

Let us look at some case studies.

Case 2: FMEA of Car Door

An automobile manufacturer had a peculiar problem of corrosion of interior door panel in a car. This affected the appearance, functioning and added cost of repaint, etc. It also affected customer opinion about the car. The failure effect led to severity ranking of seven and the probability of occurrence of corrosion was given a ranking of six. The test method employed was general durability test. The probability of detection ranking was 7. Thus, the RPN works out to be 294, which is high. The durability test failed to surface the corrosion problem in the laboratory testing. Hence, it was suggested to conduct laboratory accelerated corrosion testing. Based on the test results of laboratory accelerated corrosion testing, the specification for the thickness of the paint coating on the interior door panel was revised and raised by 150 mm. The probability of occurrence reduced from six to two and the probability of detection reduced from seven to two. Therefore, the RPN reduced from 294 to 28. Henceforth, this problem was not reported in the field. Therefore, by conducting FMEA study and carrying out corrective and preventive actions, one can prevent failures from reaching the customers.

Table 1 Failure Mode Effects and Criticality Analysis (Task 101)

System Name : Radio Receiver
Date : 3/21/2004

I.D. No.	*Sub System Name*	*Comp. Name*	*Function*	*Failure modes and Failure Causes*	*Failure Effects*			*Failure Detection Method*	*Compen-sating provi-sions*	*Sev Class*	*Remark*
					Local Effect	*Next Higher*	*End Effects*				
1	5 V psu power supply	C1 Capacitor	To filter	Change in value	No effect	No effect	Significant effect	None	–	4	–
2	5 V psu power supply	C1 Capacitor	To filter	Opened –	Loss of filtering	Ripple presence in 5v dc supply from psu	Radio operates with noise	None	–	3	–
3	5 v psu power supply	C1 Capacitor	To filter	Shortened –	5 v dc supply grounded	Loss of 5v dc from psu	Radio fails	None	–	2	–
4	5 v psu power supply	D1 Diode	Rectifies the input ac voltage into dc	Opened –	No rectification	Loss of 5 v dc from psu	Radio fails	None	–	2	–
5	5 v psu power supply	D1 Diode	Rectifies the input ac voltage to dc	Shortened –	No rectification	Loss of 5 v dc from psu	Radio fails	None	–	2	–
6	5 v psu power supply	T1 Transformer T100	To step down the input voltage to 5v ac	Degraded output –	Degraded o/p from transformer	Degraded o/p from psu	Radio functions with reduced volume	None	–	4	–
7	5 v psu power supply	T1 Transformer T100	To step down the input voltage to 5v ac	Opened –	Loss of voltage step down function of transformer	Loss of 5 v dc from psu	Radio fails	None	–	2	–
8	5 v psu power supply	T1 Transformer T100	To step down the input voltage to 5v ac	Shortened –	Loss of voltage step down function of transformer	Loss of 5 v dc from psu	Radio fails	None	–	2	–

Table 2 Failure Mode Effects and Criticality Analysis (Task 102)

System Name : Radio Receiver
Date : 3/21/2004

I.D. No.	*Sub System Name*	*Comp. Name*	*Function*	*Failure Modes and Failure Causes*	*Sev Class*	*FEP* β	*Failure Mode Ratio* α	*Failure Rate* $\lambda\pi$	*Operating Time* t	*Cm*	*Cr* $\times 10^{-6}$	*Remarks*
1	5 v psu power supply	C1 Capacitor	To filter	Shorted –	2	1.00	0.55	.016	1,000.00	8.5993 $\times 10^{-6}$	8.5993	–
2	5 v psu power supply	C1 Capacitor	To filter	Opened –	3	0.10	0.20	.016	1,000.00	.3127 $\times 10^{-6}$	0.3127	–
3	5 v psu power supply	C1 Capacitor	To filter	Change in capacitor –	4	0.10	0.25	.016	1,000.00	.3909 $\times 10^{-6}$	0.3909	–
4	5 v psu power supply	D1 Diode	Rectifies the input ac voltage into dc	Opened –	2	1.00	0.40	0.13	1,000.00	5.0208 $\times 10^{-6}$		–
5	5 v psu power supply	D1 Diode	Rectifies the input ac voltage in to dc	Shorted –	2	1.00	0.60	0.13	1,000.00	7.5312 $\times 10^{-6}$	12.5520	–
6	5 v psu power supply	T1 Transformer	To step down the input voltage to 5 v ac	Opened –	2	1.00	0.40	.008	1,000.00	3.0460 $\times 10^{-6}$		
7	5 v psu power supply	T1 Transformer	To step down the input voltage to 5v ac	Shorted –	2	1.00	0.40	.008	1,000.00	3.0460 $\times 10^{-6}$	6.0920	–
8	5 v psu power supply	T1 Transformer	To step down the input voltage to 5vac	Degraded output –	4	0.10	0.20	.008	1,000.00	.1523 $\times 10^{-6}$	0.1523	–

Failure Rate—No. of failures per million Hours Cr—Item Criticality FEP—Failure Effect Probability
Cm—Failure mode criticality Sev class—Severity class Approved by: RR

Case 3: FMEA of Painting Process

The process under study was manual application of paint inside the car door in order to cover inner door and lower surfaces at optimum paint thickness to retard corrosion. The process failure mode is "insufficient paint coverage over specified areas". The consequence is deteriorated life of the door leading to unsatisfactory appearance due to rust over a period of time and impaired function of interior door hardware. This led to severity ranking of seven. The potential cause of this problem was manually inserted spray head, not inserted far enough and therefore, unable to cover the vicinity of the inner door. The probability of occurrence ranking was eight. The existing design control was to inspect or visually check every hour the film thickness. The probability of detection ranking was five. The RPN was therefore 280. The FMEA team suggested automating the process with on-line measurement of thickness of spray, which was readily accepted and implemented. This resulted in probability of occurrence ranking of two and finally RPN came down to 70.

Case 4: FMEA of Washing Machine

An automatic washing machine manufacturer was facing a serious problem with intermittent operation of the washing machine. The machine used to halt or hang at random. On FMEA study, it was revealed that electro-mechanical relay used in the electronic controller card of the washing machine was the root cause of this problem. During machine soldering process of the electronic controller card, some flux used to ingress inside the relay casing, which in due course of time resulted in corrosion of the relay contact points. This led to intermittent operation of electronic controller card hence, intermittent operation of the machine. Probability of occurrence of this problem was eight, severity nine and probability of detection was eight. Thus, the RPN was 576. Since the RPN was very high and it will be very expensive to reduce the numbers through improvement of process, the FMEA team suggested replacing electro-mechanical relay with a solid-state relay. The new design had the following figure of merit:

Occurrence:	1
Detection:	8
Severity:	1
RPN =	8

Hence, the problem was never reported again.

SUMMARY

Reliability of products and services is quite important for quality and TQM. In this chapter, a brief introduction to reliability covering bath tub curve, probability density function and sample calculation of reliability were discussed. FMEA is all about studying the effect of failure of parts or components on the systems, thus a reliability analysis tool. FMEA is aimed at improving the reliability of the products. The FMEA requires understanding of the following:

- Failure modes
- Failure causes
- Failure effects

In this chapter, we discussed two methodologies. First one is FMEA Risk Priority Number (RPN). FMEA RPN technique is the most popular in automobile industry. FMEA Risk Priority Number (RPN) is the product of the following:

- Severity of the effect
- Probability of failure occurrence
- Likelihood of detection

The higher the number, the more risky is the failure of the part.

FMEA has to be carried out by a team and it requires knowledge of reliability and system functioning and design. Five types of FMEAs were discussed. Thereafter, the design FMEA was discussed in detail. Process FMEA is a similar technique. However, the object under consideration in the former will be product and in the latter case it will be the process such as manufacturing operations. A case study on fan assembly was discussed using the software tool CFR-FMEA-RPN for understanding FMEA RPN technique.

There is another technique called FMECA. It consists of the following:

- FMEA
- Criticality Analysis

This technique is advocated by the standards. Although the procedure varies in comparison with FMEA RPN, it is more useful in electronics and allied industries. In FMECA we have to calculate C_m. This depends on the following factors:

- Probability of mission loss
- Failure rate of the part
- Intended mission time
- Failure mode ratio

A component or a part may fail in a number of modes. Failure mode ratio depicts the probability of the occurrence of the particular failure mode.

λ_p—It is the part failure rate

Duration of the applicable mission, i.e. we always calculate the failure mode criticality number for a given time t.

Item criticality is used in criticality matrix. It is represented by C_r. It is the sum of failure mode criticality for each severity level of a particular part.

At the end of FMECA a criticality matrix can be constructed which will give pictorial representation of the criticality in the particular mode. Four case studies are given at the end of the chapter to get a feel of its importance and indicate the application of FMEA.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. Failure mode criticality depends on
   (a) Beta
   (b) Alpha
   (c) Mission time t
   (d) All the above
2. Failure mode ratio arises because
   (a) Component may have more than one failure mode
   (b) Effect of failure of one components on the other
   (c) All the above
   (d) None of the above

3. Possibility of mission loss is
   (a) Failure effect probability (b) Varies from 0 to 1
   (c) Qualitatively assessed (d) All the above
4. FMEA includes
   (a) Design FMEA (b) Process FMEA
   (c) Software FMEA (d) All the above
5. In exponential distribution, the hazard rate is
   (a) Exponentially increasing (b) Exponentially decreasing
   (c) Constant (d) None of the above
6. RPN is the product of
   (a) Severity (b) Ease of detection
   (c) Probability of occurrence (d) All the above

II. True or False

1. FMEA is an analytical technique.
2. FMEA is a requirement of QS 9000 standard.
3. FMECA is same as FMEA.
4. Automobile industry requires FMECA.
5. Design FMEA is used for process.
6. Product design requires process FMEA.
7. Each failure mode has to be analyzed.
8. Each failure cause has to be analyzed.
9. Higher the severity, lower the effect on the system.
10. Higher the probability of occurrence, the corresponding rank will be higher.
11. FMEA improves design.
12. FMEA reduces reliability.

III. Explain briefly

1. Probability of occurrence
2. Probability of detection
3. Severity levels
4. FMEA RPN
5. Process FMEA
6. Bath tub curve
7. Failure mode criticality number
8. Part criticality number
9. Criticality matrix
10. FMECA
11. Failure modes
12. Failure causes
13. Failure effects
14. Exponential pdf

IV. Solve the following problems

1. Calculate the RPN of a gearbox. Given that probability detection = 9, probability of occurrence = 7, severity = 3.
2. Calculate C_m . Given that failure rate = 1×10^{-6}, operating time = 100000 hours and failure effect probability = 1.

Failure Mode Table	
Cracked	0.5
Rattling	0.5

3. In the above problem, assuming that both of the failure modes result in severity level number 2. Find out the part criticality index.
4. Resistor has the following failure mode ratio – open: 0.59, value change: 0.36, short: 0.05. The failure rate of the resistor is 0.004×10^{-6}. The failure effect probability beta = 1. If all the failures lead to severity class 1, determine the failure mode criticality number as well as part criticality number.
5. In the above problem, if open and parameter changed results in severity 1, short results in No. 2, find out the failure mode criticality number and part criticality number.

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Section **V**

Quality Systems

In this concluding section, we will discuss about the standards, certification and award schemes, which facilitate and motivate implementation of TQM.
This section contains the following chapters:

20. QUALITY SYSTEM—ISO 9000 STANDARD

This chapter gives the need for ISO 9000 and other quality system. It gives requirement and guidelines for implementing all the elements of ISO 9001. It brings out the additional features of QS 9000.

21. ENVIRONMENTAL MANAGEMENT SYSTEM (EMS)—14001

A brief overview of ISO 14000 is given.

22. QUALITY AWARDS

This chapter brings out the salient features of the following awards:

- MBNQA
- EQA
- Deming Award
- Rajiv Gandhi National Quality Award (RGNQA)

Chapter 20

Quality System—ISO 9000 Standard

"The great use of life is to spend it for something that will outlast it."

– William James

INTRODUCTION

TQM calls for continuous improvement, which may happen due to changes in the way the employees perform their duties, the operation of the machinery, innovative changes to the methods, etc. Changes and improvements cannot be consolidated in the absence of a proper system in the organization. ISO 9000 standards virtually force the organization to evolve a system for managing quality in the organization. The companies have to fulfill the requirements stipulated in the standard for certification. These requirements are well formulated and are in the interest of the organizations. For instance, no company has ever started its operations without a long-term plan, or a strategic plan or a vision or a mission. However, this remains a secret with the CEO. It may not be the intention of the CEO to keep it as a secret, but due to many reasons the employees do not know what is the long-term objective of the organization. In the absence of awareness about the long-term objective, it is likely that there is a lot of misinterpretation of the objective of the organization amongst the employees. In some cases, it may so happen that even the first line managers may not be aware of what is the objective of the organization. To eliminate this communication gap, ISO 9000 calls for documentation of quality policy and its wide circulation in the organization. Since quality manual contains the quality policy and since every employee has to read the quality manual, the employees will definitely come to know what is the quality policy. ISO 9000 calls for removing the gaps in understanding between the CEO and the junior employees about the policy and objectives of the organization. Therefore, the employees should also be educated in knowing what is the meaning of the quality policy statement of the CEO. Thus, the communication gap about the long-term objective of the company between the CEO and the junior employee is automatically removed. It is just an example, the whole ISO 9000 standards, if implemented in true spirit, will help the organizations to be managed efficiently and effectively. Thus, the ISO 9000 standards help the organizations to establish a documented system, which will not give rise to different interpretations by different employees. It will bring an order in the organization. Therefore, the first step towards TQM could be certification by an independent certifying body under the relevant ISO 9000 standards. Such an approach has been taken by many organizations. If an organization is certified under ISO 9000 standards, then it can continuously improve the system. It will be rather easier for a company, which get certified under ISO 9000 to improve. If an organization does not have a system, it will be difficult to identify what changes are required. But if the company has a documented system and procedures, with trained people, then it will definitely be easy to find out where they are lacking, so that they can take appropriate corrective and preventive actions. Therefore, ISO 9000 is an important tool in the journey towards TQM. Every organization should understand the requirements of ISO 9000 standards and establish a quality system meeting ISO requirements.

In this chapter we will learn about establishing a quality management system in the organizations and getting them certified as per ISO 9000 standards or other equivalent standards. We will also discuss about the following sector specific standards on quality systems.

- QS 9000
- AS 9100
- ISO/TS 16949
- TL 9000

ISO

ISO is the abbreviation for International Organization for Standardization, head-quartered in Geneva. This is a world standards body, in which most countries are members. ISO is engaged in formulating standard specifications in a variety of disciplines such as quality management, information technology, metrology, etc. There is also another world body called International Electro-Technical Commission (IEC), which specializes in formulating standard specifications, pertaining to the electro-technical area, i.e. electrical and electronics engineering areas. ISO has published many standards. One of the most acclaimed standard worldwide is the ISO 9000 family of standards.

ISO 9000 Family of Standards

In the modern industry, it is very important to finalize the requirements or specifications before a product is manufactured or a service is designed and delivered. Each company has some form of specifications for the product it manufactures or the services it renders. The product specifications are specific to each product and contain various details such as the functional requirements, safety requirements, and reliability requirements and so on as discussed in Chapter 1. After World War II, it was found necessary that there should be specifications or requirements for the quality management system in the organizations to ensure production of products meeting the requirements consistently.[1]

ISO 9000:2000 standard defines management system as

"Set of interrelated and interacting elements to establish policy and objectives and to achieve those objectives."

The first standard on this subject was issued by the US Military and known as MIL-Q 9895. The specifications for the quality system gained importance by the year 1987 when the International Organization for Standardization released the first set of ISO 9000 series of standards. The formulation and release of the standards at a rapid pace was necessitated by the European Unification move and the resolution of the European countries to adopt ISO Standards as European Standards. Since some countries in Europe were taking a stand that they will not buy products from those not certified under the ISO 9000 family of standards, the manufacturing and service organizations took it seriously. While UK was certifying many organizations under an equivalent standard BS 5750, even before the release of ISO standards, such certification was almost absent throughout the rest of the world. After the release of ISO 9000 standards in the year 1987, every country including USA, Japan, Australia and India adopted the standards and made efforts for certification of their companies under ISO 9000 standards. The standards were revised first in the year 1994 and later in the year 2000. More than 200,000 companies all over the world have been certified under the ISO 9000 standards by various certifying bodies all over the world. The organizations certified include *Fortune 500* companies in the US, world leaders in many disciplines, hospitals and even schools. The size of the certified organizations also varies widely from an organization having two employees to thousands of employees. The number of ISO 9000 certifications is not reducing, but is increasing very fast. At this rate, the ISO 9000 certifications may become the fundamental requirement of every business enterprise and even government organizations, which are engaged in providing public services.

The following standards constitute the ISO 9000 family of standards.

ISO 9000	: 2000	Quality Management System – Fundamentals and Vocabulary
ISO 9001	: 2000	Quality Management System – Requirements
ISO 9004	: 2000	Gives guidance for implementation of the standard ISO 9001:2000
ISO 19011	:	Guidelines on quality and/or environmental system auditing
ISO 10012-1	: 1992	Quality assurance requirements for measuring equipment —Part 1: Metrological confirmation system for measuring equipment
ISO 10012-2	: 1997	Quality assurance for measuring equipment —Part 2: Guidelines for control of measurement processes
ISO 10013	: 1995	Guidelines for developing quality manuals

Benefits of ISO 9000 Certification International Organization for Standardization (ISO) has contributed to the improvement of quality in all spheres of life through the release of ISO 9000 standards. Organizations go for ISO 9000 certification because of the following advantages it offers:

- Provides a know-how for establishing a quality management system that has been found to improve the bottom-line of businesses.
- Certification of ISO 9000 has become the minimum requirement of quality for any tender. Therefore, the organization is supposed to go in for ISO 9000 certification and prove their competence. Larger organizations require their suppliers to qualify under ISO 9000. Therefore, the suppliers after certification become eligible for participating in the tenders.
- It is a status symbol for the organizations.
- It improves employee morale, because it improves system in the organization.
- The customers get the benefit directly because they improve products and services.
- The suppliers get to know the exact customer requirements on account of ISO 9000 certification. The organization benefits because every contract has to be reviewed before acceptance. This reduces the waste.
- Since ISO 9000 is targeted towards practicing TQM, the organization becomes healthy and prosperous in the long run.
- The employees also get trained in the latest methodology for managing the organization, which will directly benefit the organization.

These are some of the advantages of certification under ISO 9000 standards.

ISO 9001 Standard

The standard ISO 9001:2000 is a contractual standard. This standard could be used for contracts such as:

- Certification of an organization by a certifying body, also called ISO 9000 Registrar
- Agreement between the supplier and the customer

The ISO 9001 standard in its introduction gives a number of guiding principles. It suggests that adoption of a quality management system as per ISO 9001 should be a strategic decision for an organization. The standard provides generic guidelines for establishing a quality management system in an organization. It is the responsibility of the organization to design and implement the quality management system for the organization, taking into consideration specific needs, objectives, product range, process employed and size and structure of the organization. The standard also adds that the requirements for quality management system as in ISO 9001 are complementary to the requirements of products. They do not in any way reduce the importance of the product specifications.

The standard can be used to assess the organization's ability to meet the customer's, regulatory and the organization's own requirements. Thus, the standard can be used by the organization for self-improvement. The certification bodies and its customers can also use it to assess the capability of the organization.

The complementary standard ISO 9004 cannot be used for contract related matters. It is only for self-improvement. The 2000 revision has brought in one to one correspondence between the elements of ISO 9001 and ISO 9004. ISO 9001 is a standard against which an organization is certified. Let us now look at the requirements for the quality management system as brought out in the ISO 9001 standards.

Process Approach This is the first time ISO 9001 has come out specifically suggesting adoption of process approach for developing, implementing and improving the effectiveness of the quality management system. Thus, the standard indicates that there should be chain of processes in every organization. It gives a term process approach to indicate "application of a system of processes within an organization together with the identification and interactions of these processes and their management". The standard gives advantages of process approach as given below:

(a) Understanding and meeting the requirements
(b) The need to consider processes in terms of added value
(c) Obtaining results of process performance and effectiveness and
(d) Continual improvement of processes based on objective measurement

PDCA Introduction to the standard also suggests adoption of PDCA. PDCA can be applied to all the processes.

Requirements of ISO 9001: 2000

The scope of ISO 9001:2000 Standard[2] is given below:

"Specifies quality management system requirements for organizations to

- Demonstrate ability to consistently provide product that meets customer and applicable regulatory requirements
- Enhance customer satisfaction"

The requirements of the standard are applicable to all the organizations regardless of type, size and product provided.

The standard has also defined supply chain as given in Fig. 20.1:

Supplier ⟶ Organization ⟶ Customer

Figure 20.1 Supply Chain

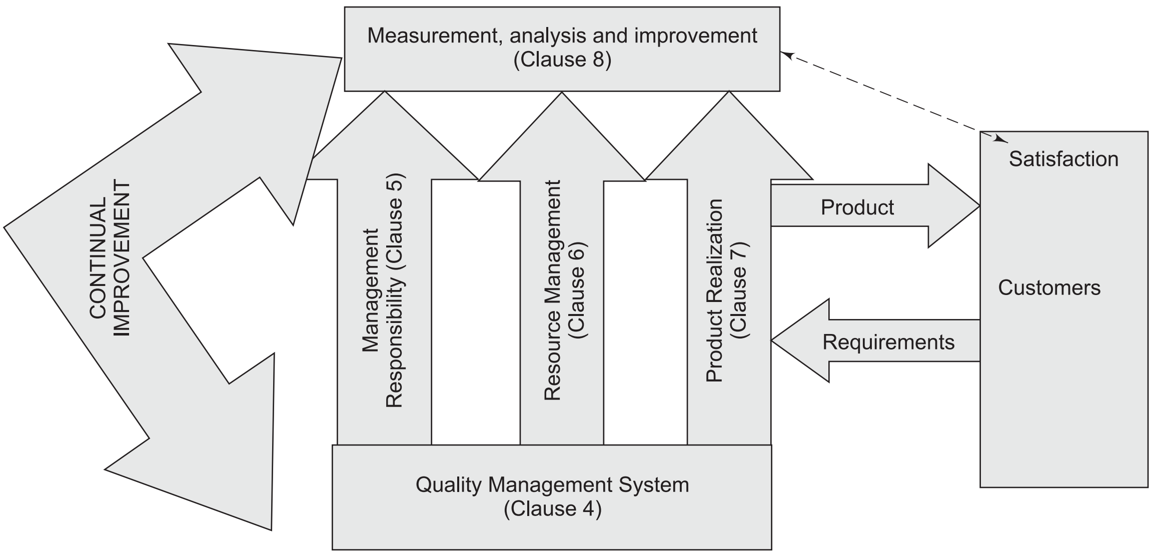
The suppliers are the subcontractors or vendors. This is a change as compared to the previous versions of the standard.

QUALITY MANAGEMENT SYSTEM (QMS)

The ISO 9000 standards brings out the requirements for the quality management system. The requirements are conveyed through the various elements from clause 4 to 8.

The QMS is the foundation for the organization as indicated in Fig. 20.2. The standard has grouped the various requirements as given below.

- QMS – Clause 4
- Management responsibility – Clause 5
- Resource management – Clause 6
- Product realization – Clause 7
- Measurement, analysis and improvement – Clause 8



ISO 9001 Model

Figure 20.2

As indicated in Fig. 20.2, QMS is the foundation and the other four clauses provide the structure for building and improving the quality in the organization, as well as delivering products and services and delighting the customers.

Now, we will look at each one of the elements and briefly discuss one way of implementation of the same.

CLAUSE 4—QUALITY MANAGEMENT SYSTEM

General Requirements

The clause brings out the steps involved in establishing a quality management system meeting the standards succinctly. The sequences of events are:

- Establishing
- Documenting
- Implementing
- Maintaining
- Continuously improving its effectiveness

Implementation means practicing the quality management system as documented. Maintenance indicates consistently adhering to the QMS and updating the documented quality management system. Such systems should be improved periodically. The organization has to carry out the following in particular:

- Identifying the processes needed for the quality management system for the entire organization
- Making a process flow chart indicating the sequence of processes and their interactions
- Determining methods to ensure that the system established is effective

It will be effective if the operations are carried out as per the system and the processes are under control. Therefore, the organization should evolve a methodology for ensuring that the system operates as documented and it is controlled. Sometimes, the systems are not practiced because of lack of resources and non-availability of the information necessary to support the operation and monitoring of the processes. Therefore, the management to enable practicing the documented quality management system should provide adequate resources. The processes are to be monitored and the process parameters measured. This is an ongoing activity to ensure that the processes are under control. Each process should also have a goal in terms of their performance as measured through specific parameters. For instance, in a wave-soldering machine, the temperature is critical. The temperature in a wave-soldering machine should be maintained at a desired value with allowable tolerances. Therefore, the measure of the goal for wave-soldering machine is maintaining the temperature. The temperature has to be periodically measured to confirm that the wave-soldering machine is operating within limits. In addition, the process as a whole should meet the specific requirements set by the organization. The management should support in achieving all such requirements. Once the goals are met, the process should be further improved.

The processes referred above include the following:

- Process for management activities
- Provision of resources—both human and material
- Product realization
- Measurement

The requirements of a quality management system are summarized below:

- Develop a QMS for the organization
    - Identify processes needed for QMS
    - Describe the QMS processes
- Implement the QMS
- Improve the QMS
    - Monitor and improve process performance

Documentation Requirements

The organization has to identify the set of documents required to establish and implement its quality management system. There are five types of documents as given below:

1. Quality policy and quality objectives
2. Quality manual
3. Documented procedures as required by the standard ISO 9001
4. Documents needed by the organization to ensure the effective planning, operation and control of its processes
5. Records

While procedures indicate what has to be done, the records should indicate what has actually been done. Strictly the records do not form part of the quality management system documents. The documentation should be carried out taking into consideration the following:

- Size of the organization
- Type of activities
- Complexity of processes
- Competence of personnel

Documentation Structure The document should be organized in a hierarchical manner[1] as indicated in Fig. 20.3.

Hierarchy of Documents

Figure 20.3

As the level goes down in a hierarchy, the documents should be more detailed. However, the documents should be traceable to the quality policy and objectives as well as requirements of ISO 9001. Traceability means that the lower level document is issued to elaborate a particular clause or element of the higher-level document. The bottommost tier—the specifications of both the company as well as standard body's, drawings, etc. are retained for reference purpose. This hierarchical structured document will also ensure that the document, which requires frequent revision, will be at a lower level. This way, the efforts for documentation could be reduced.

Documentation Style The documents should be prepared with a clear focus on the processes. Every document should use a standard template. Some of the contents, which add value to the documents, are:

- Unique identification of the document and date of issue
- Purpose
- Scope
- Controlled / uncontrolled
- Applicable specifications / documents
- Reference to clause no. in the ISO 9001 standard
- Persons responsible for implementation
- Records to be generated
- Traceability to the quality manual / higher level documents
- Inter-relationships with other processes of the organization
- Amendment record
- Authority issued

The issuing authority's designation should be clear from the documents. The organization will need both controlled documents and uncontrolled documents for implementing ISO 9001 standard.

Documentation management is an important activity and should be carried out as per approved procedure on the same. Controlled documents are those, which are issued to specific persons in the organization. The holders of the same will also receive any amendments to the documents. Holders of uncontrolled document may not receive any amendments. The old copies of controlled document will be collected back before issue of amended copy. The documents shown in the pyramid are all controlled documents.

The documentation requirements is summarized below:

- Develop documents that will provide guidance for implementation of a QMS for the organization's specific requirements.

Quality Manual

The quality manual is an apex document for quality management system. It should contain the following:

- Scope of the quality management system
- Documented procedures established for a quality management system or reference to them
- Description of the interaction between the processes of a quality management system

Control of Documents

The procedure for control of documents has emerged clearly over the years. Each organization has a documentation controller or a department for controlling the documents. While the authorized persons can evolve the quality manual and associated procedures, the documentation control department releases every document that is of importance with a reference number, date, etc. Such documents, which have a bearing on product quality, will be controlled documents. There should be documented procedure to define the control of documents. This procedure should address the following:

(a) To approve documents for adequacy prior to issue
(b) To review and update as necessary and re-approve documents
(c) To ensure that changes and the current revision status of documents are identified
(d) To ensure that relevant versions of applicable documents are available at points of use
(e) To ensure that the documents remain legible and readily identifiable

(f) To ensure that the documents of external origin are identified and their distribution controlled
(g) To prevent the unintended use of obsolete documents and to apply suitable identification to them if they are retained for any purpose.

Control of Records

A record is a special type of document. They provide evidence of conformity to the requirements and the effective operation of a quality management system. Any documented record should be legible, easily identifiable and retrievable. The organization has to establish a documented procedure to define the controls, needed for the identification, storage, protection, retrieval, retention time and disposition of records.

The requirements of control of records are summarized below:

- Maintain quality system records
- Use the records collected to prove that requirements have been met
- Develop a procedure to control records
- Ensure that the records are useable

CLAUSE 5—MANAGEMENT RESPONSIBILITY

ISO 9000 will be successful only when the management is committed to a quality management system meeting the standards.

Management Commitment

The management commitment for implementation of a quality management system and continuously improving its effectiveness should be made visible through the following:

(a) Communicating to the organization the importance of meeting the customer as well as statutory and regulatory requirements
(b) Establishing the quality policy
(c) Ensuring that quality objectives are established
(d) Conducting management reviews
(e) Ensuring the availability of resources

The requirements of management commitment are summarized below:

- Develop a QMS
  - Facilitate the development of a QMS
  - Formulate the organization's quality policy and objectives
  - Provide resources for QMS
- Implement the QMS
  - Provide resources to implement the quality system and motivate them
  - Improve the quality management system

Customer Focus

ISO 9001 standard also gives the responsibility for ensuring that customer requirements are determined and met with the aim of enhancing customer satisfaction.

The requirements of customer focus are summarized below:

- Top management should ensure that the organization
  - identifies customer requirements
  - meet them
  - enhance customer satisfaction

Quality Policy

This clause provides the guidelines for quality policy. Quality policy should include commitment to comply with the requirements of ISO 9001 and continually improve the effectiveness of quality management system. Quality policy shall provide a framework for establishing and reviewing quality objectives. The quality objectives should be communicated widely and should be understood by everyone in the organization. The quality objectives should be reviewed periodically.

A sample quality policy of M/s.Rane Brake Linings Limited, Chennai is given below:

Quality Policy

RBL believes:

- That customer satisfaction is an imperative and this is achieved by supplying quality products in time at competitive prices
- That quality should be designed, engineered and built into the product through appropriate technology
- In ensuring adequate in-house testing facilities, to create confidence and trust in customers, on the performance of its products
- In total employee involvement and commitment, by imparting adequate knowledge and skills to all levels of employees
- In doing things right first time, every time.

The requirements of quality policy are summarized below:

- Define the organization's quality policy
- Manage the organization's quality policy
  - Communicate the policy to the organization
  - Review the policy to ensure that it is still suitable

Quality Planning

Quality Objectives The top management should ensure that quality objectives including those needed to meet the requirements of the product are established at every department in the organization. Every employee in the organization should understand this. The quality objectives for the product should be measurable. The requirements of quality objectives are summarized below:

- Formulate organization's quality objectives
  - Ensure that objectives are set for all functional areas
  - Ensure that objectives are set at all organizational levels
  - Ensure that objectives facilitate product realization
  - Ensure that objectives support the quality policy
  - Ensure that objectives are measurable

Quality Management System Planning Quality management system should be planned to meet the standard ISO 9001 as well as the quality objectives set forth by the management. The documents of the quality management system should be subjected to documentation control. Furthermore, changes may be required in the quality management system often. Whenever changes are made it should be ensured that original objectives set are not affected by the changes to quality management system.

The requirements of quality management system planning are summarized below:

- Plan the QMS for the organization
  - Plan the development of the QMS
  - Plan the implementation of the QMS
  - Plan the improvement of the QMS
  - Plan the modification of the QMS as needed

Responsibility, Authority and Communication

The top management should ensure that the responsibility and authorities are defined and communicated to every employee. It should also be communicated within the organization. Quality manual may contain the organization structure at the top level.

Management Representative Each organization should have a management representative for the quality management system. His responsibilities are given below:

(a) Ensuring that the processes needed for the quality management system are established, implemented and maintained
(b) Reporting to the top management on the performance of the quality management system and any need for improvement
(c) Ensuring the promotion of awareness of customer requirements throughout the organization
(d) Liaison with external parties on matters relating to the quality management system

The management should also ensure that appropriate communication processes are established within the organization. There should be on-going communications regarding the effectiveness of the quality management system.

The requirements of management representatives are summarized below:

- Appoint a management representative to
  - Oversee QMS implementation
  - Report on the status of the QMS
  - Support the improvement of the QMS

Management Review

General The Management Review Board (MRB) has to be set up in every organization. The MRB can be the quality council itself. The top management should review the quality management system at planned intervals. Usually, it is reviewed once in a year or once in six months. The review should aim at improving the quality management system and the processes. The records of management review should be maintained in the form of minutes of the meeting.

Review Input The following constitute some of the inputs to the management review board:

(a) Results of audits
(b) Customer feedback

(c) Process performance and product conformity
(d) Status of preventive and corrective actions
(e) Follow-up actions from previous management reviews
(f) Changes that could affect the quality management system and
(g) Recommendations for improvement

The requirements of review input are summarized below:

- Examine management review inputs
  - Examine the previous quality management reviews
  - Examine the audit results
  - Examine the product conformity data
  - Examine the opportunities to improve
  - Examine feedback from customers
  - Examine the process performance information
  - Examine corrective and preventive actions
  - Examine changes that might improve QMS

Review Output The MRB after the meeting should give directions or approval or authorization in respect of the following:

(a) To make amendments to the quality manual and quality policy and such high level documents
(b) MRB should have a bird's view on the whole of the organization and systems and authorize corrective and preventive actions as needed.

The requirements of review output are summarized below:

- Generate management review outputs
  - Generate actions to improve QMS
  - Generate actions to improve the products
  - Generate actions to address resource needs

CLAUSE 6—RESOURCE MANAGEMENT

Now, the next most important element for any business will be discussed namely—resource management. Lack of adequate resources can cause quality problems. It is the responsibility of the management to provide adequate resources—human resources, infrastructure and work environment.

The requirements of resource management are summarized below:

- Identify quality resource requirements
  - Identify resources needed to support the quality system
  - Identify resources needed to improve customer satisfaction
- Provide quality system resources
  - Provide resources needed to support the quality system
  - Provide resources needed to improve customer satisfaction

Human Resources

General The following are the pre-requisites for employees whose work will affect the quality of the product or services:

- Education
- Training
- Skill
- Experience
- Ensure that the personnel have the right
  - Experience
  - Education
  - Training
  - Skills

Competence, Awareness and Training This clause addresses competence building through awareness and training. Competence is built through providing training or taking other actions to satisfy the requirements for competence. It could be mentoring on the job. Each employee who contributes to the quality of the product should have the necessary competence. The employee should be fully aware of the relevance and importance of their activities and how they can contribute to the achievement of the quality objectives. The records of education, training, skill and experience of the employees should be maintained and made use of.

The requirements of competence, awareness and training are summarized below:

- Define acceptable levels of competence
- Identify training and awareness needs
- Provide training and awareness programs
- Evaluate effectiveness of training and awareness
- Maintain a record of competence

Infrastructure

The infrastructure consists of the following:

(a) Buildings, workspace and associated utilities
(b) Process equipment (both hardware and software)
(c) Supporting services (such as transport or communication)

The organization should determine the required infrastructure and provide them and maintain them for the smooth conduct of the operations.

The requirements of infrastructure are summarized below:

- Identify infrastructure needs
  - Identify needs for building
    - workspace
    - hardware
    - software
    - utility
    - equipment
    - support service
- Provide needed infrastructure identified above
- Maintain all the infrastructure provided above

Work Environment

The work environment should be conducive for achieving the goals of the organization. The work environment should facilitate making products, which meet the requirements of the customer.

CLAUSE 7 – PRODUCT REALIZATION

Planning of Product Realization

The organization should plan and develop the processes needed for product realization. The following are to be determined by the organization.

(a) Quality objectives and requirements for the product
(b) The need to establish processes, documents and provide resources specific to the product
(c) Required verification, validation, monitoring, inspection and test activities specific to the product and the criteria for product acceptance
(d) Records needed to provide evidence that the realization processes and resulting product meet the requirements

The requirements of planning of product realization are summarized below:

- Define product quality objectives and requirements
- Identify product realization needs and requirements
- Develop product realization documents and record keeping systems
- Develop methods to control quality of product realization

Customer-Related Processes

Determination of Requirements Related to the Product The organization should determine the requirement related to the product or services. Some of them are:

(a) Requirements specified by the customer, including the requirements for delivery and post-delivery activities
(b) Requirements not stated by the customer but necessary for specified or intended use, where known
(c) Statutory and regulatory requirements related to the product

The requirements of clause determination of requirements related to the product are summarized below:

- Identify customers product requirements
    - Identify the requirements of customers, imposed by external agencies and requirements of the organization itself.

Review of Requirements Related to the Product The requirements should be reviewed prior to committing to supply the product to the customer. The commitments include the following:

(a) Submission of tenders
(b) Acceptance of contracts or orders
(c) Acceptance of changes to contracts or orders

While reviewing the requirements, the organization should ensure that the requirements are clearly defined and the organization has the ability to meet the defined requirements. In case of new requirements, they have to be mutually agreed to.

The records of the result of the review and actions arising from the review should be maintained. Even when the customer does not provide the documented statement of requirement, the requirement should be confirmed by the organization with the customer before acceptance. Whenever changes are encountered to the requirements, the organization should ensure that relevant documents are amended and the relevant personnel are made aware of the changed requirements.

The requirements of clause review of requirements related to the product are summarized below:

- Review customers product requirements
  - Review requirements before accepting orders from the customers
  - Maintain a record of the product requirement reviews
  - Control changes to product requirements

Customer Communications The organization should take effective steps for communicating with the customers in relation to:

(a) Product information
(b) Enquiries, contracts or order handling, including amendments
(c) Customer feedback, including customer complaints

Design and Development

Design and Development Planning During design and development planning, the organization should determine:

(a) The design and development stages
(b) The review, verification and validation that are appropriate to each design and development stage
(c) The responsibilities and authorities for design and development

The requirements of clause design and development planning are summarized below:

- Plan design and development
  - Define product design and development stages of the organizations
  - Assign design and development responsibilities and authorities
  - Facilitate proper interactions between design and development groups

Design and Development Inputs The design and development inputs include the following:

(a) Functional and performance requirements
(b) Applicable statutory and regulatory requirements
(c) Where applicable, information derived from previous similar designs

Design and Development Outputs The design and development outputs include the following:

(a) Meet the input requirements for design and development
(b) Provide appropriate information for purchasing, production and for service provision
(c) Contain or reference product acceptance criteria
(d) Specify the characteristics of the product that are essential for its safe and proper use

Design and Development Review The design and development should be reviewed at periodic intervals to make sure that the design meets the requirements and to identify and resolve any problem.

The requirements of clause design and development review are summarized below:

- Carry out the design and development reviews
  - Perform product design and development reviews
  - Maintain records of product design and development reviews

Design and Development Verification The standard requires that the verification activities should have been identified, planned and documented as part of the quality planning. Verification should be carried out as planned.

Design and Development Validation Again the validation also should be performed in accordance with the quality planning. Validation is performed to ensure that the resulting product is capable of meeting the customer requirements. Validation is essential to confirm that we have built the right product.

Control of Design and Development Changes Any changes to the design should be reviewed, verified and validated. The effect of the changes should also be analyzed.

The requirements of clause control of design and development changes are summarized below:

- Manage design and development changes
  - Identify changes in product design and development
  - Record changes in product design and development
  - Review changes in product design and development
  - Verify changes in product design and development
  - Validate changes in product design and development
  - Approve changes before they are implemented

Purchasing

Purchasing Process We have discussed in detail about purchasing in Chapter 9.

The requirements of clause purchasing process are summarized below:

- Control purchasing process
  - Ensure that purchased products meet the requirements
  - Ensure that suppliers meet the requirements
- Document product purchases
  - Describe the products being purchased
  - Specify the requirements that must be met
- Verify purchased products
  - Verify purchased products on receipt in the organization
  - Verify purchased products at suppliers' premises (when required)

Production and Service Provision

Control of Production and Service Provision The production process should be carried out under controlled conditions. Controlled conditions include:

(a) Availability of information that describes the characteristics of the product
(b) Availability of work instructions, as necessary
(c) Use of suitable equipment
(d) Availability and use of monitoring and measuring devices
(e) Implementation of monitoring and measurement
(f) Implementation of release, delivery and post-delivery activities

Validation of Processes for Production and Service Provision Validation should demonstrate the ability of the production process to achieve the planned results. For this to happen, the organization should establish the following arrangements:

(a) Defined criteria for review and approval of the processes
(b) Approval of equipment and qualification of personnel
(c) Use of specific methods and procedures
(d) Requirements for records
(e) Revalidation

The requirements of clause validation of processes for production and service provision are summarized below:

- Validate production and service provision
  - Prove that special processes can produce planned outputs
  - Prove that process personnel can produce planned results
  - Prove that process equipment can produce planned results

Identification and Traceability The organization should identify the product by suitable means throughout product realization. The status of the product with respect to monitoring and measurement requirements should be clear, i.e. whether the product has been tested and if so whether it has passed or not. It is important to record the status of production, on the semi-finished product. There could be a tag stuck to the item under production or there could be some marks. Unique identification of finished product may also be required in some cases.

The requirements of identification and traceability are summarized below:

- Establish, maintain and record the identity of the products or semi-finished products (when required)
- Identify the status of your products (when needed)
- Record the identity of your products (when required)

Customer Property It goes without saying that the customer property should be protected and safeguarded.

The requirements of customer property are summarized below:

- Identify property supplied to you by the customers
- Verify the property supplied to you by the customers
- Safeguard property supplied by the customers

Preservation of Product Any product that is being made or already made should be preserved. Preservation includes appropriate identification, handling, packaging, storage and protection. It also applies to sub-assemblies or materials used for the product.

The requirements of the preservation of product are summarized below:

- Preserve the products and components
  - Preserve products and components during internal processing
  - Final delivery

Control of Monitoring and Measuring Devices This clause addresses the requirements of calibration. For more details, one can look at the standards ISO 10012-1 and ISO 10012-2. The requirements brought out in this standard with regard to calibration are given below:

Inspection, Measuring and Test Equipment (IMTE) are required for various activities in an organization such as incoming inspection, in-process inspection, final good inspection. The equipment selection should have a relevance to the process requirements. The IMTE should be:

(a) Calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards, where no such standards exist, the basis used for calibration or verification should be recorded

(b) Adjusted or readjusted as necessary
(c) Identified to enable the calibration status to be determined
(d) Safeguarded from adjustments that would invalidate the measurement result
(e) Protected from damage and deterioration during handling, maintenance and storage

It should be the goal of the organization that IMTE remains within the tolerance limit all the time[3]. Therefore, when an equipment is sent for calibration and if it is found on receipt of the equipment in the calibration laboratory that it is out of tolerance limit, then the analysis about the validity of the previous measurement results carried out using this equipment are to be made. It may require recall of the items shipped using the measurement results of such non-conforming equipment. Whenever computer software is used for measuring, they should also be subjected to similar exercises.

The requirements of control of monitoring and measuring devices are summarized below:

- Identify the monitoring and measuring activities, which should be carried out.
- Select the equipment which will meet the monitoring and measuring needs of the organization
- Calibrate monitoring and measuring equipment
- Protect monitoring and measuring equipment
- Protect the equipment
  - from unauthorized adjustment
  - from damage or deterioration
- Validate monitoring and measuring software
- Use monitoring and measuring devices
- Use equipment to ensure that the products meet the requirements

CLAUSE 8 — MEASUREMENT, ANALYSIS AND IMPROVEMENT

General

This clause provides the requirements to plan and implement measurement of the processes, quality system and product as a whole. Based on the measurement, the organization has to analyze the current status. Thereafter, it should initiate and accomplish improvement in the product, processes and system.
The requirements of measurement, analysis and improvement are summarized below:

- Plan how remedial processes will be used to
  - assure conformity
  - improve the system
- Use remedial processes to demonstrate conformance
- Use remedial processes to improve quality management system

Monitoring and Measurement

Customer Satisfaction This sub-clause provides the requirements for measuring customer satisfaction continually. It should carry out the following:

- Determine methods for collecting data pertaining to customer perceived quality
- Provide resources and facilities for data collection
- Determine customer satisfaction based on the data collected

The requirements of customer satisfaction are summarized below:

- Monitor and measure customer satisfaction
    - Identify ways to monitor and measure customer satisfaction
    - Monitor and measure customer satisfaction
    - Use customer satisfaction information

Internal Audit The purpose of this sub-clause is to carry out periodic internal quality audits to confirm that the system

- Operates as planned
- Conforms to the requirement of ISO 9001
- Conforms to the quality policy of the top management of the organization

The internal audits should be conducted as planned and records of the same maintained.

The requirements of internal audit are summarized below:

- Plan and perform regular internal audits
    - Set up an internal audit program
    - Develop an internal audit procedure
    - Plan internal audits on a periodic basis
    - Perform regular internal audits
    - Take corrective actions

Monitoring and Measurement of Processes The purpose here is to assess the performance of processes identified under the quality management system (QMS). The processes should be assessed for their effectiveness and efficiency. The effectiveness may be revealed by the defects. The efficiency can be assessed through the cost benefit ratio. Thus, process monitoring and measurement should be periodic and ongoing.

The requirements of monitoring and measurement of processes are summarized below:

- Monitor and measure the quality of processes
    - Use suitable methods to monitor and measure the processes
    - Take action when processes fail to achieve the planned results

Monitoring and Measurement of Products In the previous paragraph, we discussed about in-process measures in order to control the processes that enable manufacturing of products. The end product should be validated to confirm that the product meets the stated requirements; whenever there are deviations from the requirements, the product release and delivery should be authorized by the competent authority in the organization.

The requirements of monitoring and measurement of products are summarized below:

- Monitor and measure product characteristics
    - Verify that product characteristics are being met
    - Keep a record of product monitoring and measuring activities

Control of Non-conforming Product

The purpose of this requirement is to ensure that products (which includes sub-assemblies, parts and materials), which do not conform to the requirements, are identified and controlled to prevent unintended use or delivery. The organization should develop a procedure to ensure achieving the objective set forth as above.

The requirements of control of non-conforming product are summarized below:

- Develop a procedure to control non-conforming products
    - Define how non-conforming products should be identified
    - Define how non-conforming products should be handled
- Identify and control non-conforming products
    - Eliminate or correct product non-conformities
    - Prevent the delivery or use of non-conforming products
    - Avoid the inappropriate use of non-conforming products
- Prove that corrected products now meet the requirements
- Control non-conforming products after delivery or use
- Maintain records of non-conforming products
    - Describe the product non-conformities
    - Describe the actions taken to deal with non-conformities

Analysis of Data

The overall objectives of the standard are the following:

- ➢ To demonstrate the suitability and effectiveness of QMS
- ➢ To evaluate opportunities of continuous improvement of the effectiveness of the QMS

For the above purpose, the organization should collect data. Some data will come out as a result of implementing, monitoring and measurement.

The analysis of data should provide information relating to:

- ➢ Customer satisfaction
- ➢ Conformity to product requirements
- ➢ Characteristics and trends of processes and products including the opportunities for preventive action
- ➢ Suppliers

Thus, analysis of data is quite important.

Improvement

Continual improvement The organization should improve the effectiveness of QMS and thereby its processes on a periodic basis. The following should be used for making it happen:

- ➢ Quality policy
- ➢ Quality objectives
- ➢ Internal and external audit results
- ➢ Corrective and preventive actions
- ➢ Management review

Corrective Action

A corrective action results from a failure. The non-conformities should be identified and corrected. The organization should record all non-conformities and track it to closure. The records of the same should be maintained. It is also important to review the effect of corrective action taken.

The requirements of clause corrective action are summarized below:

- Correct actual non-conformities
    - Review non-conformities
    - Find out the causes of non-conformities
    - Evaluate whether corrective action is needed
    - Develop corrective actions to prevent recurrence
    - Take corrective actions when they are necessary
    - Record the results of corrective actions taken
    - Examine the effectiveness of corrective actions taken

Preventive action Preventive actions are taken to prevent failures. Therefore, the potential causes of non-conformities should be identified and prevented. This may lead to amendment in the QMS. Timely action for preventing non-conformities will save a lot of money. The preventive actions proposed should be recorded and tracked to closure. The records of preventive actions should be maintained. Effect of preventive action should also be reviewed. The audit results, corrective action and preventive action are important agenda points to the management review board meeting and should always be there on the agenda of MRB meeting. Preventive actions are preferred than corrective actions, obviously.

The requirements of clause preventive action are summarized below:

- Prevent potential non-conformities
    - Detect potential non-conformities
    - Identify the causes of potential non-conformities
    - Study the effects of potential non-conformities
    - Evaluate whether preventive actions are needed
    - Develop preventive actions to eliminate causes
    - Take preventive actions when they are necessary
    - Record the results of preventive actions taken
    - Examine the effectiveness of the preventive actions taken

IMPLEMENTATION OF ISO 9001 AND CERTIFICATION

Over the years, the steps involved in implementation of ISO 9001 and certification have become almost standardized. The various steps involved are shown in Fig. 20.4 and discussed briefly.

1. Top Management Decision The top management after evaluating the pros and cons decides to implement QMS as per the ISO 9001 standard. The top management should do the following in particular:

➢ Provide financial and human resources
➢ Convince the board
➢ Prepare a vision, mission, quality policy and the objectives
➢ Designate the management representative (MR)
➢ Select a consultant

2. Gate Meeting The CEO organizes a meeting of all the employees and addresses them. He will highlight the advantage of certification to ISO 9001 and seek the cooperation of all employees. He will also state the time schedule for implementation and certification. He should touch upon the basic principles of ISO 9001 and TQM.

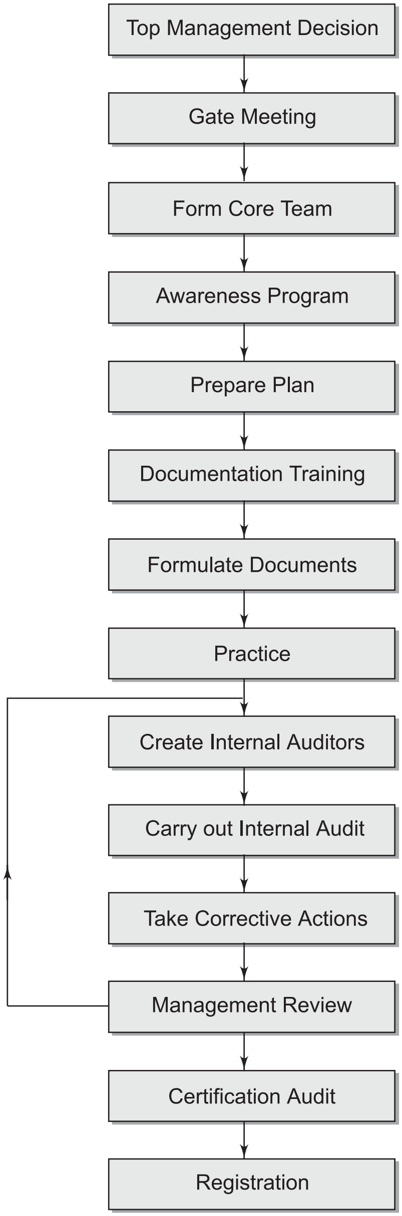


Figure 20.4 ISO 9000 Implementation and Certification

3. Form a Core Team Depending on the size of the organization, the CEO constitutes a core team of senior employees to act as a clearinghouse for ISO 9000 implementation. The MR will be the convener for the core team meetings. The consultant works through the MR and core team.

4. Awareness Program Every employee should be made aware of the requirements of the standard. Therefore, the core team will undergo a detailed ISO 9001 awareness program conducted by the consultant.

Thereafter, the core team members may conduct multiple awareness programs in the organization. The required enthusiasm to implement ISO 9001 should be built through the awareness programs. The content and meaning of the quality policy and objectives should be brought out clearly in the awareness program.

5. Prepare Plan The core team should prepare a plan for implementation of ISO 9000 and all activities till certification. They should prepare this during or after the awareness program. The plan should contain schedule dates for each activity.

6. Documentation Training The core team members attends a training program on how to document the QMS. This may be a 2–3 day workshop conducted by the consultant.

7. Formulate Documents The core team is responsible for preparing the documents. The consultant will review them with reference to the requirements of ISO 9001 and the quality policy of the organization. The documents could be formulated by using either top down approach or bottom up approach. The hierarchy of documents is given in Fig. 20.3. All lower level documents should be traceable to next higher-level documents.

8. Practice The whole organization has to practice ISO 9001. Therefore, the core team should help the organization to practice the system as documented. The core team members should encourage the employees to read the documents made for them.

9. Create Internal Auditors The consultant conducts an internal auditor training program. All the members of the core team and some more employees will attend the training program and qualify as internal auditors.

10. Carry out Internal Audit The organization has to make a plan for carrying out an internal audit of all functions in the organization. Teams of two or three auditors may carry out the internal audit as per audit schedule.

11. Take Corrective Actions The non-conformities brought out by the audit teams should be corrected by the process owners. During the first round of audits, the process owners may need help from the core team to decide on the corrective actions.

12. Management Review The MRB should hold a meeting after the corrective actions have been taken in all functions. The board will also fine-tune the system based on experience. The MRB consists of the senior management and hence it is the appropriate forum to review the existing system and propose amendments. This is the appropriate time to send an application to the chosen certification body.

The last three steps should be repeated at least once to bring stability to the system.

13. Selection of Registrar Selection of a registrar or certifying body is an important decision. The registrar should be selected based on the following:

- Credibility/reputation
- Their accreditation status
- Organization's major customers' acceptance
- Familiarity with the subject dealt by organization
- Lead time required
- Cost

While sending application the quality policy manual may be required to be sent.

14. Certification Audit The certification body will depute auditors for carrying out a third party audit. The audit will also bring out non-conformities. The organization should correct all of them and report to the certification body.

15. Registration Based on the organization meeting the requirements of ISO 9001, the certifying body also called a registrar, will issue a certificate to the organization as complying with ISO 9001 with defined scope. It is now the celebration time for the organization.

CONTINUING ISO 9000 CERTIFICATION

The activities shown in Fig. 20.5 should be continued on periodic basis for maintaining certification. Usually, ISO 9000 registration is valid for three years. There will be periodic checks by the certification authority even within these three years.

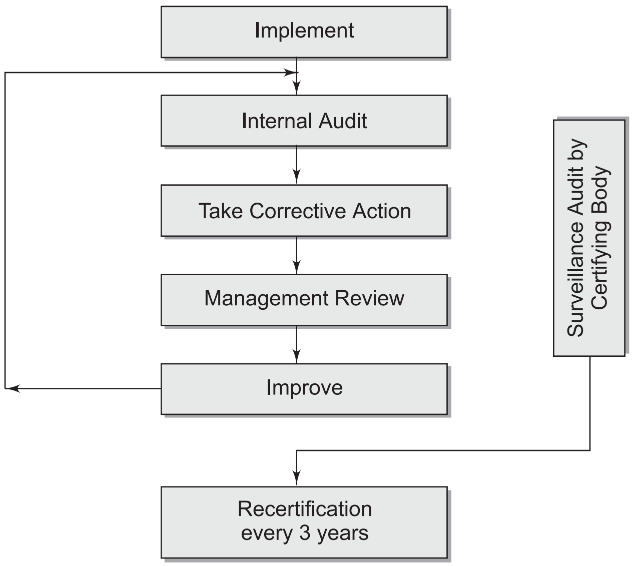


Figure 20.5 ISO 9000 Certification Maintenance Cycle

Quality Audit

Few decades ago audits were synonymous with accounting and financial matters. The scenario has changed and now there are thousands of quality auditors all over the world. The popularity of quality audit is attributable to the popularity of certification under ISO 9000 standards. There are three types of audits—first party audit, second party audit and third party audit. The third party audit is generally carried out by a certifying agency as is the case with certification under ISO 9000 standards. These are carried out to check whether the organization has an effective quality system, so as to ensure a consistent quality of products and services irrespective of varying demands and varying internal situations. Major buyers carry out the second party audit as part of the contract between the supplier and the customer. The customer may follow all the clauses or some clauses of ISO 9000 standards. In fact, the certification under ISO 9000 should eventually eliminate the second party audits. It is one of the purposes of ISO 9000 standards that multiplicity of audits should be eliminated through these standards. The first party audit is the internal audit. The employees themselves check the conformance of the system to the relevant quality system standards. The internal audits are never ending. They will continue to be performed as long as the organization exists. In fact, at least once in a year each activity should be audited.

Definition of Quality Audit Definition of a quality audit is given in ISO 9000 standard and reproduced below:

"A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these planned arrangements are implemented effectively and are suitable to achieve objectives".

In short, the auditors have to examine whether the quality system has been established as per the requirements and is effective. In case of the companies following ISO 9000 standards the auditors should see whether the system has been established as per the requirements of the relevant ISO 9000 standards. Such systems should be documented before carrying out the audit. The auditors will see whether the documented system meets the requirements. Then the auditors would see whether the system is implemented as documented. They would try to gather objective evidence that the documented system is implemented and finally they should see whether the system is effective in achieving the goals and objectives of the organization.

The Power of Internal Quality Audit The internal audit is a powerful management tool and it is quite useful in the TQM environment. In fact, it is one of the important TQM tools. Unless the audits are held, it would be difficult to find out whether the system is effective or not. Therefore, periodic audits should be conducted for all functions. The auditors would be able to translate senior management's goals and objectives and check whether the system is meeting them. After the audit, they provide the senior management with an essential set of corrective actions. Each corrective action is a step towards improvement. Therefore, independently the auditors lead the management to identify the problem areas and their corrective actions.

In every organization, the needs are more than what the organization can do due to financial and human resource constraints. There may be lots of suggestions for improvements. But the management has to set the priority. The internal audit automatically provides the set of priorities along with justification for allocation of resources. The internal audit helps in the development of a number of executives as auditors. Since auditing needs people skills; the auditor training should provide necessary interpersonal skills to help cross-functional as well as departmental teams work together. In turn, the auditors can train the staff in problem identification and analysis. Every auditor has to clearly know the policy and objectives of the organization before auditing. Therefore, an internal audit helps the organization in making their employees learn more clearly the objectives and policies so that they can assist the management in defining priorities. Through the audit reports the senior management can easily find out the progress in implementation of organizational policies. Since cross-functional teams audit all the functions, the audit becomes transparent. Each audit is carefully documented. The organization will not be affected when employees leave for other jobs. The audit findings are the basis for continuous improvement in the system.

Internal Audits are a Formal Activity The internal auditors should be drawn from within the organization. They should be trained on the methodology of auditing. It must be emphasized that the internal audit is a formal activity. It is very essential that it is formal, so that auditee will give their cooperation. The methodology for auditing has been widely accepted with the advent of ISO 9000 certification. Each organization has to evolve a procedure for scheduling, carrying out and reporting audits. Even in the internal audit, the person who is auditing will not be from the same function as that of the auditee to ensure objectivity.

Audit Process During the audit, the auditors need to examine the quality system in operation. For this purpose, the auditors have to look at the following:

- Documentation
- Records
- Processes

The activities, i.e. the actual operation is examined to see whether the employees carry out their activities as per the documented system. The auditor looks at these three aspects to evaluate the organization, its resources and the system as explained below:

- the organization, whether it produces quality products and services
- the resources, whether they are adequate to perform the activities
- the procedures, whether they facilitate achievement of organizational goals and objectives.

Audit Cycle A set pattern has emerged for carrying out the audit. Each audit starts from audit schedule and ends up at follow up as described below. The sequence of audit activities is called audit cycle.

Audit Schedule Every year the person in-charge of quality in the organization or the management representative (MR) will draw up the annual schedule for auditing the various functions in the organization. This could be spread throughout the year. The schedule will be such that the same auditor is not repeatedly assigned to audit the same function. This is to avoid the development of vested interest. Sufficient rotation should be given so that the auditee's confidence in the audit is not brought down.

Audit Planning For each audit scheduled, coordinating executive that is the MR will detail two or three auditors including one lead auditor. The lead auditor will be coordinating the audit. MR will also indicate the timeframe, scope and purpose. The number of auditors and the duration of the audit should commensurate with the size and activities of the function audited.

Preparation In this phase of the audit, the audit team will thoroughly prepare for the audit. They may get the documents, i.e. the quality manual and quality system procedures and review them for adequacy in meeting the requirements of the standards. If they find any inadequacy, they should also bring it to the notice of the auditee. Documentation inadequacies should be resolved before the actual audit takes place. While they are perusing the documents, they should also draw up the checklists for the audit, which are essentially the points to be checked during the audit. The checklist is a useful tool for carrying out the audit. The lead auditor should distribute the areas to each auditor. Hence, for each area to be audited, the auditors should draw a checklist of items to be looked at during the audit. The lead auditor will also review the checklist and may add or delete some points. Thus, the auditors should thoroughly prepare before the actual audit.

Carrying Out the Audit During this phase, the following activities are involved:

Opening meeting with the senior executives in the function to be audited. During this meeting, the auditors would briefly explain the scope and purpose of the audit and seek the cooperation of the auditee. They would also put them at ease. They should also reiterate that doing is more difficult than advising and that their findings should not in any way be construed as a fault-finding mission. They can also tell the auditee that since a third party is looking at the system, it is easy for them to identify non-conformities than a person who is working within the system and that is how the audits bring out non-conformities very easily. After the opening meeting the auditors will look at the activities in progress. They may also talk to some selected people in the function audited. Through these, they will try to find out if there is objective evidence that the system is not implemented or not effective. The word objective evidence is important because any of the auditor's finding should not be subjective. The auditee would lose faith in the audit process if the auditors were not objective. Therefore, the auditors should bring out only those non-conformities for which there are objective evidences. The benefit of doubt should always be given to the auditee and the auditor should not aim at finding out as much non-conformity as possible. The auditors should also look at the various records and results of measurements, customer feedback, customer complaints and the system by which the top management is kept informed of the progress about the status of quality in the organization. The auditee should give due importance to the audit by informing all the employees about the audit well in advance and seek their presence at the time of the audit. They should also take care to see that the critical employees are definitely present during the audit. The auditors should also not suggest corrective actions during the audit. This will be interpreted by the auditee that the auditor is trying to push through his ideas. Therefore, before a non-conformity is discussed, the auditor should think himself what could be the corrective action, but he should not reveal it. The reason for thinking of corrective action is that if there is no corrective action possible, then there is no need to raise the non-conformity. After the audit is over, if the auditee needs the guidance of the auditor, then at that time, the auditor can give his suggestions for corrective action.

Preparation of Audit Report The audit team should discuss among themselves and bring out a clear and concise report incorporating the non-conformances. They should also give the reference clause in the quality manual or in the standard under which the points observed could be treated as non-conformities. This will increase the credibility of the audit report. They could also classify the non-conformances either as major or minor depending upon the severity. Once the audit team unanimously agrees on the report, then they should meet the auditee and give the final presentation of their findings. This is generally called closing meeting. In this meeting, the senior executives will also be present in addition to the other executives in the organization. In the closing meeting, the lead auditor will quickly read out the non-conformities. To make the auditee at ease, they should also highlight the positive aspects of the system. It is better to highlight one positive aspect for every negative aspect and say the positive aspect before a negative aspect. They should not get into debates with the auditee, since each auditee if given a chance would like to prove that the auditor is wrong. Since the audits are management tools, both the auditor and the auditee should treat it positively and welcome the audits. The audit should be positive and constructive. The auditors should also be positive. They should avoid emotions. They should also avoid fixing up responsibilities on individuals of the organization. For instance, even if a person is inefficient in a particular team, they should only say that the team is ineffecient to avoid bad consequences and should not say that the individual is ineffecient. They can comment about the process, but not about the persons.

Follow Up In this phase, the auditee will take corrective action. Generally, as soon as the audit is over all the non-conformities will be entered into a database. Teams will be formed to suggest corrective action. Such suggested corrective action should be approved by the management. Thereafter the corrective action should be applied. It is not only enough to find out and apply the corrective action, but it is also important to check whether it is effective. Therefore, during the subsequent audits effectiveness of corrective action taken should be reviewed.

SECTOR SPECIFIC QUALITY SYSTEM STANDARDS

1. QS 9000 This is a document specifying quality system requirements for automotive sector. Standards generally refer to the documents released by standardization bodies either national or international. This document is released by three automobile manufacturers in the USA, namely:

- Chrysler Corporation
- Ford Motor Company
- General Motor Corporation

It is entitled 'Quality System Requirements—QS 9000'

The first edition was issued during August 1994. Prior to that, the three automobile majors in USA had developed their own (individual) expectation for supplier (vendor) quality systems. In 1988 the purchasing and supply vice presidents of the three companies assembled a task force to standardize them. In December 1992, these vice presidents directed the task force to harmonize the fundamental supplier quality system manual and assessment tools. It was also realized that each company might still have company specific requirements. The QS 9000 document distribution and training coordination is handled by the Automotive Industry Action Group (AIAG). The purpose of QS 9000 is to define the fundamental quality system expectations of the three automobile majors, and truck manufactures and other companies engaged in manufacturing parts and materials. These companies are committed to working with suppliers to ensure customer satisfaction beginning with conformance to quality requirements and continuing with reduction of variations and waste to benefit the ultimate customer.

The goal of QS 9000 is the development of fundamental quality systems that provide for continuous improvement, emphasizing defect prevention and reducing variations and waste in supply chain.

The QS 9000 is derived from the ISO 9000 standards. It provides specific guidelines for the automobile industry. Figure 20.6 gives in a nutshell the QS 9000 approach to quality systems.

QS 9000 is meant for production part approval process. The company specific requirements still exist. Each of the three major companies and truck manufacturers have given additional requirements in section III of the QS 9000 document. Thus a supplier should understand the QS 9000 standard and company specific requirements. The sector specific requirements are given in section II. The ISO 9000 requirements are given in section I. The additional requirements of QS 9000 fall in the following areas:

- Measurement System Analysis (MSA)
- SPC
- Failure Mode and Effect Analysis
- Product Quality Planning and Control Plan

MSA addresses measures to ensure quality of measuring instruments. This is much more detailed than the requirements of calibration as per ISO 9001 standard. The suppliers have to carry out gauge R&R studies as per the Measurement System Analysis reference manual of QS 9000 family of documents. The documentation structure has also been standardized. The level 4 documents contain the record, which should reveal that the quality system is functioning correctly.

To summarize QS 9000 provides sector specific requirements and guidelines for establishing quality system in the automobile sector. The control of the document lies jointly with Ford, Chrysler and General Motors. However, QS 9000 draws the core of the requirements from ISO 9001. The additional concepts advocated are all aimed at continuous improvement of organizations. Every automobile industry establishes a quality system meeting QS 9000 standard and get certified as per QS 9000. Some may be additionally getting certified under ISO 9001. Thus QS 9000 is also a document providing requirements for quality systems. We will now look at some more standards on quality systems.

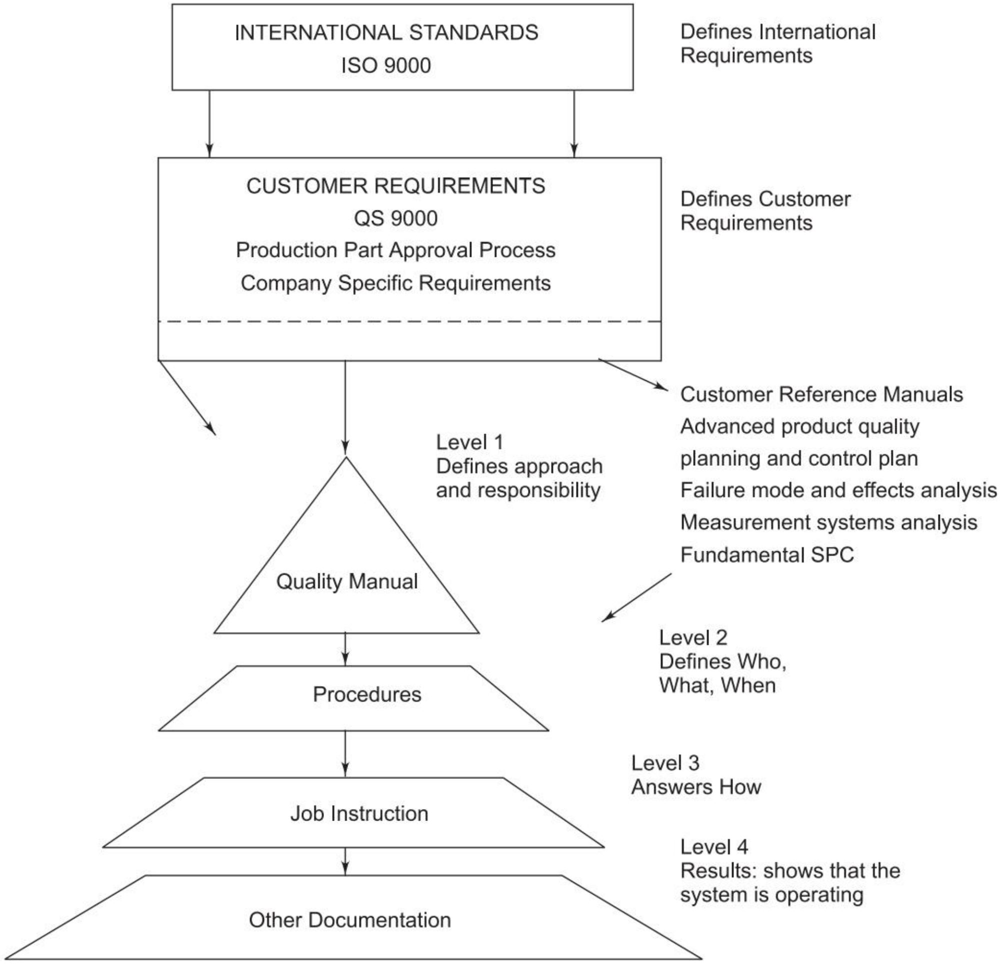


Figure. 20.6 QS 9000 in a Nutshell

2. AS 9100 Aerospace is a major sector of industry. National Aeronautic Space Agency (NASA), USA, US Depatment of Defence (DOD), etc. had their own requirment for quality systems. They brought out a document for quality systems in aerospace industry called AS 9100 to unify the requirements of NASA, DOD, etc. Now this has been aligned with ISO 9001:2000 standard. AS 9100 additionally provides aerospace specific requirements.

3. ISO/TS 16949 The technical specifications were released by ISO. It harmonizes the requirements of QS 9000 with that of the requirements of French, German and Italian automobile industry. The technical specifications are applicable to automobile industries and provides sector specific requirements in addition to ISO 9001 requirements.

4. TL 9000 This document is applicable to telecommunication industry. This was developed by a forum called the Quality Excellence of Suppliers of Telecommunications Forum (QUEST). The five layers of the document are illustrated below:

Layer 1 — ISO 9001 Requirements
Layer 2 — Common TL 9000 Quality Systems Requirements (QSR)—Book 1
Layer 3 — Requirements for
- Hardware
- Software
- Services

Layer 4 — Common TL 9000 Quality System Measurements (QSM)— Book 2
Layer 5 — Measurements for
- Hardware
- Software
- Services

CASE STUDY

Bangalore World Bank Health Project Benefits From ISO 9000[4]

Bangalore, the capital of Karnataka state in India, is one of the fastest growing cities in Asia. Unprecedented migration from rural areas to the city during the last decade has resulted in growing slum areas with inherently poor sanitary conditions and meager health care facilities.

In response, the Bangalore City Corporation initiated the " India Population Project VIII" (IPP VIII) in 1994–95, funded by the World Bank. Its broad objective was to provide free primary health and maternity services to women and children in Bangalore urban slums, encompassing family planning, health care for mothers, immunization for children, post- and ante-natal care, and ultimately to reduce infant mortality.

IPP VIII is a community development programme covering some 850,000 urban poor residing in over 500 slums in a city corporation area of 225 sq. km. Highly experienced doctors holding senior positions in the government health sector were appointed as project managers, and community leaders, non-governmental organizations and link workers from the local areas became involved in health education, and in mobilizing the community to make use of the services. To date, 55 health centres and numerous maternity homes have been established in city areas close to the slums.

Once IPP VIII had taken shape, the project managers decided that ISO 9002 quality management system (QMS) implementation would improve health centre performance and help achieve project goals. It was also felt that early success with ISO 9002-based systems would act as a stabilizing influence before embarking on more ambitious projects. And so an initial 25 primary health centers were chosen to undergo the process.

Some, particularly at top level, welcomed the move believing it would help encourage a more systematic approach. Many others, including some senior officers, felt that the quality of work in the primary health centres was already fairly high and that the ISO 9000 systems would not bring any significant improvement. Middle level employees were initially concerned that their documentation workload would increase substantially.

A number of lower level staff were worried that the flexibility they enjoyed in remote villages would be a thing of the past when posted to urban areas under the scrutiny of senior officers. They felt that ISO 9000 implementation would demand greater accountability. However, most of the medical officers in charge of the health centers were on contract employment, and saw an opportunity for their services to be regularized in government jobs if they showed sufficient commitment to the certification process.

At the same time, there was a desire at top and middle levels to make the IPP VIII health centers stand apart from other government units, be perceived as highly service oriented, and distance them from the stigma of apathy and inefficiency generally attached to government organizations.

Programme Steps

Appointment of Quality System Consultants Being new to establishing and implementing a QMS, the project managers decided to seek professional guidance and appointed consultants in March 1999 to help establish ISO 9002-based systems in the primary health centres, train personnel, assist during implementation, and provide certification guidance.

Formation of a Core Group A core group consisting of a mix of experienced senior and committed junior medical officers was formed to document the systems already in use in the centres. The project managers, who also monitored group progress, provided support and guidance.

Core group members, other senior officers, project managers and centre medical officers participated in an ISO 9000 awareness programme, which included the ISO 9004-2 guidelines for service industries. They were also trained in drafting operational procedures, work instructions, and the quality manual.

Developing QMS Documents and Implementation With core group members being new to drafting procedures, their efforts concentrated more on documenting the technical aspects (which would normally be covered in the work instructions) than on addressing the system aspects. The consultants developed acceptable procedures and work instructions based on the inputs provided and on interactions with the core group. By September 1999, the QMS documents were ready. They incorporated many ISO 9004-2 guidelines.

All personnel received extensive training in procedures and work instructions during the next two months. Each step was scrutinized for conformance with the actual practice and with ISO 9002 requirements. Practical difficulties anticipated during implementation were also identified during the training sessions, which helped in fine-tuning the documents and ensured consistency of practice among the centres.

Although time consuming, this process helped build a sense of participation and ownership of the documents among operating personnel. It also led to a clearer understanding of ISO 9002 requirements.

Audits and Review A group of selected medical officers in charge of some of the centers were trained as internal quality auditors. Technical audits carried out in a few centres by recognized experts in community medicine and witnessed by the trainee auditors, identified numerous weaknesses, ranging from inadequate knowledge in some areas to poor implementation and practices. These included practices not fully in line with procedures; child immunization schedules and post-natal cases not monitored effectively; need for further improvement in immunization practice including vaccine storage; incomplete information recorded on antenatal cards; emergency kits incomplete or containing out-of-date drugs; inadequate follow up of high risk pregnancies, and monthly staff meetings that failed to cover quality issues or progress towards objectives.

All identified problems were investigated and appropriate corrective actions taken. This was the "moment of truth" which prompted significant re-training of personnel concerned and reinforcement of the need for continual monitoring and improvement.

Subsequently, the trained auditors, carried out two rounds of internal quality audits at all centres first on technical aspects only and then on the system itself. Again, those concerned discussed all discrepancies and observations. This information sharing and pooling of knowledge led to common solutions, consistency of practice, and enabled individual centres to anticipate problems before they occurred. The consultants then carried out independent audits of all primary health centres to assess both system and technical aspects. While most of the earlier non-conformities had been eliminated, problems included poor monitoring of performance against immunization targets, infant mortality and maternal morbidity statistics; inconsistencies in identifying high risk pregnancies, and inadequate monitoring of the activities of field staff. These issues were discussed by project managers and all centres and necessary corrective measures implemented.

Certification All 30 primary health centers in Bangalore, part of the " India Population Project VIII " funded by the World Bank, are ISO 9002-certified, in the first attempt, by the chosen ISO 9000 Registrar.

Problems Faced Achieving certification was not entirely smooth sailing. Considerable difficulties and problems Were encountered. For example, project managers repeatedly assured employees that they were already doing good work and all that was required for certification was to maintain appropriate records. Such over-simplification proved counterproductive. Workers were lulled into a false sense of security, and it took considerable effort on the part of consultants to alert them to the reality of the situation. There was the feeling at certain levels that as the health services are provided free of cost; the target population should be content with the treatment they receive. To change such attitudes, the consultants had to give everybody a document explaining their duties and responsibilities in clear, unambiguous terms and provide further explanation in open forums. The importance of each individual's contribution, however simple, was strongly emphasized. In addition, the sense of individual self-fulfillment and recognition, and the benefit to customers in achieving organizational goals, was highlighted.

There was little appreciation of the process linkages and interactions. Individual activities were perceived as "stand alone ", which led to inadequate performance monitoring and measurement. The concepts of a process approach and systems approach were communicated to improve overall effectiveness.

The perception of insufficient time for the additional work in achieving ISO 9002 implementation was widespread. The consultants had to emphasize that quality was not an additional task but an integral part of the organization's role.

Benefits and future outlook

Employees at many levels believe that certification was well worth the effort, and saw the following advantages of ISO 9002 implementation:

- A significant boost in personnel morale across the organization.
- A more positive attitude towards, and greater concern for, the health care "customer".
- Clearer communication and more trusting relationships at all levels.
- Better understanding of the role of each individual and of the role and purpose of the health centres.
- Enhanced teamwork.

Based on the IPP VIII experience, other government hospitals in the state of Karnataka are now considering ISO 9001 certification for their maternity homes, blood banks and maintenance units.

SUMMARY

ISO 9000 standards released for the first time in the year 1987 and the revised during 1994 and then in 2000 provide a tool for the organizations world-wide to establish, maintain and improve quality systems. ISO 9000 is a popular term all over the world. Thus, their contributions for continuous improvement are beyond doubt.

The revised ISO 9000 calls for continual improvements in the quality system and in turn the processes. In fact, the latest standard stipulates process approach in the organization. Therefore, ISO 9000 certification can be considered to be the first step in the TQM journey. Organizations have to make still more efforts to make TQM happen.

We discussed briefly about the requirements for quality system stipulated in the standard. We also discussed about documentation requirements. Steps for ISO 9001 certification were also given. During the years, sector specific documents have emerged. Some sectors, which have their own Quality System Requirements, are:

- Aerospace Industry — AS 9100
- Automobile Industry— QS 9000 and ISO TS 16949
- Telecommunication — TL 9000

We discussed briefly about them in this chapter.

Audits make the improvements of quality system possible and measurable. Hence we discussed about audits in detail. Quality audit is one of the important tools of TQM for continuous improvement. There are three types of quality audits namely first, second and third party audits. The certification audit by an agency is a third party audit. The second party audit is when a customer audits and the audit performed by the organization itself is the first party audit. The popularity of ISO 9000 Standards has also brought in credibility to the quality audit. All the audits are formal activities and hence should be a planned activity. The audits should be scheduled, planned, prepared and carried out with a positive attitude. The non-conformities reported should be based on objective evidence for the same. Formality is very important in auditing so as to continue cordial relationship between the auditor and the auditee. Each audit finding is a potential source for improvement. These are to be taken seriously and systematic action taken to find out and implement corrective action. The effect of corrective actions should also be assessed in due course. Thus, audits are essential tools for improvement of the organizations.

An implementer of TQM should be aware of the requirements of ISO 9000 family of standards, since they are the stepping-stones of TQM.

REVIEW QUESTIONS

I. Choose the most appropriate answer.

1. ISO 9000 is a standard for
   (a) Product quality (b) Process quality
   (c) Quality Management System (d) All the above

2. Quality audit phases include
   (a) Planning (b) Preparation
   (c) Carrying out the audit (d) All the above
3. QS 9000 provide requirements of
   (a) ISO 9000 (b) sector specific
   (c) Company specific (d) All the above
4. TL 9000 Layers include
   (a) Sector specific requirements (b) Measurements for software
   (c) Measurements for service (d) All the above
5. Documents say
   (a) What has to be done (b) What has been done
   (c) What are the objectives of the process (d) None of the above
6. QS 9000 was initiated by
   (a) Toyota (b) Benz
   (c) Ford Motors (d) None of the above
7. Certification body should be selected based on their
   (a) Accreditation status (b) Reputation
   (c) Cost and lead time (d) All the above
8. Resource includes
   (a) Work environment (b) Infrastructure
   (c) Human resource (d) All the above

II. Say True or False

1. Every equipment has to be calibrated
2. FMEA is a requirement of ISO 9001
3. MSA is a requirement of QS 9000
4. Audits are informal activities
5. Management review board meets every week
6. Internal audit is carried out by a representative of certifying body
7. Continuous improvement is also the goal of QS 9000
8. Consultant should not be hired for ISO 9000 implementation
9. Awareness creation is an important activity of ISO 9000 implementation
10. ISO 9000 registration and certification are synonymous
11. ISO 9000 certification is usually valid for three years
12. Surveillance audits will be carried out by certification body
13. Documents should be planned in a hierarchical manner
14. Purchaser supplied part control is addressed in ISO 9001
15. Supplier refers to sub-contractor in the latest ISO 9000 standard
16. Calibration is not addressed in the standard
17. Internal audit should conform to the requirements of the organization
18. ISO 9000 standardizes QMS of all certified organizations
19. QMS procedure is at a higher level than the policy manual

20. Documented quality manual is a must for certification
21. Management representative liaises with the certification body
22. Customer satisfaction is one of the goals of ISO 9001.

III. Match the following

1.

A	**B**
ISO/TS 16949	Ford
TL 9000	All industries
QS 9000	Aerospace
ISO 9000	Automobile
AS 9100	Telecommunications

2.

A	**B**
Clause 4	Management responsibility
Clause 5	Resource management
Clause 6	Product realization
Clause 7	Measurement, analysis and improvement
Clause 8	QMS

IV. Explain briefly

1. Steps involved in ISO 9000 implementation
2. Steps involved in maintenance of ISO 9001 certification
3. Selection of certifying body
4. Resource management in ISO 9001
5. Management responsibility for ISO 9001
6. Measurement, analysis and improvement in ISO 9001
7. Product realization in ISO 9001
8. QMS
9. Analyse how the following are built into ISO 9001 standard
   (a) Customer satisfaction
   (b) Process approach
   (c) Employee involvement
   (d) Continuous improvement
10. TL 9000 standard
11. Special clauses of QS 9000 standards
12. Audit cycle
13. Purpose of management review
14. Hierarchical documentation system
15. Prepare a check list for auditing the following
    (a) Measurement, analysis and improvement
    (b) Product realization
    (c) QMS
    (d) Resource management

16. Describe which of the following are non-conformities under ISO 9001 standard. If so indicate the applicable clause number and reasons thereof
    (a) An employee was not aware of the quality policy
    (b) The number of customer complaints was not known to the MR
    (c) One department had a photocopy of the quality manual
    (d) Product requirements were not available
    (e) An important process equipment was not calibrated at all since commissioning
    (f) A heap of scrap was lying in a corner. Nobody knew what it was
    (g) Management review board meeting was not held for three years.

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Chapter 21

Environmental Management System (EMS)—14001

The good we secure for ourselves is precarious and uncertain until it is secured for all of us and incorporated into our common life.

–Jane Addams

INTRODUCTION

ISO released ISO 9000 standards in the year 1987 to improve the quality of products and services. ISO 9000 was a great success and it is one of the most accepted standards worldwide. Encouraged by the success, ISO released ISO 14000 family of standards for Environmental Management System (EMS). An EMS is a continual cycle of planning, implementing, reviewing and improving the processes and actions that an organization undertakes to meet its business and environmental goals.

The standards aim at ensuring sustainable development for everyone in the world by appropriately protecting the environment.

An organization called Business Charter for Sustainable Development (BCSD) consisting of 50 business leaders was established in the year 1990. Their theme is that economic development can happen only in a healthy environment. ISO Technical Committee TC 207 created the standards on EMS called ISO 14000 family, partially as a result of the work of BCSD. These standards are aimed at:

- Sustainable development for each and every nation
- Sustainable development for each and every person

The purposes of the standard as in ISO 14000 is reproduced below:

"An organization should implement an effective environmental management system in order to protect human health and the environment from the potential impacts of its activities, products and services and to assist in maintaining and improving the quality of the environment".

Thus, the standard is aimed at providing the requirements for implementing an effective EMS for organizations. The requirements when implemented will protect the human health and the environment from the impacts of the activities of the organization as well as its products and services. Thus, this standard is not aimed at any particular sector of the industry. These standards are for improvement of EMS in every organization. These standards have been adopted by organizations, both in manufacturing and services in various sectors such as:

- Chemicals
- Fertilizers
- Leather
- Construction
- Materials conversion
- Electro-technology
- Pharmaceuticals
- Medical devices
- Engineering
- Utilities
- Automotive
- Food
- Garments and textiles

BENEFITS OF EMS CERTIFICATION

The organizations that implemented EMS meeting ISO 14001 reported the following benefits.

- Awareness in the organization about waste reduction
- Compliance with legislation
- Enhancement of environmental awareness within the organization
- Cost savings due to reduction in usage of resources
- EMS Certification is an effective sales tool
- Competitive advantage—business won from non-ISO 14001 competitors
- A demonstration to stakeholders of environmental commitment of the organization
- Environmental awards

The organizations are implementing ISO 14001 certifications due to a variety of reasons. Some of them are:

- Establishing a uniform approach to meet the company's environmental policy
- Ensuring that the minimum regulatory requirements are consistently met
- Increasing operational efficiency and minimizing wastage
- Requirement to demonstrate the organization's commitment to the environment to stakeholders
- Enhancing relationship building with the local community

What is ISO 14000?

ISO 14000 is a series of international standards on environmental management. It provides a framework for the development of an environmental management system and the supporting audit program.

The main thrust for its development came as a result of the Rio Summit on the environment held in 1992.

The History of ISO 14000

As a number of national standards emerged (BS 7750 being the first), the International Organization for Standardization (ISO) created a group to investigate how such standards might benefit business and industry. As a result, this group recommended that an ISO committee be created to create an international standard.

What is ISO 14001?

ISO 14001 is the corner stone standard of the ISO 14000 series. It specifies a framework of control for an EMS against which an organization can be certified by a third party.

ISO 14000 Family of Standards

In the following, we will discuss about the various standards in the ISO 14000 family.

The top level EMS standards are given in Table 21.1:

Table 21.1 Top-level EMS Standards

Standard Number	*Title*
ISO 14001	Environmental management systems—Specification with guidance for use
ISO 14004	Environmental management systems—General guidelines on principles, systems and supporting techniques

ISO 14001 is a contractual standard against which organizations are certified. We will discuss about this standard in detail, later.

Contents of ISO 14004

ISO 14004 is meant for providing guidance for EMS implementation. It is a non-contractual standard. The contents of ISO 14004 are given in Table 21.2:

Table 21.2 Contents of ISO 14004

0	Introduction		
	0.1	Overview	
	0.2	Benefits of having an environmental management system	
1	Scope		
2	Normative references		
3	Definitions		
4	Environmental Management System (EMS) principles and elements		
	4.1	How to start: commitment and policy	
		4.1.1	General
		4.1.2	Top management commitment and leadership
		4.1.3	Initial environmental review
		4.1.4	Environmental policy
	4.2	Planning	
		4.2.1	General
		4.2.2	Identification of environmental aspects and evaluation of associated environmental impacts
		4.2.3	Legal requirements
		4.2.4	Internal performance criteria
		4.2.5	Environmental objectives and targets
		4.2.6	Environmental management program
	4.3	Implementation	
		4.3.1	General
		4.3.2	Ensure capability

(Contd.)

		4.3.2.1	Resources—human, physical and financial
		4.3.2.2	EMS alignment and integration
		4.3.2.3	Accountability and responsibility
		4.3.2.4	Environmental awareness and motivation
		4.3.2.5	Knowledge, skills and training
	4.3.3	Support action	
		4.3.3.1	Communication and reporting
		4.3.3.2	EMS documentation
		4.3.3.3	Operational control
		4.3.3.4	Emergency preparedness and response
4.4	Measurement and evaluation		
	4.4.1	General	
	4.4.2	Measuring and monitoring (ongoing evaluation)	
	4.4.3	Corrective and preventive action	
	4.4.4	EMS records and information management	
	4.4.5	Audit of the EMS	
4.5	Review and improvement		
	4.5.1	General	
	4.5.2	Review of the EMS	
	4.5.3	Continual improvement	
Annexure A	Examples of international environmental guiding principles		
A1.1	The Rio Declaration on Environmental and Development		
A1.2	The ICC Business Charter for Sustainable Development		
Annexure B	Informative references		

This standard is complimentary to ISO 14001. It provides guidance for implementation of EMS. A person new to EMS may read this standard first to get an understanding of the subject.

Environmental Auditing

There are three standards under this category as given in Table 21.3:

Table 21.3 EMS Auditing Standards

ISO 14010	Guidelines for environmental auditing—General principles
ISO 14011	Guidelines for environmental auditing—Audit procedures—Auditing of Environmental management systems
ISO 14012	Guidelines for environmental auditing—Qualification criteria for environmental auditors

Environmental guidelines for performance evaluation are covered under the standard ISO 14031.

These standards are applicable to organizations. There are additional standards available for product evaluation in the context of environmental protection. There is a set of standards for environmental labeling. The labeling standards are given in Table 21.4:

Table 21.4 EMS Labeling Standards

ISO 14020	General principles for all environmental labels and declarations
ISO 14021	Environmental labels and declarations—Self-declaration environmental claims—Terms and definitions
ISO 14022	Environmental labels and declarations—Self-declaration environmental claims—Symbols
ISO 14023	Environmental labels and declarations—Self-declaration environmental claims—Testing and Verification
ISO 14024	Environmental labels and declarations—Type I guiding principles and procedures

There are four standards for life cycle assessment of each inventory in the organization, as given in Table 21.5:

Table 21.5 EMS Life Cycle Assessment Standards

ISO 14040	Life cycle assessment—Principles and framework
ISO 14041	Life cycle assessment—Inventory analysis
ISO 14042	Life cycle assessment—Impact assessment
ISO 14043	Life cycle assessment—Interpretation
ISO 14050	Terms and Definitions
ISO 14060	Guide for the inclusion of environmental aspects in product standards

ISO 14000 was evolved from a growing concern to protect environment. The series of standards dealing with EMS are called ISO 14000 family of standards. Out of these only ISO 14001 is a normative or contractual standard. All others are for guidance only. The contractual standard is entitled ISO 14001—Environmental Management System—Specifications with guidance for use.

REQUIREMENTS OF ENVIRONMENTAL MANAGEMENT SYSTEM (EMS)

The standard ISO 14000 consists of five sections and three annexures. The introduction part provides importance of EMS and purpose of the standard. The requirements of EMS start at clause four. Annexure A provides guidance on the use of the standard. This is to further clarify the intent of the standard. Let us look at some of the elements of the standard to understand the essence of this standard.

Introduction Clause

The organizations of various kinds are interested in achieving sound environmental performance by controlling the impact of their activities, products or services on the environment. They would also like to demonstrate their conformance to the standards due to:

- Stringent legislation
- Development of economic policies and other measures to foster environmental protection
- Rising concern about environmental matters including sustainable development

For instance, the United Nations held a conference on Environment and Development in Rio de Janeiro, Brazil in the year 1992. In fact, this is one of the triggers for the development of the standard. The International Standard ISO 14001 provides structured management system for environment that can be integrated with the overall management activity. It provides elements of EMS, which can be integrated with ISO 9000 requirements, to assist the organization to achieve environmental and economic goals. It is applicable to all types and sizes of organizations and to accommodate diverse geographical, cultural and social conditions. Like the ISO 9000 it can be implemented in every organization in every country. Top management commitment is essential to implement the requirements of EMS. The overall aim of this standard is to support environmental protection and prevention of pollution in balance with socio-economic needs.

The certification under ISO 14001 by a duly accredited registrar is a demonstration of conformance to the standards. Certification under the standard can be used by an organization to assure those concerned that appropriate EMS is in place. While, ISO 14001 provides the requirements of EMS, which are contractual in nature, ISO 14004 provides guidance on a broad range of EMS. The standard also adds that EMS can be built on top of ISO 9000. It means that only the additional requirements are to be implemented keeping the management system common to both ISO 9001 and ISO 14001.

Clause Reference 1 in ISO 14001—Scope

The standard specifies requirements for an EMS to enable an organization to formulate a policy and objectives taking into account legislative requirements and information about significant environmental impacts. It applies to those environmental aspects, which the organization can control and over which it can be expected to have an influence. These are to be decided by the organization since the standard itself does not state any specific environmental performance criteria.

It is worth understanding some definition of related terms given in clause three of the standard.

Environment Surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation.

Note—Surroundings in this context extend from within an organization to the global system.

Environmental Aspects Element of an organization's activities, products or services that can interact with the environment.

Note—A significant environmental aspect is an environmental aspect that has or can have a significant environmental impact.

Environmental Impact Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.

Environmental Management System The part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

Environmental Objectives Overall environmental goal, arising from the environmental policy, that an organization sets itself to achieve and which is quantified where practicable.

Environmental Performance Measurable results of the environmental management system, related to an organization's control of its environmental aspects, based on its environmental policy, objectives and targets.

Environmental Policy Statement by the organization of its intentions and principles in relation to its overall environmental performance, which provides a framework for action and for the setting of its environmental objectives and targets.

Environmental Target Detailed performance requirement, quantified where practicable, applicable to the organization or parts thereof, that arises from the environmental objectives and that needs to be set and met in order to achieve those objectives.

Prevention of Pollution Use of process, practices, materials or products that avoid, reduce or control pollution, which may include recycling, treatment, process changes, control mechanisms, efficient use of resources and material substitution.

Note—The potential benefits of prevention of pollution include the reduction of adverse environmental impacts, improved efficiency and reduced costs.

Clause 4 of Standard ISO 14001

EMS Requirements

4.1 General

The organization should establish and maintain EMS as per the requirements given in clause four, which are briefly described below:

Annexure A of the standard provides the following guidance[1.]

Integration of environmental matters with the overall management system can contribute to the effective implementation of the environmental management system, as well as to the efficiency and clarity of roles.

This international standard contains management system requirements, based on the dynamic cyclic process of "plan, implement, check and review". This model leads to continual improvement based upon:

- Planning, including identifying environmental aspects and establishing goals [plan];
- Implementing, including training and operational controls [do];
- Checking, including monitoring and corrective action [check]; and
- Reviewing, including progress reviews and acting to make needed changes to the EMS [act].

The system should enable an organization to:

(a) Establish an environmental policy appropriate to itself;
(b) Identify the environmental aspects arising from the organization's past, existing or planned activities, products or services, to determine the environmental impacts of significance;
(c) Identify the relevant legislative and regulatory requirements;
(d) Identify priorities and set appropriate environmental objectives and targets;
(e) Establish a structure and a programme(s) to implement the policy and achieve objectives and targets;
(f) Facilitate planning, control, monitoring, corrective action, auditing and review activities to ensure both that the policy is complied with and that the environmental management system remains appropriate;
(g) Be capable of adapting to the changing circumstances.

4.2 Environmental Policy

The top management should define the organization's environmental policy. The policy should:

- Be appropriate to the nature, scale and environmental impact of its activities, products or services
- Include a commitment to prevention of pollution
- Include a commitment to comply with regulations and other requirements of the organization
- Provide a framework for establishing and reviewing the environmental objectives and target
- Be documented, implemented, maintained and be available to the public, which means it should be transparent

4.3 Planning

4.3.1 Environmental Aspects The organization should establish and maintain procedures to identify environmental aspects of its activities, products or services, which are under its control. These aspects should be addressed in its environmental objectives.

The process to identify the significant environmental aspects associated with the activities at operating units should consider:

(a) Emissions into air;
(b) Releases to water;
(c) Waste management;
(d) Contamination of land;
(e) Use of raw materials and natural resources;
(f) Other local environmental and community issues.

4.3.2 Legal and Other Requirements The organization should establish procedure to identify and have access to legal and other requirements that are applicable to it.

4.3.3 Objectives and Targets The organization builds an EMS based on the applicable environmental aspects and its policy and should establish objectives and targets to guide its EMS activities. Let us see with examples the relation between policy, objectives and targets.

Policy—High-level statement about intentions and principles.

For instance, the policy could be to “conserve natural resources”.

Objectives—Overall environmental goals. For instance, reduce consumption of water.

Targets—Detailed performance requirements that must be met to achieve environmental objectives.

For instance, reduce water consumption by using recycled water for garden, to cover 25 per cent of the area every year progressively.

4.3.4 Environmental Management Programs The organization should establish and maintain programs for achieving objectives and targets. This requires initiating projects with persons, resources, timeframe and clear goals. The programs will address activities aimed at achieving environmental objectives and targets. The programs should also identify the measures for tracking progress in achieving established targets.

4.4 Implementation and Operation

Annexure A.4.1 Structure and responsibility

The successful implementation of an environmental management system calls for the commitment of all the employees of the organization. Environmental responsibilities therefore should not be seen as confined to the environmental function, but may also include other areas of an organization, such as operational management or staff functions other than environmental.

This commitment should begin at the highest levels of management. Accordingly, top management should establish the organization’s environmental policy and ensure that the environmental management system is implemented. As part of this commitment, the top management should designate specific management representative(s) with defined responsibility and authority to implement the environmental management system. In large or complex organizations there may be more than one designated representative. In small or medium-sized enterprises, one individual may undertake these responsibilities. Top management should also ensure that appropriate resources are provided to ensure that the environmental management system is implemented and maintained. It is also important that the key environmental management system responsibilities are well defined and communicated to the relevant personnel.

4.4.1 Structure and Responsibility The responsibility for overall effectiveness of EMS should be assigned to a Management Representative (MR), a senior level executive, like general manager, executive director, etc. The implementation responsibility should lie with operational managers, clearly earmarked. For instance, the following Table 21.6 indicates the authority and responsibility for EMS.

Table 21.6 Responsibility Matrix

Responsibility	*Person responsible*
Overall direction	CEO
Develop environmental policy	CEO, MR
Monitor overall system performance	MR
Assure regulatory compliance	Senior environmental manager
Ensure internal compliance	All managers, MR
Continual improvement	All managers
Identify customer expectation for EMC	Sales staff
Identify supplier expectation	Purchase staff
Develop and maintain accounting procedures	Finance
Comply with defined procedure	All

The management should provide resources for EMS implementation. They should provide visible support to MR for EMS, similar to QMS.

4.4.2 Training, Awareness and Competence The training programs focused on environmental protection and those required for implementing EMS, should be organized and records maintained. The senior management should undergo executive seminars on strategic importance of EMS. Every employee should be provided awareness program on EMS. Those who are implementing EMS and those who are responsible for EMS compliance should undergo detailed training programs. Furthermore, mentoring and on-the-job training will help the organization in implementing EMS.

4.4.3 Communications Annexure A 4.3 provides the following guidance with regard to communications inside and outside the organization.

Organizations should implement a procedure for receiving, documenting and responding to relevant information and requests from interested parties. This procedure may include a dialogue with interested parties and consideration of their relevant concerns. In some circumstances, responses to interested parties concerns may include relevant information about the environmental impacts associated with the organization's operations. These procedures should also address necessary communications with public authorities regarding emergency planning and other relevant issues.

Appropriate internal and external communications with regard to environmental aspects and EMS should be established and maintained.

4.4.4 EMS Documentation Organizations certified under ISO 9000 standards would like to establish hierarchical structure for EMS documentation consisting of:

- EMS manual
- EMS procedures
- Environmental records, work instructions, standards, forms etc.

The standard vide Annexure A 4.4 provides the following guidance with regard to EMS documentation.

The level of detail of the documentation should be sufficient to describe the core elements of the environmental management system and their interaction and provide direction on where to obtain more detailed information on the operation of specific parts of the environmental management system. This documentation may be integrated with documentation of other systems implemented by the organization. It does not have to be in the form of a single manual.

Related documentation may include

(a) Process information;
(b) Organizational charts;
(c) Internal standards and operational procedures;
(d) Site emergency plans.

4.4.5 Document Control The guidance given for ISO 9000 more than satisfies this requirement.

4.4.6 Operational Control As per clause 4.3.1, the organization should identify environmental aspects of its activities, products and services that it can control and over which it has an influence. Such aspects should have the potential to have significant impact on the environment. Few of these aspects are listed below:

- Emissions into air
- Discharge into water or soil
- Use of natural resources, such as pulp, paper, oil, water etc.
- Use of certain rare materials or metals, etc.

In order to protect environment and save natural resources, the organization should identify those operations and activities that are associated with the identified environmental aspects. The organization should formulate procedures that will address meeting environmental policy and objectives of the organization in these operations and activities. This can be done either explicitly or implicitly. Those operations where lack of a procedure could result in failure to meet the policy should have an explicit procedure. Other operations may address these concerns implicitly.

4.4.7 Emergency Preparedness and Response Emergency situations such as accidents should have been anticipated and contingency plan for them documented. Some emergency situations are:

- Accidental leak of poisonous gaseous materials
- Accidental discharge of fumes or polluted water
- Accidental releases of unplanned liquid, gas or solid either through air or water or land

The organization should make procedures available for handling such emergencies. They should address the following:

- Emergency response team
- Their authority and responsibility
- Details of emergency services
- Communications, alarms etc.
- Training requirements and skill determination

The organization should be prepared for such emergencies. To confirm, the emergency response procedure should be tested periodically through mock exercises to check the preparedness of the organization.

4.5 Checking and Corrective Action

Clause 4.3 was 'planning' phase, 4.4 was 'do' phase and obviously clause 4.5 will be 'check' phase of PDCA for EMS.

4.5.1 Monitoring and Measurement The organization should compare their actual environmental performance with objectives and targets. There should be a documented procedure to determine whether the company is conforming to its stated policy as well as legal requirements.

4.5.2 Non-conformance and Corrective and Preventive Action This is similar to the corresponding requirement in ISO 9001. Here, non-conformance is with respect to planned or established EMS.

4.5.3 Records Collection and maintenance of records is similar to ISO 9001. The records to be established are given in Annexure A in the standard. They are given below:

A.5.3 Records Procedures for identification, maintenance and disposition of records should focus on those records needed for the implementation and operation of the EMS and for recording the extent to which planned objectives and targets have been met.

Environmental records may include

(a) Information on applicable environmental laws or other requirements;
(b) Complaint records;
(c) Training records;
(d) Process information;
(e) Product information;
(f) Inspection, maintenance and calibration records;
(g) Pertinent, contractor and supplier information;
(h) Incident reports;
(i) Information on emergency preparedness and response;
(j) Records of significant environmental aspects;
(k) Audit results;
(l) Management reviews;

Proper account should be taken of confidential business information.

> Transport Canada is committed to making sustainable development a fundamental principle of policy development, and ensure that all of its operations are conducted in an environmentally responsible manner.
>
> One of the challenges for sustainable transportation, for which Transport Canada has a direct responsibility, is to improve the department's own environmental practices and take action to mitigate the environmental impacts of the department's operations. Using the principles of the International Organization for Standardization (ISO) 14000 series of standards, Transport Canada has developed a system that will incorporate environmental considerations into all aspects of decision-making. The successful integration of an EMS into the overall management scheme will contribute to the fulfillment of Transport Canada's sustainable development strategy.
>
> From the Internet

4.5.4 EMS Audit

A.5.4 Environmental Management System Audit The audit program and procedures should cover

(a) The activities and areas to be considered in audits;
(b) The frequency of audits;
(c) The responsibilities associated with managing and conducting audits;
(d) The communication of audit results;
(e) Auditor competence;
(f) How audits will be conducted.

Audits may be performed by personnel from within the organization and /or by external persons selected by the organization. In either case the persons conducting the audit should be in a position to do so impartially and objectively.

Thus this clause is also similar to ISO 9000.

4.6 Management Review

Management Review Board for EMS should be constituted. The procedure is same as that applicable to ISO 9000. The essential purpose of review is to confirm that the EMS is implemented as planned and to determine the extent to which objectives and targets have been met.

EMS in a Nutshell The EMS, ISO 14000 is built using PDCA concept. The various activities carried out at each stage of implementation of EMS are given in Fig. 21.1.

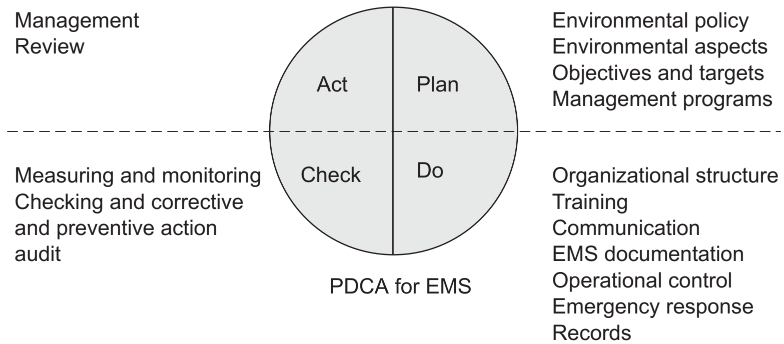

Figure 21.1

The standard has also provided guidance for formulating procedures. Some require documented procedure. But, some other elements require procedures, but not necessarily documented. The procedures are given in Table 21.7.

Table 21.7

I Documented Procedures

Subject	*Clause reference*
Operating procedures for activities associated with significant environmental aspects	4.4.6a
Monitoring and measurement of activities that can have a significant environmental impact	4.5.1
Periodic evaluation of regulatory compliance	4.5.1

II Documented Activities

Subject	*Clause reference*
Environmental policy	Section 4.2e
Environmental objectives	4.3.3
Roles, responsibilities and authorities	4.4.1
Communication from external parties	4.4.3b
Decision regarding external communication about significant environmental aspects	4.4.3
EMS documentation	4.4.4
Calibration and maintenance of monitoring equipment	4.5.1
Changes in any documented procedures	4.5.2
Training	4.5.3
Results of audits and reviews	4.5.3
Management review of the EMS	4.6

III Procedures required but can be optionally documented

Subject	*Clause reference*
Identification of environmental aspects	4.3.1
Identification of and access to legal and other requirements	4.3.2
Identification of training needs	4.4.2
Internal communication	4.4.3
Receiving, documenting and responding to relevant communication from external interested parties	4.4.3
Document control	4.4.5
Identifiable significant environmental aspects of goods and services used by the organization	4.4.6c
Identification of the potential for and response to accidents and emergencies	4.4.7
Defining responsibility and authority for addressing nonconformance and corrective / preventive action	4.5.2
Identification, maintenance and disposition of environmental records	4.5.3
EMS audits	4.5.4

Rio Declaration

Implementation of effective EMS becomes important in the light of the Rio declaration. The highlights of declaration in 1992 United Nations Conference on Environment and Development are given below:

- Principle 20 assigns vital role to women in environmental management and sustainable development, requiring their full participation.
- Principle 21 strongly recommends that the youth of the world be mobilized to forge the global partnership for sustainable development.

(1) Sovereign Rights to Sustainable Development Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature. States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction.

(2) Global Partnership for Sustainable Development The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, shall be given special priority. International actions in the field of environment and development should also address the interests and needs of all countries. States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the earth's ecosystem. In view of the different contributions to global environmental degradation, states have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressure their societies place on the global environment and of the technologies and financial resources they command.

(3) Equitable Environmental Legislation States shall enact effective environmental legislation. Environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries can be inappropriate and of unwarranted economic and social cost to other countries, in particular, developing countries.

(4) Internal Environmental Impact Assessment National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment. Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.

Integrating with ISO 9000

In order to save cost and time, the organization may integrate the systems for both QMS meeting ISO 9001 and EMS meeting ISO 14001 standards. The registration procedures for EMS are similar to ISO 9000. The organizations can choose the same registrar for both the certifications, if available. Although integration of both systems may appear to be difficult in the beginning, it is certainly possible. The organizations may therefore integrate them to reduce efforts and cost and get the cooperation of the employees.

CASE STUDY

Indian Petrochemicals saves costs, gains competitiveness and employee commitment with ISO 14001 based EMS

Indian Petrochemicals Corporation Limited (IPCL) manufactures and markets polymers, synthetic fibers, intermediate chemicals, catalysts and other petrochemicals-based products.

Environmental protection has been incorporated in all stages of evolution of its major Maharashtra Gas Cracker Complex (MGCC) at Nagothane in the Raigad district of Maharashtra State, which achieved ISO 14001 certification in 2000. IPCL focuses on environmental management at all stages of its activities.

IPCL's approach to environmental protection

IPCL focuses on environmental management at all stages of its activities, from selecting technology to operating and monitoring process plants. Environment friendly, low waste technologies were selected during the project stage at MGCC, followed by environmental impact assessment studies to determine air emissions, water effluents, etc.

IPCL commissioned a state-of-art effluent treatment system designed to release treated wastewater into the estuary of the Amba River, 26 km downstream from the plant site at Nagothane. The government-funded National Institute of Oceanography (NIO) identified the disposal site after 15 months of detailed studies.

In order to upgrade the eco-system of the region, IPCL initiated arboriculture (greenbelt) development activities in 1986, consisting of planting some 1.8 million saplings on 400 hectares of land.

Route map to ISO 14001

ISO 14001 provides a framework to institutionalize environmental protection and integrate environmental management practices with day-to-day activities.

Implementation of the international EMS standard at IPCL's Nagothane complex began during 1st quarter 1999. The task covered 19 units, including process plants, utilities, service groups, medical units and township services, and culminated in ISO 14001 certification some 15 months later.

Today, environmental management at IPCL focuses on five core elements:

(1) Commitment to environmental policy

To fulfill the requirements of ISO 14001, IPCL environmental policy focuses on "4C's":

- *Compliance* with legislation
- *Conservation* of resources by minimizing waste and maximizing recycling
- *Continual improvement* to enhance environmental performance and reduce impact by prevention
- *Communication* to raise awareness among employees so they work in an environment-friendly manner.

(2) Planning

This is the key element of the EMS undertaken by a multi-disciplinary core team of 35-40 members in collaboration with an environment management group. During this demanding phase, approximately 350 "environmental aspects" were identified by the environmental audit and mass flow diagrams indicating resources, waste emissions, etc. were prepared. A bio-medical waste incinerator was installed in December 2001 to ensure environmentally safe disposal of infectious and contaminated hospital waste in compliance with Bio-Medical Waste Rules 2000 legislated by the Indian Government. The team also identified "significant environmental aspects" based on ISO 14001 guidelines, classified as:

- Regulations and laws
- Impacts

- Wastage of resources
- Interested parties
- Frequency, control, preventive mechanisms, etc.

The core team set a number of environmental objectives in line with the environmental policy. These included technically and commercially viable targets based on significant environmental aspects and in compliance with legislative requirements, focused on improving environmental performance, conserving resources, recycling, reduction of waste, etc. Resource allocation for legislative compliance was given highest priority.

Forty-nine long- and short-term specific, challenging, achievable and time-bound targets with clearly defined responsibility were established.

(3) Implementation

This was the resource allocation phase, involving money and manpower. Here, the core team established procedures for communications, document control, preparedness for emergency response, etc. by preparing environmental system and procedure manuals and an environmental legislative compliance register.

Training programs played a key role in developing competency and an environmental-friendly approach among employees.

(4) Measurement and evaluation

Internal audits are the principal means of measuring, monitoring and evaluating environmental performance at IPCL. Trained internal EMS auditors conduct these every six months in order to identify procedural or system nonconformities, if any.

(5) Review and improvement

Top IPCL management continuously reviews the EMS to ensure its suitability, adequacy and effectiveness. It focuses particularly on the extent to which objectives and targets have been met, on policy formulation, and on addressing chronic or long pending environmental issues.

Benefits of ISO 14001 implementation

There is no doubt that implementation of the ISO 14001-based EMS at IPCL-MGCC's manufacturing operations at Nagothane has enhanced employee commitment towards resource conservation and prevention of pollution across the organization. Previously, the environment was considered the responsibility of a small group only, but now all personnel are involved and contribute increasingly to the betterment of the environment.

The comprehensive audit undertaken during the initial environment review phase of ISO 14001 implementation has helped us estimate resource losses. This led to a change in mindset, and the acceptance that "waste is a misplaced resource". As a consequence, each plant and department has identified significant aspects and has set techno-commercially viable targets of waste reduction, recycling, re-use, elimination, or conservation of the resource. Savings resulting from such schemes are estimated at INR 20-25 million per annum. Furthermore, water recycling and reduction projects are expected to save INR 1,7-1,8 million per annum.

Also, ISO 14001 implementation has improved the housekeeping and work environment at IPCL. In this context, the company has developed and implemented objective evaluation mechanisms based on the Japanese 5S Principles.

Furthermore, ISO 14001 certification has helped us gain in competitiveness versus other organizations in the sector as it reflects IPCL's proactive approach to protecting the environment through preventive rather than corrective mechanisms.

SUMMARY

ISO 14000 family of standards provides a framework for the organizations to establish Environmental Management System (EMS). EMS is quite important for sustainable development of nations. ISO 14001 standard is the counter part of ISO 9001. The EMS is aimed at identifying environmental aspects pertaining to the organization's activities, products and services. The EMS should provide objectives and targets for implementing EMS for the identified aspects. The organization should ensure that they neither cause pollution nor consume natural resources blindly. This comprehensive standard on the lines of ISO 9001 provides the requirements for EMS. This can be implemented by taking guidance from the standard ISO 14004. The modus operandi for ISO 14000 is similar to ISO 9000, but the focus here is environment protection and conservation of natural resources. Every citizen should become aware of the goals of this important standard.

REVIEW QUESTIONS

I. Choose the most appropriate answer

1. EMS certification is against
   (a) ISO 14000 (b) ISO 14004
   (c) ISO 14001 (d) None of the above
2. EMS is aimed at
   (a) Protecting health (b) Sustained development
   (c) Protecting environment (d) All the above
3. ISO 14001 suggests the following for EMS
   (a) Plan (b) Do
   (c) Check (d) All the above
4. ISO 14001 requires
   (a) EMS Manual (b) Targets
   (c) Objectives (d) All the above
5. ISO 14001 certificate will be given after
   (a) Audit by team sponsored by registrar (b) Internal audit
   (c) Audit of external experts (d) All the above

II. True or false

1. QMS and EMS can be integrated
2. EMS can be applied to any sector
3. ISO 14001 is applicable to organizations of any size
4. MR is required for EMS
5. Document hierarchy is applicable to EMS
6. Corrective action is not applicable to EMS
7. Environmental policy should address relevant legislations on the subject
8. Environmental policy should be available to the public

9. Targets are derived from objectives
10. The same documentation control system as that of QMS can be applied to EMS
11. Emergency response is not applicable to EMS
12. Records are irrelevant to EMS
13. EMS provides non-documented procedures also
14. Conservation of petrol is covered under EMS

III. Explain briefly

1. Benefits of EMS
2. Rio convention declarations
3. Common elements of QMS and EMS
4. The activities to be performed during the planning phase
5. Reasons why an organization should set up EMS as per the standard
6. Scope of ISO 14001
7. Policy, objectives and targets of EMS
8. Environmental aspects
9. EMS documentation
10. EMS records
11. ISO 14000 family of standards
12. PDCA and EMS
13. Background and history of ISO 14000 family of standards
14. Contents of ISO 140004
15. Authority and responsibility for EMS

IV. Match the following

	Clause number
Environmental aspects	4.5.3
Targets	4.4.4
Training	4.3.3
EMS documentation	4.5.4
Records	4.4.2
EMS audit	4.3.1

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Chapter 22

Quality Awards

The secret of joy in work is contained in one word—excellence.
To know how to do something well is to enjoy it.

—Pearl S. Buck

INTRODUCTION

To accelerate and facilitate application of TQM in the industry, a number of quality awards are given in various countries periodically, generally on an annual basis. Certification under ISO 9000 is not a quality award, but a quality certification. There is no limit to the number of organizations, which could receive the ISO 9000 certification. If an organization fulfills the requirements of the ISO 9000 standards, it will be certified by a certifying agency. But the quality awards are limited in number. These awards are given to a few successful organizations practicing TQM principles. The award criteria provide guidelines for organizations to evolve and practice TQM in their organizations. An organization receiving any of these national awards will indicate that it is practicing TQM and has achieved substantial success in the implementation of the same. The awards are given in an objective oriented manner. They stipulate marks for each one of the quality characteristics, thus indirectly indicating the relative importance of each one of the criteria. Some of the popular awards are the Deming Prize in Japan, Malcolm Baldrige National Quality Award (MBNQA) in USA, The European Quality Award (EQA) and Rajiv Gandhi National Quality Award in India.

THE DEMING PRIZE

Although, Deming hailed from USA, the award is instituted in his name in Japan to appreciate his contribution for the Japanese quality movement. It was instituted in the year 1951 by the Union of Japan Scientists and Engineers (JUSE). The aim of the Deming Prize was to motivate the companies to embrace Company Wide Quality Control (CWQC). CWQC and TQM are synonymous. The Deming Prize evaluates the following.

1. Company Policy and Planning
2. Organization and its management
3. Quality control education and dissemination
4. Collection, transmission and utilization of information on quality
5. Analysis
6. Standardization
7. Control
8. Quality Assurance
9. Effects
10. Future Plans

The Deming Prize is accepted to be one of the top most recognition for quality of organizations in Japan and elsewhere. Here is a case study.

CASE STUDY (From the Internet)

The most famous name in Japanese quality control is an American

His name is Dr. W. Edwards Deming, and he's a quality control expert.

In 1950, the Union of Japanese Scientists and Engineers (JUSE) invited Dr. Deming to lecture several times in Japan, events that turned out to be overwhelmingly successful.

To commemorate Dr. Deming's visit and to further Japan's development of quality control, JUSE shortly thereafter established the Deming Prizes, to be presented each year to the Japanese companies with the most outstanding achievements in quality control.

Today, Dr. Deming's name is well known within Japan's industrial community, and companies compete fiercely to win the prestigious Demings Prize.

In 1953, Sumitomo Metals was fortunate enough to win the Deming Prize for Application. In retrospect, we believe it may have been the single most important event in the history of quality control at Sumitomo. By inspiring us to even greater efforts, it helped us to eventually become one of the world's largest and most advanced steel-makers.

Sumitomo Metals owes a great deal to the American quality control expert who became one of Japan's greatest inspirations.

Thus, Deming Prize is the oldest of the Quality Awards internationally. The award is also given to industries outside Japan. A few companies in India have also received the prestigious award.

MALCOLM BALDRIGE NATIONAL QUALITY AWARD (MBNQA)

MBNQA was instituted in USA in the year 1987 through Malcolm Baldrige National Quality Improvement Act by the US government. Malcolm Baldrige was the Secretary of State for Commerce in USA during the year 1981 to 1987. The award lays emphasis on customer satisfaction. The award criteria were revised in the year 1992. The Malcolm Baldrige award is given to three categories of organizations as given below:

(1) Manufacturing
(2) Service
(3) Small Business

Up to two awards may be given for each one of the categories every year. The small business is defined to be independently owned organization with less than 500 full time employees. MBNQA has been continuously giving awards from the year 1988. MBNQA criteria are widely circulated, although only few of the organizations that think that they stand a chance may apply for the award. In the year 1991, it was estimated that about 2,35,000 booklets of information containing the award criteria were supplied on request from organizations[2].

Award Criteria

There are seven parameters for evaluating the organizations as to whether they qualify for the award and marks are allocated for each one of the parameter and its sub-parameters. The major parameters and marks allocated percentage-wise are:

Leadership	9 per cent
Information and Analysis	8 per cent
Strategic Quality Planning	6 per cent
Human Resources Development and Management	15 per cent
Management of Process Quality	14 per cent
Quality and Operational Results	18 per cent
Customer Focus and Satisfaction	30 per cent

Notice 30 per cent marks are allotted for customer focus and satisfaction. The sub-parameters of the customer focus and satisfaction are:

- Customer relationship management
- Commitment to customers
- Customer satisfaction determination
- Customer satisfaction results
- Customer satisfaction comparison
- Future requirement and expectations of customer

The operational results include the following:

- Product and service quality results
- Company operational results
- Business process and support results
- Supplier quality results

These are the most important parameters for measuring the quality of an organization.

Thus, the MBNQA criteria are truly the TQM criteria. The award is determined by a jury and followed by site visits. We will not go into the details of the actual award process. It has to be noted that MBNQA gives a system of measurement for implementation of TQM. At the initial reading, awarding of marks may appear to be unwarranted, although it is very essential to compare different organizations claiming to practice TQM. The striking feature of MBNQA is its emphasis on strategic planning and linkage between strategic planning and quality planning. In other words, if quality is good, it should result in better business results. If quality is good, but it does not lead to better business results, then it would not be considered as a TQM organization. Therefore, the aim of TQM is “in essence a way of managing the organization” including the profits. MBNQA criteria can be treated as a TQM assessment guide. The organization could evaluate themselves based upon the MBNQA criteria and determine, where they stand and whether they are making progress.

STATE LEVEL AWARDS IN USA

15 states in USA have also followed the steps taken by the federal government by instituting the state level awards for quality. For instance, New York State announced its award program in the year 1992 and it is called the Excelsior Award. It is based on the Malcolm Baldrige criteria, but with two differences. First, it places emphasis on labour management and hence customer satisfaction is given equal weightage with human resources excellence. Secondly, New York State gives the award for the following three sectors:

- Private sector applicants
- Public sector applicants and
- Education sector applicants

There are many other awards also in the USA such as the President's Award for Quality, which is administered by the Federal Quality Institute in Washington, D.C[2].

EUROPEAN QUALITY AWARD (EQA)

14 Western European nations have jointly formed the European Foundation for Quality Management (EFQM) in the year 1988. The mission of EFQM is aimed at accelerating the acceptance of quality as a strategy for global competitive advantage. The European Quality Award was presented for the first time in the year 1992 and is awarded to the most successful TQM organization in Western Europe. The European Quality Award is based on the following ten parameters:

Leadership	10 per cent
People management	9 per cent
Policy and strategy	8 per cent
Resources	9 per cent
Processes	14 per cent
People satisfaction	9 per cent
Customer satisfaction	20 per cent
Impact on society	6 per cent
Business results	15 per cent

Even here, the highest marks are allocated to customer satisfaction, which is 20 per cent followed by business results, which is 15 per cent. Therefore, both MBNQA and EQA lay emphasis on customer satisfaction and business results.

RAJIV GANDHI NATIONAL QUALITY AWARDS IN INDIA

There is an annual quality award known as " Rajiv Gandhi National Quality Award" in India.

The assessment criteria for Rajiv Gandhi National Quality Award includes the following 9 parameters:

- Leadership
- Policies objectives and strategies
- Human resource management
- Resources
- Processes
- Customer focused result
- Employees' satisfaction

- Impact on environment and society
- Business results

The awards given are as under:

1. Best of All Award
2. Category Awards
   - Large scale manufacturing industry
   - Small scale manufacturing industry
   - Service sector

In addition, Commendation certificates are also given. The first best among winners was given to Kirloskar Cummins Ltd. Pune for the year 1991-92. The awards are given every year.

CASE STUDY (From the Internet)

Tata International—The Leather and Leather Products Division

The leather and leather products division of Tata International, the international business gateway of the Tata Group, has won the Rajiv Gandhi National Quality Award in the 'best of all' category for the year 2000.

Tata International's state-of-the-art leather manufacturing facility at Dewas (Madhya Pradesh), India is the world's third largest goat skin tannery. The company is the leading leather exporter from India, and it's leather division has evolved from being world-class manufacturers to becoming leading global supply-chain managers.

The Bureau of Indian Standards instituted the Rajiv Gandhi National Quality Award in 1991 to encourage Indian manufacturing and service organizations to strive for excellence, and to give special recognition to leaders of the quality movement in India. Past winners have included companies like BHEL, SAIL, L&T and Tata Bearings. The award has been designed in line with respected awards such as the Malcolm Baldrige National Quality Award in USA, the Deming Prize in Japan, and the European Quality Award.

The company was the first to get an ISO 9001 certification for its entire manufacturing set-up-producing finished leather, footwear and leather garments. The manufacturing facility's success in improving air quality and keeping pollution under check motivated it to go for ISO 14000 certification.

To have an integrated approach to business excellence, the company identified business excellence as a key business process to build a culture of performance improvement, which is the central theme of any business-excellence initiative. The company instituted the Balance Score Card (BSC) methodology to track and review performance measures at all levels. BSCs also form the basis for all reviews, and for identifying improvement opportunities in line with the organization's endeavor towards achieving excellence.

The company initiated the evaluation and improvement of processes through regular reviews for performance improvement. Performance improvement initiatives were implemented using various tools and techniques like QIPs, Quality Circles and benchmarking. These initiatives have helped the Leather and Leather Products SBU to define its processes and make them customer oriented, with the clear objective of business excellence.

Tata International's objective — to become a customer-driven and knowledge-rich organization, have internal processes and systems in alignment, and have a high performance work culture — were in line with the defined purpose of the Rajiv Gandhi National Quality Award. Moreover, the company realized that striving for this coveted award would also give it an external perspective on its business excellence journey, and helps it to assess direction and pace.

Tata International is honoured to win this coveted award. But, the company recognizes that this journey towards business excellence is a race without a finishing line. Winning the Rajiv Gandhi National Quality Award has reinforced the company's resolve to continuously pursue excellence for leadership, to paraphrase the idea behind the company's e-logo. It is a journey that has now become even more exciting and interesting.

SUMMARY

While there is a clear-cut criterion for assessment of organization's compliance to ISO 9000 Standards, there are no such criteria for determining the compliance to TQM. In this context, the award criteria announced by various countries serve as a good checklist and self-assessment guide. The Deming Prize in Japan, Malcolm Baldrige National Quality Award in USA, Rajiv Gandhi Quality Award in India and the European Quality Award have been recognized as TQM awards all over the world. The organizations could get the criteria and establish a system for self-assessment of their organizations based upon these criteria. Since this is an objective oriented assessment, the organizations will be able to evaluate themselves how much progress has been made towards TQM. This will also help them to set targets for succeeding years. In this manner, the organizations will be able to reach the goal of achieving TQM in their organizations. Thus, the awards and their criteria serve as an important tool for implementing TQM.

REVIEW QUESTIONS

I. Choose the most appropriate answer

1. National Quality awards are given to
   (a) Processes (b) Employees
   (c) Organization (d) None of the above
2. RGNQA is awarded in
   (a) USA (b) India
   (c) Europe (d) All the above
3. The most important parameter in MBNQA is
   (a) Leadership (b) Process
   (c) Customer satisfaction (d) None of the above
4. MBNQA is awarded to an organization in
   (a) Manufacturing (b) Service
   (c) Small Businesses (d) All the above

II. True or False

1. ISO 9000 is an award
2. MBNQA is a certification

3. Deming prize is given in Japan
4. Deming price was initiated by JUSE.
5. Customer relationship management is a sub-parameter of MBNQA
6. There are state level quality awards in USA
7. European quality award was given for the first time in the year 1991.
8. Customer satisfaction has the highest marks in EQA also.
9. RGNQA has 9 Parameters for assessment.
10. Only one award is given under RGNQA per year.

III. Explain Briefly

1. MBNQA
2. State awards in USA
3. Deming award
4. RGNQA
5. EQA
6. Objective of national quality awards.
7. Common threads in all the quality awards
8. Relationship between MBNQA and RGNQA
9. Compare EQA with MBNQA
10. Human resource parameter in all awards
11. Importance of strategic planning in quality awards
12. Customer orientation of the awards
13. Differences between ISO 9000 certification and quality awards
14. Importance of certification for awards
15. Awards and TQM

IV. Match the Following

A	B
Deming Prize	Certification
State award	Japan
RGNQA	TQM
ISO 9001	USA
CWQC	Award

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APPENDIX - A

REVISION OF ISO 9001 STANDARD IN THE YEAR 2008

The ISO 9001 standard has been revised again in the year 2008. *However, the structure and basic philosophy of the ISO 9001:2008 standard remains the same as the ISO 9001:2000 standard with a few editorial changes. According to the International Organization for Standardization (ISO), the ISO 9000:2000 has been amended to clarify points in the text and to enhance the compatibility with the ISO standard on environmental management system (EMS), ISO 14001:2004. Some of the significant changes are listed below:

The revised standard states the following with regard to design of QMS in an organization:

The design and implementation of an organization's quality management system is influenced by its organizational environment, change in that environment, and the risks associated with that environment, such as

- Its varying needs
- Its particular objectives
- The products it provides
- The processes it employs
- Its size and organizational structure

The revised standard states that ISO 9004 standard is under revision. The revised edition of ISO 9004 will provide guidance to management staff across the world in achieving sustained success for any organization in a complex, demanding and ever-changing environment. ISO 9004 provides a wider focus on quality management than ISO 9001: it addresses the needs and expectations of all interested parties and their satisfaction by the systematic and continual improvement of the organization's performance. However, it is not intended for certification, regulatory or contractual use.

The standard has added a paragraph regarding exclusions of applicable classes as given below:

'Where exclusions are made, claims of conformity to this International Standard are not acceptable unless these exclusions are limited to requirements within Clause 7, and such exclusions do not affect the organization's ability, or responsibility to provide a product that meets customer and applicable statutory and regulatory requirements.'

The ISO 9000:2000 standard on fundamentals and vocabulary of quality management systems has been revised in 2005 and it is now known as ISO 9000:2005.

The standard has given a new note as stated below:

'Conformity to product requirements can be affected directly or indirectly by personnel performing any task within the quality management system.'

It has also added another new note as stated below:

'The term 'Work environment' relates to those conditions under which work is performed including physical environment and other factors (such as noise, temperature, humidity, lighting or weather).'

Therefore, it is very important that the workplace should be conducive to working for the employees.

The revised standard appropriately calls measuring devices as *measuring equipment*.

The standard has introduced a new note with regard to monitoring customer perceptions as stated below:

'Monitoring customer perception can include obtaining input from sources such as customer satisfaction surveys, customer data on delivered product quality, user opinion surveys, lost business analysis, compliments, warranty claims and dealer reports.'

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*Visit http://www.iso.org/iso/iso_catalogue.htm for further details on ISO

RECENT CHANGES TO ISO/ TS 16949

The Technical Specifications TS 16949 is applicable to the design/development, production and, where relevant, installation and servicing of automotive-related products. ISO/TS 16949:2009 is entitled as 'Quality Management Systems'—particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations. This technical specification was released in the year 1992 and subsequently revised in the year 2009. This revision was necessitated due to the revision of ISO 9001 standard in the year 2008.

ISO/TS 16949:2009 were developed by the International Automotive Task Force (IATF). Along with the embedded ISO 9001:2008 text, it defines the quality management system requirements for the design and development, production and, when relevant, installation and service of automotive-related products.

The IATF has provided the following transition information to certification bodies:

1. **No New Requirements**

   ISO/TS 16949:2009 introduces no new or changed requirements. The incorporated ISO 9001:2008 standard is based on clarifications or amendments to ISO 9001:2000 and those intended to improve consistency with ISO 14001:2004.

2. **Differences between 2002 version and 2009 version of the TS**

   Most of the differences in ISO/TS 16949:2009 compared to ISO/TS 16949:2002 are due to including the ISO 9001:2008 standard to replace the withdrawn ISO 9001:2000 text. Some minor changes are given below:

   1. Change from 'product quality' to 'conformity to product requirements' in multiple places for consistency with the same change made in ISO 9001:2008.
   2. Change from 'regulatory' requirements to 'statutory and regulatory' requirements in multiple places for consistency with the same change made in ISO 9001:2008.
   3. It modifies the titles for clauses 6.2.2 and 7.6 to match the changed titles in ISO 9001:2008.
   4. It replaces 'ISO 9001:2000' with 'ISO 9001:2008' and 'ISO 9000:2000' with 'ISO 9000:2005'.
   5. It adds new references in the Bibliography section and remove the withdrawn standards.

TQM IN MANUFACTURING

TQM is a management process that will focus on company-wide quality assurance. The use of TQM has proven to increase the overall productivity and efficiency of organizations. When a manufacturing organization looks at the overall productivity the business is experiencing, it generally finds that there is a great deal of waste involved. The solution to minimize waste and change the overall processes is provided by TQM.

Implementing TQM in a manufacturing organization involves attention to and improvement of the following.

1. Design of the product
2. Workmanship
3. Equipment used in manufacturing
4. Raw materials

In order for TQM to work correctly, there needs to be an overall smooth flow in each of the above areas. There needs to be tracking, training and manufacturing of the products in a timely manner and all of this needs to be completed accurately. TQM will not only help the total process of the manufacturing of products work more efficiently, but it also will help build a sense of pride in the entire company. This pride will also increase the overall quality that a business will work by.

TQM increases the productivity and efficiency of manufacturing. If the manufacturing process is carried out right from the beginning, properly there is less likely a chance for incorrectly made devices or products. It is important that training for the workmanship needs to be accurate, well defined and consistent for all employees.

There are metrics that can be tracked and statistics that will prove that using the TQM method will not only increase productivity, but will also instill a higher level of pride in the employees. This is because each person becomes responsible for a higher level of quality in his or her work. The deployment of these TQM programmes need to be started at the top-management level, and then subsequently passed on to different levels of the organization. Implementation of TQM takes time. Since it starts with training, there will be some cost involved. However, the savings from not wasting time, material and money pays off within a short time. Many of the large manufacturing organizations are using TQM to increase their overall efficiency.

There are four main steps in the TQM process of the Japanese industries as given below:

- *Kaizen*: The focus on continuous improvement
- *Atarimae Hinshitsu*: Each thing will work the way it is designed to
- *Kansei*: When used, the use of that product will provide a way for improvement to come about
- *Miryokuteki Hinshitu*: Each product needs to have an aesthetic quality

The principles of TQM help to build a stronger sense of teamwork and, therefore, facilitate more work to be completed. If there is a team working to complete a project, with each member of the team contributing, ideas, interest, effort and knowledge, the project will be completed more efficiently.

The main stress of the application of total quality management in case of the manufacturing services industry is to make sure that the production process runs smoothly. The emphasis is also on minimizing the amount of products that are of an inferior quality. It may be opined that the total quality management process is extremely important in case of the manufacturing industry.

Lean Manufacturing and TQM

It is well known that lean manufacturing had been influenced by many techniques. One such management technique is Total Quality Management. The influence of TQM on lean manufacturing is very large and therefore many techniques are common to both lean manufacturing and TQM. In lean manufacturing, TQM is one of the prime tools used to achieve its objective. Many of TQM gurus like Deming and Juran played a major role in shaping the Toyota Production system (TPS).

Note: *Quality in Services* is covered in the book from pages 5.4 to 5.7.

TQM IN HEALTHCARE

The rapidly expanding scope of healthcare has led to increasing complexity in its delivery. Patient satisfaction is increasingly taken as an important measure of quality. The expectations of the people towards medical care are ever increasing and are limited not only to the clinical outcomes but also to involve the delivery process, margin of safety and behaviour of personnel. There is increasing willingness to provide protection against illnesses by way of healthcare insurance. This has made it pertinent that management of quality is done on a wider basis than mere medical audits. There is need to use the principles of quality assurance systems covering all activities of the healthcare unit. Some of the reasons for the implementation of a formal quality system are

- Increased demands for cost effective and appropriate care.
- Need for standardization
- Defining a patient's needs and expectations

Implementing quality system controls the cost by

a. Reducing unnecessary interventions
b. Getting it right first time, e.g., cost of repeat surgery in angioplasties, revisions of hip replacements and unsuccessful keyhole surgery
c. Avoidable complications, e.g., post-operative infections
d. Imbalances of resources—lack of theatre time or lack of access to diagnostic facilities leading to increased length of stay
e. Employee turnover and consequent training costs

Quality Control and Quality Assurance in Healthcare

There is a difference between the two terms. *Quality control* is an after-event phenomenon (just like a post -mortem exercise). It consists of a set of checks and inspections to be carried out after the mistake has occurred. For example, suppose a patient visits ophthalmologist for a refractive-error problem. The doctor prescribes the suitable correction. The patient wears the glasses but there is no improvement. The patient comes back and registers his grievances about the poor service of the clinic. Now, the reasons for this need to be found out. So, the clinic starts investingating the causes of the error. The likely reasons may be as follows:

1. The patient was not checked by a qualified ophthalmic assistant/ doctor.
2. There is no standard checklist which may serve as guideline for a thorough check-up.
3. If there is a checklist, the doctor/ophthalmic assistant had omitted one or more checks and the problem was not correctly diagnosed.
4. Instead of carrying out a complete check up, the doctor believed (whatever the patient said) and concluded it to be a refractive-error problem but the root of the problem may be something else.
5. If everything (as stated above) was in order, may be the diagnostic equipment was not properly calibrated and it gave an error and hence, the patient got the wrong spectacle number.

There may be one or more reasons as stated above. So, quality control focuses on finding out the reasons and take corrective actions. On the other hand, quality assurance stresses on prevention of the mistake. The aim is to detect the mistake at an early stage. Hence, emphasis remains on all aspects of a job so that a mistake is detected as soon as it takes place. The stage of inspection is a must before proceeding further. In the above case, the QA strategy will be as given below. It will ensure that

1. The patient is examined by an authorized qualified doctor/ophthalmic assistant.
2. The patient is examined as per the standard valid checklist.
3. All data pertaining to various checks are maintained.
4. All checks are carried out in totality.
5. Only valid and properly calibrated diagnostic equipment is used for the check-up. QA stresses on documentation, the mistake is detected at an early stage and suitable corrective action is taken.

Quality Management System

Working on the concept of QA, hospital can work for the establishment of a quality system in its various departments and sections to ensure that whatever is done is as per the documented procedures with necessary checks and inspections to make sure that quality is in-built into the system. If such a system is established, it will be called a Quality Management System.

How do we establish a QMS? How can a patient know that QMS of the hospital will meet his her requirements? In absence of clear-cut guidelines, any hospital may go for any suitable system. Therefore, there is a need for a standard which will give the customer/patient a sense of confidence about the assurance of the quality of the service of a hospital. There exist such standards, namely, the ISO-9000 quality system standards. Therefore, hospitals should establish a QMS meeting the ISO 9000 standard and get themselves certified. This will not only enhance the quality of service hospitals, but also give the desired confidence to the patients.

Total Quality Management

ISO 9000 certification is not an end in itself. It may be looked upon as a process to achieve the target of TQM. Also, it is worth mentioning here that TQM must not be viewed as a static goal. The system targeting for TQM must be an open system which is continuously influenced by the intrinsic (factors within the system) and extrinsic factors (environmental factors). So, the TQM is a moving target which keeps on changing depending on various social, economic and environmental factors. None of the activities, whether minor or major, in an organization, can escape the ambit of TQM. The Seniormost doctor is important and so is the lowest-level employee. The OPD is important and so is the security. There is enough emphasis on human resource development too. Training is a regular and on-going process for TQM. ISO-9004 is a set of guidelines that can help a lot in introducing TQM in an organization. The following principles can form the basis for introducing TQM:

1. Every work in the hospital is important.
2. Do right things right first time and every time.
3. Let the QMS be dynamic and modify it as per the changes taking place within and without the system.
4. Take care of human resource. It is the greatest asset!

QUALITY IN EDUCATION

The late 1980s saw the introduction of industrial quality concepts (such as Total Quality Management — TQM) in education and training institutes; and in the early 1990s, some pioneers embraced ISO 9000. Since then, there has been increasing evidence that the adoption of TQM principles and methods, including those embedded in the ISO 9000 requirements, could be relevant and useful for education and training organizations. Not surprisingly, education and training institutions seek, in this way, to improve or maintain the quality of their education or training provision. There are other reasons, in particular the following, for educational institutions to adopt ISO 9000 standards:

- the promotion of a high quality image, with high visibility and credibility
- a way of responding to external factors, in particular, pressures from customers (directly or indirectly), governments or funding bodies
- a method for developing a full quality assurance system which covers the whole organization
- the need to improve a number of specific activities of the organization which are currently badly organized

Overall, it would appear that the reasons for seeking certification in the education and training world do not differ fundamentally from those elsewhere.

The ISO 9000 family of standards are international standards for quality management requirements in business-to-business dealings and have earned a worldwide reputation as a 'generic management system standard'. *Generic* means that the same standards can be applied to any organization and any product. In this context, the term 'product' may include services in any sector, business enterprises, public administration, or governmental entity. No matter what the organization does, the ISO 9000 family spells out essential features of a quality management system.

Management system refers to a systematic approach to managing processes and/or activities, people, resources and infrastructure. ***Quality management*** refers to activities aimed at meeting customer demands and applicable regulatory requirements, as well as efforts to continually improve the organization's performance. ISO 9001:2000 defines minimum requirements for a Quality Management System (QMS). The standard specifies activities that need to be considered during implementation of the system. The requirements are applicable to all organizations. Continual improvement of the organization's quality management system is a further requirement of the standard.

In May 2007, ISO published updated guidelines to facilitate the implementation of quality management systems in educational organizations: IWA 2:2007, *Quality management systems– Guidelines for the application of ISO 9001:2000 in education*. More and more educational institutions including schools are opting for ISO 9000 certification.

TOTAL QUALITY MANAGEMENT (TQM) IN SMALL BUSINESS

Almost all small businesses start small and stay that way. Usually they are started by an entrepreneur who has a bright idea about a service or has developed a new product that fills a niche. A majority of small firms are privately owned, or jointly owned by close family members. The management is independent; usually the owner is the manager and reports to no one, or to other members of the family if they are also owners. Absentee ownership is very rare. Although owners/entrepreneurs are generally experts in the product or service they produce, they usually have neither the education nor the skills required to manage a business.

Organization structure in a small firm is usually very simple, with few layers. Sometimes management positions are filled by family members, making it a truly family business. Employees usually perform a variety of tasks, often giving the business greater flexibility than larger businesses have. In general, organizational complexity and the number of levels increase as one moves from companies with a few employees to the higher end of the size continuum.

Capital and Resources

Because of the nature of ownership, typical small-business firms often suffer from a shortage of capital. Originally, capital is supplied by the owner or the owner's family. Additional capital for growth, or short-term credit for weathering bad times, is very difficult to raise. The main reason for the difficulty in obtaining long-term financing is that a large proportion of a typical small firm's assets include short-lived equipment and fixtures, leaving insufficient long-term assets to qualify for long-term loans. Many small businesses do not even have sufficient record-keeping facilities to provide the necessary documents for bank loans. Insufficient capital is usually the main reason why most small businesses are service companies. In addition to sparse physical resources, small businesses are also severely limited in human resources, and so cannot attract highly qualified and experienced managers or professionals. Again, this weakness disappears as the firm grows in size and sales.

TQM has received considerable attention in many large corporations and government organizations. As with large corporations, small businesses must provide quality products and services to survive and grow. Yet, the mechanism for obtaining customer feedback was only occasionally being used; employees had limited responsibility for resolving customer issues; operating procedures were not well defined; and process improvements were not being made. Despite the fact that these are the basic tenets of TQM as explained by the gurus of quality—Deming, Juran, and Crosby—they still were not being followed.

Learning and implementing TQM to address the issues just described requires a long-term commitment of time and resources—quantities that may be in short supply in many small firms. So why would the owner of a small business make the decision to adopt TQM? One good reason might be to survive against competitors who are doing it, or simply to survive at all in this era of quality management pioneered by larger corporations.

TQM principles, procedures, and tools that work for large organizations could be effective in small ones as well. After all, customer orientation, employee involvement, and continuous improvement are not new management concepts. The question is which ones to use. Processes in a small business can be less complex and more informal. So a structured approach to problem solving may not be equally applicable or may need adjustment.

The main assumption is that quality is as important for small businesses as it is for large corporations. One reason is that some small companies have been competing directly with foreign firms for a long time; some have suffered the same consequences as large companies, while others have prospered in the competition. A second reason is that many large firms rely on a number of small companies for parts and services they use in producing their products. Quality-conscious corporations are demanding continuously higher quality in the goods and services they buy from small businesses; and at the same time, they are reducing considerably the number of vendors. Criteria used in deciding which company to keep as a vendor are based almost entirely on cost and quality. Third, new conditions emerge to which small firms have to adapt. Quality and productivity seem to be the indispensable main ingredients in a small firm's struggle for survival in these new conditions. TQM provides a unique and appropriate solution to solve the problems of small businesses too.

QUALITY IN NON-PROFIT MAKING AND PUBLIC SECTOR ORGANIZATIONS

When we talk about organizations, most of us think of either profit-making companies or public sector organizations. But, at some point in our work or personal lives, many of us come across many nonprofit organizations. In fact, nonprofits are one of the fastest-growing sectors today (in terms of the number of people working in the sector). Nonprofits—also known as not-for-profits, charities, and social sector organizations—are highly professional entities. As such, managers working in this sector need all of the same skills as their counterparts in the for-profit and public sectors. But to succeed, nonprofit managers also need other skills, and they need a clear understanding of the very specific nature of nonprofit organizations.

By their very nature, nonprofit organizations usually fill gaps in services provided by public sector organizations. After all, if the government did everything that was needed in the nonprofit's areas of interest, the nonprofit wouldn't need to exist. This makes nonprofits different from for-profit companies and public sector organizations in two key ways:

- Nonprofits are usually dependent on donations. If it were possible to make money doing what a particular nonprofit does, then market forces probably would have created a company to fill that opportunity. This, in turn, means that nonprofits must be extremely careful in using their resources.
- The gaps that nonprofits fill sometimes disappear as government organizations begin to do the work that the nonprofit had been doing.

Measuring Organizational Performance

For-profit companies have a simple way to measure how they are doing relative to previous years and relative to their competitors: the bottom line. Whether they look at revenue or various profit calculations, financial measures are typically straightforward—and they allow direct comparisons with other companies.

In the nonprofit sector (and the public sector), measurement is less obvious. Of course, some aspects of a nonprofit's work can be measured financially. For example, fundraising revenue and grant income are two obvious numbers, and the nonprofit can also calculate the proportion of this money that is directly spent on their mission.

But in other cases, nonprofits, like public sector organizations, should be creative about developing their own measures of what they achieve—for management information purposes and to motivate their staff. For example, if the mission is to educate the public on an issue, measures can be surveys of public awareness; if the mission is to work directly with people, the measure can be the number of people helped. Nonprofit managers need to develop a balanced scorecard of measures to give a full picture of what the organization is doing.

In the twenty-first century, quality is essential in every type of organization. Even in not-for-profit organizations, satisfying customers is quite important. TQM and ISO 9000 certification demands arise from customers. The balanced scorecard developed by Kaplan and Norton is quite appropriate for such organizations. The performance of such organizations are to be evaluated against the four perspectives of the balanced scorecard as given below.

- Customer perspective
- Business process perspective
- (Employees) Learning and growth perspective
- Financial perspective

Thus, TQM needs to be practiced in not-for-profit and public sector organizations so as to result in improvement in performance when measured against all the above four perspectives as per the balanced scorecard.

Crosby's Theory on Quality Management

Philip B Crosby is known for his strategies for quality improvement, i.e. *Do Right Things* and *Do it Right First Time*. Crosby's book *Quality is Free* was published and became a bestseller in the field of management. Crosby is also the author of *Let's Talk Quality* (1989); *The Eternally Successful Organization* (1988); *Running Things: The Art of Making Things Happen* (1986); *Quality Without Tears: The Art of Hassle-free Management* (1984); and *The Art of Getting Your Own Sweet Way* (1972). Crosby's books have been translated into 10 languages. He is best known for popularizing the zero-defects concept that originated in the United States at the Martin Marietta Corporation where Crosby worked during the 1960s. The ultimate goal of his quality improvement process is 'zero defects' or 'defect-free' products and services. He says that since companies permit deviations, give concessions and waiver, it becomes necessary for them to spend about 20 per cent of their revenues in doing things wrong and doing them all over again. According to him zero defects does not mean that employees never commit mistakes, but that the company does not start out by expecting them to make mistakes.

Crosby formulated fourteen steps for quality improvement. They are discussed in the following paragraphs.

1. ***Management Commitment*** The need for quality improvement must be recognized and accepted by the management, who then draws up a quality improvement program with an emphasis on the need for defect

prevention. Quality improvement equates to profit improvement. According to Crosby, a quality policy is needed which states that '...each individual is expected to perform exactly like the requirement or cause the requirement to be officially changed to what we and the customer really need.'

2. ***The Quality Improvement Team*** The representatives from each department or function should be brought together to form a quality improvement team. Such members should have the necessary competence to be a member of the designated team.

3. ***Quality Measurement*** The status of quality should be determined throughout the organization. This means that establishing and recording quality measures for each area of activity in order to show where improvement is possible and where corrective action is necessary. Crosby advocated delegation of this task to the people who actually do the job, thus setting the stage for defect prevention on the job, where it really counts.

4. ***The Cost of Quality Evaluation*** The cost of quality is not an absolute performance measurement, but an indication of where the action necessary to correct a defect will result in greater profitability.

5. ***Quality Awareness*** This involves making employees aware of the cost to the company of defects, through training and information, and the provision of visible evidence of the results of an organization for quality improvement. Crosby stresses that this sharing process is a key, or even the key, step in the progress of an organization toward quality.

6. ***Corrective Action*** When causal analysis of problems is carried out, it will result in finding of solutions and also reveal other elements in the organization which need improvement. Employees need to see that problems are regularly being resolved. Corrective action should then become a habit.

7. ***Establishing an ad hoc Committee for the Zero Defects Program*** 'Zero defects' is not a motivation program. Its purpose is to communicate and instill the notion that everyone should do things right first time and every time. An organization may set up a committee to implement the program.

8. ***Supervisor Training*** All managers should undergo formal training on the fourteen steps before they are implemented. Managers should understand each of the fourteen steps well enough to be able to explain them to their junior employees.

9. ***Zero Defects Day*** It is important that the commitment to zero defects as the performance standard of the company makes an impact, and that everyone gets the same message in the same way. Zero defects day, when supervisors explain the program to their people, should make a lasting impression as a 'new attitude' day.

10. ***Goal setting*** All supervisors ask their employees to establish specific, measurable goals that they can strive for. Usually, these comprise 30-, 60-, and 90-day goals.

11. ***Error Cause Removal*** Employees are asked to describe, on a simple, one-page form, any problems that prevent them from carrying out error-free work. Problems should be acknowledged and begin to be addressed within 24 hours by the function or unit to which the memorandum is directed. This constitutes a key step in building up trust, as it will make people begin to grow more confident that their problems will be attended to and dealt with.

12. ***Recognition*** It is important to recognize those who meet their goals or perform outstanding acts with a prize or award, although this should not be in financial form. The act of recognition itself is what is important.

13. ***Quality Councils*** The quality professionals and team leaders should meet regularly to discuss improvements and upgrades to the quality programme.

14. ***Doing it Over Again*** During the course of a typical programme lasting from 12 to 18 months, turnover and change will dissipate much of the educational process. It is important to set up a new team of representatives and begin the programme again from the beginning, starting with zero-defects day. This 'starting over again' helps quality to become ingrained in the organization.

Crosby suggests a quality vaccine for quality improvement which consists of three distinct management actions:

- Determination
- Education
- Implementation

The top management is responsible for continually administering the quality vaccine. Determination surfaces when the management sees the need to exchange and recognizes that change requires management action. Education is the process of providing all employees with the common language of quality, helping them to understand what their role is in the quality improvement process, as well as helping them to develop a knowledge base for preventing problems. The third action is implementation, which consists of the development of a plan, the assignment of resources, and the support of an environment consistent with a quality improvement philosophy. In this phase, the management must lead by example and provide follow-up education.

According to Crosby, education–the second management action of–quality vaccine is a multi-stage process that every organization must go through, a process he calls the *Six C's*. The 6 C's are given below:

1. Comprehension
2. Commitment
3. Competence
4. Communication
5. Correction
6. Continuance

We will look at each of them briefly.

1. Comprehension The first stage is comprehension. It is the capability of employees to comprehend the quality assurance and improvement initiatives right first time and every time. Comprehension must begin at the top and eventually include all employees. Without comprehension, quality improvement will not occur. If the employees do not understand the improvement initiatives correctly then it will be a futile exercise. It is necessary that the organization adopts a multipronged approach such as training, mentoring, etc., so that the employees understand the quality assurance and improvement initiatives correctly. The training and mentoring are not a one-time activity, but continuing efforts are needed to achieve the right comprehension.

2. Commitment The second C is commitment. Commitment is a process and it is the most important prerequisite for quality improvement in the organization. Crosby calls for commitment by all employees across the organization, which also must begin at the top management and represents the stage when managers establish a quality policy. Vision and Mission statements provide the motivation to the employees to make commitment for quality improvement.

3. Competence The third is competence; developing an education and training plan during this stage is critical to implementing the quality improvement process in a methodical way. The competence of employees depends on the educational qualification, training on the job and off the job as well as their motivation level. The management should assess the competence of each employee and formulate a plan for further improving their competence in a systematic manner.

4. ***Communication*** The communication systems are of paramount importance to communicate requirements and specifications and improvement opportunities around the organization. Customers and operators know what needs to be put in place to improve and listening to them will give the organization an edge. All efforts must be documented and success stories published so that complete understanding of quality by all people in the corporate culture is achieved.

5. ***Correction*** The fifth is correction, which focuses on prevention and performance. An organization should foresee problems occurring in the system, process and product and take advance preventive actions. Despite preventive actions, in an organization quality problems will arise due to men, machine, material and methods. When such problems arise, suitable corrective actions need to be taken. Corrective action includes long-term solutions to such problems.

6. Continuance Finally, the sixth is continuance, which emphasizes that the process must become a way of life in the organization. Continuance is based on the fact that it is never cheaper or quicker to do anything right the second time, so quality must be integrated into all day-to-day operations. An organization needs to take new initiatives in a periodic manner for quality improvement. In every cycle of quality improvement, the 6 C's need to be revisited for success.

QUALITY GURUS

A V Feigenbaum

Armand V Feigenbaum was the originator of 'Total Quality Control (TQC)', often referred to as total quality.

He defined TQC as

'An effective system for integrating quality development, quality maintenance and quality improvement efforts of the various groups within an organization, so as to enable production and service at the most economical levels that allow full customer satisfaction'.

He saw it as a business method and proposed three steps to quality:

- Quality leadership
- Modern quality technology
- Organizational commitment

Feigenbaum's ideas are contained in his book *Total Quality Control,* first published in 1951 under the title *Quality Control: Principles, Practice, and Administration,* and based on his earlier articles and programme installations in the field. The book has been translated into more than a score of languages, including Japanese, Chinese, French, and Spanish.

Feigenbaum is recognized as an innovator in the area of quality cost management. His was the first text to characterize quality costs as the costs of prevention, appraisal, and internal and external failure. Feigenbaum's work centralized around the notion for a systematic or total approach to quality. He argued that total approach to quality requires the involvement of all functions of the quality process, and not only manufacturing. His idea was to build in quality in the early stage rather than inspecting and controlling after the processes have been completed.

Feigenbaum served the American Society for Quality Control (ASQ) for two consecutive terms as president (1961–1963). Feigenbaum's message was to move away from the concerns of the technical aspect of quality control and make a focus of quality control as a business method, including administrative and human relation functions. Another one of his emphases is that quality does not mean ‘best’ but ‘best for the customer.’

Feigenbaum saw Modern Quality Control as the stimulating and building up of operator responsibilities and interests in quality. Feigenbaum also argued that all levels of quality need to be emphasized. For quality control to achieve its specified results, there is the need for complete support from management as well as the need of the quality control programme to develop gradually from within the organization.

Kaoru Ishikawa

Kaoru Ishikawa is a quality guru from Japan. His contributions to quality include his total quality viewpoint, company-wide quality control, his emphasis on the human side of quality, the Ishikawa diagram and the collection and use of the ‘seven basic tools of quality’:

- Pareto analysis—*which are the big problems?*
- Cause-and-effect diagrams—*what causes the problems?*
- Stratification—*how is the data made up?*
- Check sheets—*how often does it occur or is done?*
- Histograms—*what do overall variations look like?*
- Scatter charts—*what are the relationships between factors?*
- Process control charts—*which variations to control and how?*

He believed these seven tools should be known widely in the organization and used to analyze problems and develop improvements.

One of the most widely known of these is the Ishikawa (or fishbone or cause-and-effect) diagram. Like other tools, it assists groups in quality improvements. The diagram systematically represents and analyzes the real causes behind a problem or effect. It organizes the major and minor contributing causes leading to one effect (or problem), defines the problem, and identifies possible and probable causes by narrowing down the possible ones. It also helps groups to be systematic in the generation of ideas and to check that it has stated the direction of causation correctly. The diagrammatic format helps when presenting results to others.

With his cause-and-effect diagram, Ishikawa made significant and specific advancements in quality improvement. With the use of this new diagram, the user can see all possible causes of a result, and find the root of process imperfections. By pinpointing root problems, this diagram provides quality improvement from ‘bottom up.’ Dr W Edwards Deming—one of Isikawa’s colleagues—adopted this diagram and used it to teach Total Quality Control in Japan as early as the period of World War II. Both Ishikawa and Deming used this diagram as one the first tools in the quality management process.

Additionally, Ishikawa explored the concept of quality circles—a Japanese philosophy which he drew from obscurity into worldwide acceptance. Ishikawa believed in the importance of support and leadership from top-level management. He continually urged top-level executives to take quality control courses, knowing that without the support of the management, these programmes would ultimately fail. He stressed that it would take firm commitment from the entire hierarchy of employees to reach the company’s potential for success. Another area of quality improvement that Ishikawa emphasized is quality throughout a product’s life cycle—not just during production. Although he believed strongly in creating standards, he felt that standards were like continuous quality improvement programs—they too should be constantly evaluated and changed. Standards are not the ultimate source of decision making; customer satisfaction is. He wanted managers to consistently meet consumer needs; from these needs, all other decisions should stem.

Poka-yoke

Instead of inspection and correction of mistakes, it is more economical to aim at prevention of defects. The strategy of preventing mistakes before they occur is the best way to reduce failures and waste, resulting in lower costs. This applies not only to the production line, but also in the office. This approach of trying to make it difficult for the worker to make mistakes is credited to Shigeo Shingo, an industrial engineer at Toyota. Poka-yoke is a simple device or method to prevent mistakes at their source. These devices are used either to prevent the special causes that result in defects or to inexpensively inspect each item that is produced to determine whether it is acceptable or defective.

Eliminate Errors

The causes of many defects lie in errors committed by employees. The defects are the results of neglecting those errors. Thus, if we devices methods to eliminate such errors, many defects will be eliminated. The Japanese manufacturing engineer, Shiego Shingo, has incorporated error-proof techniques into a formidable tool to achieve zero defects. Poka-Yoke stands for 'mistake-proof' or 'foolproof'. The idea was very simple—to respect the intelligence of production workers. Poka-yoke (permanent error-proof) can benefit operators involved in repetitive tasks that depend on vigilance, concentration and memory by allowing them to concentrate on other value-added manufacturing tasks. Having error-proof in place permanently will free an operator's mind and time. Poka-yoke is a concept of elimination of any defects that might pass through the process to the next step. To compete with the world-class manufacturing companies, we must adopt the philosophy and practice of producing zero defects.

Some examples of using poka-yoke devices are the following:

- To make sure an assembler uses three screws, the screws can be packaged in groups of three. This package is a poka-yoke device.
- At General Motors, a simple electrical check is made to verify that nuts are properly welded to a sheet metal panel.

Another example of a mistake-proof design is the three-prong electrical plug. There is only one way that you can plug it into a wall socket.

MURA, MURI AND MUDA

Kaizen in Japanese means gradual, orderly and continuous improvement. It is a Japanese strategy for continuous improvement. One of the three principles of Kaizen is elimination of waste, strain and discrepancy, the three 'Mu's. Every organization has to find ways to eliminate the three 'Mu' s. Waste reduction is an effective way to increase profitability.

Mura

The *Toyota Production System* (TPS) identified three types of wastes and they start with 'Mu', i.e., *Muda*, *Mura, Muri* for enabling Kaizen. The term 'Mura' in Japanese means unevenness, inconsistency in physical matter or human spiritual condition. Mura is avoided through Just in Time manufacturing systems which are based on little or no inventory, by supplying the production process with the right part, at the right time, in the right amount, and first-in, first out component flow. Just-in-Time systems create a 'pull system' in which each subprocess withdraws its needs from the preceding subprocesses, and ultimately from an outside supplier.

When a preceding process does not receive a request or withdrawal, it does not make more parts. This type of system is designed to maximize productivity by minimizing storage overhead.

Examples

1. The assembly line 'makes a request to,' or 'pulls from' the paint shop, which pulls from body weld.
2. The body weld shop pulls from stamping.
3. At the same time, requests are going out to suppliers for specific parts, for the vehicles that have been ordered by customers.
4. Small buffers accommodate minor fluctuations, yet allow continuous flow.

If parts or material defects are found in one process, the Just-in-Time approach requires that the problem be quickly identified and corrected.

Muri

Muri is a Japanese term for overburden, unreasonableness or absurdity, which has become popular in the West by its use as a key concept in the continuous improvement journey. Muri can be avoided through standardized work. To achieve this standard condition or output, to assured effective judgment of quality must be defined. Then every process and function must be reduced to its simplest elements for examination and later recombination. The process must then be standardized to achieve the standard condition. This is carried out by taking simple work elements and combining them one-by-one into standardized work sequences. In manufacturing, this includes

- work flow, or logical directions to be taken,
- repeatable process steps and machine processes, or rational methods to get there, and
- *Takt time*, or reasonable lengths of time and endurance allowed for a process.

The results observed with the practice of Muri include the following:

- improved employee morale (due to close examination of ergonomics and safety)
- higher quality
- improved productivity
- reduced costs

Muda

The third 'Mu' of TPS is Muda. Muda means waste, where waste is any activity that does not add value. Reducing or eliminating Muda is, of course, one of the fundamental objectives of any quality management system.

Taichi Ohno of Toyota identified what are called the *seven wastes* or *seven mudas*, being the most common form of muda found:

- *Waste from overproduction*
  - This leads to excess inventory, paperwork, handling, storage, space, interest charges, machinery, defects, people and overhead
  - It is often difficult to see this waste as everyone seems busy
- *Waste of time in waiting*
  - Which leads to excess inventory, paperwork, handling, storage, space, interest charges, machin-People may be waiting for parts or instructions.

- Which leads to excess inventory, paperwork, handling, storage, space, interest charges, machin- Mostly they are waiting for one another, which often happens because they have non-aligned objectives.

- *Transportation waste*
  - Poor layouts lead to things being moved multiple times.
  - If things are not well in place, they can be hard to find.
  - It can aggravate alignment of processes.
- *Processing waste*
  - Additional effort may be required in an inefficient process.
- *Inventory waste*
  - Excess buffer stocks a whole host of sins, which will be uncovered by gradually lowering inventory (doing it all at once will cause total breakdown!).
- *Waste of motion*
  - This includes movement of people, from simple actions when in one place to geographic movement. Having everything at hand as it is needed to reduces to motion muda.
- *Waste from product defects*
  - Defects cause rework, confusion and upset a synchronized set of processes.
- A simplified view of muda is
  - Wasting time
  - Wasting a consumable resource, such as materials
  - Causing dissatisfaction (including incomplete satisfaction)

THE QUALITY TRILOGY

According to Juran, the underlying concept of the quality trilogy (Figure 1) proposed by him is that managing for quality consists of three basic quality-oriented processes as given below.

- Quality planning
- Quality control
- Quality improvement

QUALITY PLANNING

Quality planning is creating a process that is able to meet established goals under the given operating conditions. Quality planning has to be carried out for all the processes in manufacturing or service organizations. The following steps are to be carried out during quality planning:

- Identify the customers, both external and internal.
- Determine customer needs.
- Develop product features that respond to customer needs. (Products include both goods and services.)
- Establish quality goals that meet the needs of customers and suppliers alike, and do so at a minimum combined cost.
- Develop a process that can produce the needed product features.
- Prove process capability—prove that the process can meet the quality goals under operating conditions.

QUALITY CONTROL

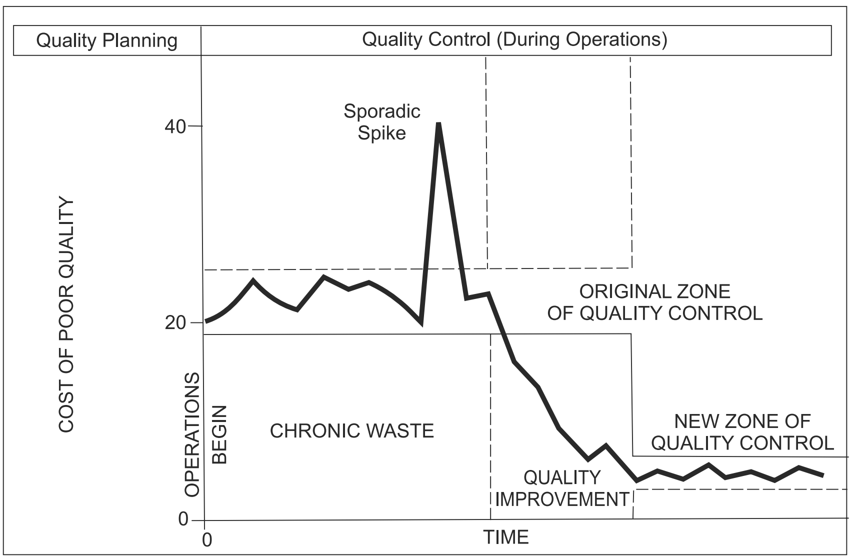
After quality planning is carried out, the process is transferred to the operations department. It is the responsibility of the operations department— by whatever name it is called, such as production department—to execute the process as planned. Due to deficiencies in the original planning process, the process may not run as originally envisaged. It leads to a lot of waste since the process does not performing as planned. Because the waste is inherent in the process, the operations department is unable to avoid the waste. Hence they resort to ‘quality control’—keep the waste at the minimum. The following steps are taken for ‘quality control’.

- Choose control subjects—what to control.
- Choose units of measurement.
- Establish measurement.
- Establish standards of performance.
- Measure actual performance.
- Interpret the difference (actual versus standard).
- Take action on the difference.

If it does get worse (sporadic spike), a fire-fighting team is brought in to determine the cause or causes of this abnormal variation. Once the cause(s) has been determined, and corrective action is taken, the process again falls into the zone defined by the ‘quality control’ limits.

QUALITY IMPROVEMENT

As Figure 1 shows, in due course the chronic waste falls to a much lower level. Such a reduction does not happen of its own accord. It results from purposeful action taken by upper management to introduce a new managerial process into the system of managers’ responsibilities—the quality improvement process. This quality improvement process is superimposed on the quality control process—a process implemented in addition to quality control, not instead of it.



Quality Triology
Figure 1

Juran proposes the following 10 steps to quality improvement:

1. **Build awareness of the need and opportunity to improve.**
   This is the preparatory phase of quality improvement. In this phase, the senior management should educate and emphasize with employees on the need to improve the performance of the processes in the organization. They should also list areas where quality improvement is desirable and possible.
2. **Set goals for that improvement.**
   In this phase, a detailed analysis of current achievements in the processes should be measured. The management thereafter sets targets for future performance in clear and measurable terms.
3. **Create plans to reach the goals.**
   No tangible benefits can occur without a plan. Keeping the end points in view the management should make a plan to achieve the goal. Such a planning exercise may also list the techniques for achieving the goal.
4. **Provide training.**
   The highest return on investment is possible only by educating and training employees. Therefore, the management should formulate a plan to train the concerned employees and provide the training. The effectiveness of training provided should be measured.
5. **Conduct projects to solve problems.**
   Each improvement action should be organized as an improvement project. The improvement projects should be executed by a duly constituted cross-functional team. Such teams should have a senior employee as a moderator. The project team should evolve a time-bound action plan to complete the improvement project. The teams may adopt PDCA cycle for the improvement projects.
6. **Report on progress.**
   For each improvement project, milestones should be fixed. Each improvement team should periodically report on the progress made to the management.
7. **Give recognition for success.**
   All teams may not be equally competent or enthusiastic. Therefore, the management may evolve a suitable award/reward scheme to keep the teams motivated and focused on the improvement project.
8. **Communicate results.**
   The results obtained by the improvement projects should be widely circulated within the organization.
9. **Keep score.**
   Each team should submit a closure report highlighting the initial performance, proposed modifications to the process and results obtained. This should be archived in the organization’s repository.
10. **Maintain momentum.**
    Processes are never static. New challenges may be entangled in the operations. Hence, the process team shall maintain the momentum and continue to improve.

Reliability Testing

Successful organizations are those whose products enjoy a brand image internationally. A brand image has to be built through sustained efforts. One of the basic requirements to establish a brand image, is the high reliability of products. The automobile sector, amongst others has brought out clearly that reliable products, in addition to creating a brand image, help the organizations to surpass their competitors not only in terms of volumes, but also in terms of market capitalization. The purpose of reliability testing is to uncover potential problems with the design as early as possible and, ultimately, provide confidence that the system meets its reliability requirements.

Reliability testing may be performed at several levels. Complex systems may be tested at component, circuit board, unit, assembly, subsystem and system levels. Testing proceeds during each level of integration through full-up system testing, developmental testing, and operational testing, thereby reducing system risk. System reliability is calculated at each test level. Reliability growth techniques and Failure Reporting, Analysis and Corrective Active Systems (FRACAS) are often employed to improve reliability as testing progresses.

It is not always possible to test all system requirements. Some systems are prohibitively expensive to test; some *failure modes* may take years to observe; some complex interactions result in a huge number of possible test cases; and some tests require the use of limited test ranges or other resources. In such cases, different approaches to testing can be used, such as accelerated life testing. The desired level of statistical confidence also plays an important role in reliability testing. Statistical confidence is increased by increasing either the test time or the number of items tested. Reliability test plans are designed to achieve the specified reliability at the specified *confidence level* with the minimum number of test units and test time. Different test plans result in different levels of risk to the producer and consumer. The desired reliability, statistical confidence, and risk levels for each side influence the ultimate test plan. Good test requirements ensure that the customer and developer agree in advance on how reliability requirements will be tested.

As part of the requirements phase, the reliability engineer develops a test strategy with the customer. The test strategy makes trade-offs between the needs of the reliability organization, which wants as much data as possible, and constraints such as cost, schedule, and available resources. Test plans and procedures are developed for each reliability test, and results are documented in official reports.

Accelerated Testing

The purpose of accelerated life testing is to induce field failure in the laboratory at a much faster rate by providing a harsher, but nonetheless representative, environment. In such a test, the product is expected to fail in the lab just as it would have failed in the field—but in much less time. The main objective of an accelerated test is either of the following:

- To discover failure modes
- To predict the normal field life from the high *stress* lab life.

An **accelerated testing** program can be broken down into the following steps:

- Define objective and scope of the test
- Collect required information about the product
- Identify the stress(es)
- Determine level of stress(es)
- Conduct the Accelerated test and analyze the accelerated data

Currently, the reliability test techniques, known as Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS), are widely used to test the robustness of design and thereby improving product reliability, all leading to reduced field failures, warranty costs and increasing customer delight.

HALT

HALT is performed on a product, as part of the design process. It is performed before carrying out Design Verification Testing (DVT), also known as type approval testing. The purpose of DVT is to demonstrate that the product meets its specifications. On the contrary, the goal of HALT is to overstress the product and quickly induce failures in the product. Applying various stresses in a controlled, stepped fashion while monitoring a product for failures, leads to exposure of weakest points in the design. The key value of the HALT lies in identification of the failure modes and the speed with which they are uncovered. This, in turn, leads to corrective actions and design optimization. Although these failure modes are induced by stresses in excess of specifications, they are typically valid failure modes that would show up in the product in the field. The weak links exposed by HALT are the potential sources of warranty problems in the field. The controlled over stresses applied during the HALT process, accelerates the precipitation of these failures to allow early detection and elimination through redesign. It has been well established that HALT will find most, if not all failure modes in a product.

HASS

Typically, after the design is ruggedized through HALT, and the DVT is completed, regular production begins. The production process can introduce additional failure modes that are not related to a faulty design. HASS is intended to catch these new failure modes, more quickly and more effectively than burn-in or other environmental stress screening techniques. Burn-in is designed to weed out infant mortality failures in a product. The goal in HASS is to verify that no new weak link has crept into the product since HALT. The precondition for HASS is the completion of HALT on the product. The HASS limits will be based on the operational and destruct limits established in the HALT process. Therefore, HASS follows HALT.

QUALITY CIRCLES—A WAY TO QUALITY IMPROVEMENT

Philosophy

Quality Circles (QC) contributed to the path-breaking success of the Japanese industry after World War II. This initiative was aimed at involvement of employees at all levels for problem solving in workplaces. A quality circle is a small group of 6 to 12 employees doing similar work, who meet on a regular basis to identify improvements in their respective work areas for analyzing and solving work-related problems coming in the way of achieving and sustaining excellence.

Structure of a Quality Circle

A typical organizational structure of a quality circle consists of the following composition:

Steering Committee This is the apex committee. It is headed by a senior executive and includes representatives from the top management and human resources development personnel. It establishes policy, plans and directs the programme and meets usually once in a month.

QC Coordinator He/She coordinates and supervises the work of the facilitators and administers the programme.

Facilitator The facilitator may be at the supervisory level in the organization, and coordinates the works of several quality circles through the circle leaders.

Quality Circle Leader Leaders may be any employee in the organization. A circle leader organizes and conducts QC activities.

Quality Circle Members They may be workers. They should attend all meetings, offer suggestions and ideas, and participate actively in group processes.

PREPARATION

The pre-requisite for initiating quality circles in any organization is the commitment of the top and senior management. The launching of quality circles involves the following steps:

- Training to middle-level executives
- Explaining the concept to the employees and motivating them to volunteer as members of quality circles
- Nominating senior employees as facilitators
- Constituting a steering committee
- Arranging training of coordinators, facilitators on quality circles, implementation, techniques and operation, later facilitators may provide training to circle leaders and circle members.
- Fix quality circle meetings, preferably one hour a week.
- Formal inauguration of the quality circle.
- Arranging necessary facilities for the quality circle meeting and its operation

TRAINING

Appropriate training for different sections of employees needs to be imparted. Each group should know beforehand the commitments and implications involved as well as the benefit that can be obtained from quality circles. Such training courses may comprise of the following, in particular:

- Orientation program for senior management
- Programme for middle-level executives
- Training of facilitators
- Training for circle leaders and members

Benefits of Quality Circles

A number of benefits accrue to the organization due to quality circles. Some of them are given below:

- Quality improvement
- Improved productivity
- Improved communications
- Improved worker attitudes
- Job satisfaction
- Teamwork amongst employees
- Improved safety in work places
- Transferring ownership for quality to everyone

IMPLEMENTATION OF QUALITY CIRCLES

Quality circles, also called Quality Control Circles, are a powerful concept for problem solving by involving employees on a voluntary basis. It gives a lasting solution to the chronic problems of an organization in a cost -effective and efficient manner. Of course it needs efforts of the employees to be expanded with the backing of the top management. The implementation of quality circles involves a set of sequential steps as outlined below:

1. Problem Identification

The root cause of most of the problems may be due to the system, including the quality system established in the organization. Some problems could be due to deficiency in the processes or product design. The first task is to identify problems in the process, product or system. The top management will know some problems off hand. But there are a number of sources which will bring out problems in the organization on a continuing basis in a systematic manner. For instance, both internal and external quality audits and customer complaints are important sources for problem identification. The management should be willing to receive problem reports and thereafter take action to resolve them. One of the effective mechanisms for solving quality-related problems is quality circles. Therefore, the first task in implementing quality circles is to identify the problems and document the same.

2. Prioritization

All problems do not have the same impact in the organization. The impact of a problem may be on the customer satisfaction, employee motivation, quality costs, and profits, and so on. Depending on the impact of the problems on the organization, they are to be prioritized. The management has to decide the priority and select the problem to be taken up for solving. Sometimes, some problems may be related. They could be combined together. The prioritized list of problems is to be documented.

3. Problem Analysis

A quality circle is formed for solving each one of the prioritized problems. A causal analysis is to be carried out for every problem. The problem is analyzed by the designated quality circle. It is very important to analyze the problem thoroughly. A problem is analyzed using well-known basic problem-solving techniques. For instance, a process flow chart may be needed to understand the problem. Thereafter, a cause-and-effect diagram can be used to analyze the various causes of the problem. The diagram can be constructed during the brainstorming session of the quality circles. It is the responsibility of the quality circle to analyze the problem and document the same.

4. Generate Alternative Solutions

Quality circles need to find the vital few causes rather than ones, many ones, so as to find an effective solution to the problem. Based on causal analysis, the quality circles have to generate possible alternative solutions for the problem. All solutions suggested by the members of the quality circles need to be captured and documented first. Then Pareto Analysis will lead to finding appropriate alternate solutions. No idea of the members should be ignored to enable teamwork. Due considerations need to be given to all suggestions.

5. Select the Most Appropriate Solution

The members of the quality circles should discuss and evaluate the alternative solutions by comparison in terms of investment and return on investment. Subjective bias, if any, must be eliminated. This enables us to select the most appropriate solution to the problem. The solution thus selected must be implementable. While arriving at the possible solution, brainstorming will help. If some members are not prepared for discussions then the meeting should be postponed to a later date rather than rushing and evolving a solution without the participation of all members of the quality council.

6. Prepare a Plan of Action

Prepare a plan of action for converting the solution into reality which includes the considerations 'who, what, when, where, why and how' of solving problems. Quality circles should document the nitty-gritty of the solution in detail. It will be better if the plan of action thus prepared is reviewed independently to bring out any inconsistencies in the document. The concurrence of the process owners on the proposed plan of action needs to be taken.

7. Presentation of Solution to Management for Approval

It is important that the approval of the management is taken for the proposed solution. The management, because of its experience, will be able to contribute to the improvement of the solution further. Furthermore, management approval will only remove the reluctance of the process owners for change in their process in order to implement the solution.

8. Implementation of Solution

The management evaluates the recommended solution. Then it is tested on a pilot basis and if successful, implemented on a full scale. It is important to implement the solution on a pilot basis before full-scale implementation in order to avoid any risks in implementing the solution right away.

The above eight step approach is one way of implementation of quality circles. There may be variations in the steps, but every organization should form quality circles and derive maximum benefits.

APPENDIX - B

PROJECT WORK

CHAPTER 1

1. Compare the principles and philosophies of Deming, Juran, Crosby and Ishikawa.

CHAPTER 2

1. From public statements and annual reports of manufacturing organizations, infer the cost of quality and make a summary.
2. Describe how consumer courts can help in bringing down the cost of quality.

CHAPTER 3

1. Submit a comparison between manager and leader.
2. Choose any well-known leader and describe what circumstances and happenings in his/her life helped him/her to attain a leadership position.

CHAPTER 4

1. Study the quality policies of a few service organizations and describe the common thread.

CHAPTER 5

1. Collect information on the rights of consumers in India.
2. Study the role of voluntary organizations in India in educating consumers.

CHAPTER 6

1. Collect information about employee reward schemes of at least two leading hospitals.
2. Collect information about employee-performance appraisal schemes of at least two Indian organizations.

CHAPTER 7

1. Study the relationship between lean manufacturing, Six Sigma and TQM and describe how successful companies have integrated them.

CHAPTER 8

1. Describe how you can apply 5 S in your personal life.
2. Compare the philosophies behind TQM and BPR.

CHAPTER 9

1. Study the supplier partnership programs of Maruti Udyog.

CHAPTER 10

1. Describe the activities of Balanced Scorecard Institute.
2. List and justify the top four quality metrics suitable for educational institutions.

CHAPTER 11

1. Draw a cause-and-effect diagram for improving quality of food in a student's hostel.

CHAPTER 12

1. Note your arrival time in the college for a one-month period. Find out the average, standard deviation and carry out process-capability study of your arrival in college.

CHAPTER 13

1. Describe the Black-Belt System practiced in the industry and how it facilitates achieving Six Sigma.

CHAPTER 14

1. Draw a tree diagram for improving quality of life of citizens.

CHAPTER 15

1. Assuming that you are working in a small-scale industry manufacturing toys, make a benchmarking plan for your organization.

CHAPTER 16

1. Construct a house of quality for the laptop computer you are using. List the assumptions made by you to construct the same.

CHAPTER 17

1. Construct an orthogonal array to test a water heater.

CHAPTER 18

1. List the KK losses in a road transport organization.

CHAPTER 19

1. Carry out FMEA using RPN methodology for a passenger car as a whole.

CHAPTER 20

1. Prepare a checklist for auditing a school as per ISO 9001 standards. The checklist may be prepared in the following format:

CHAPTER 21

1. Prepare a checklist for auditing a restaurant as per ISO 14001 standards. The checklist may be prepared in the following format:

CHAPTER 22

1. Study the success story of any organization which received Rajiv Gandhi National Quality Award and compare it with MBNQA awardees.

APPENDIX - C

CASE STUDY 1

Importance of Computing Cost of Quality

Presented below is one case study that may help illustrate the practical application of a Cost of Quality (COQ) process in an organization.

An organization involved in GIS data conversion had over thirty people in a production office. The conversion software was configured for 'fat client' operation, that is, the software was operating off of the desktop hard drive. The data however was stored on the server, and every few minutes, the 'client' software would send packets of data back to the server for storage and access. Since the data-conversion industry is very cost-competitive, literally every minute counts towards the bottomline.

This company, however, did not have a Uninterruptable Power Supply (UPS) for its server or its production machines. The costs associated with implementing enterprise UPS protection was deemed unnecessary and too costly since there was no immediate need to justify the expenditures."If it isn't broke, why fix it?"

During one month however, power failures and 'hiccups' were being reported in the local news, and in adjacent commercial centers. Still there was no sense of urgency in the organization. The first power outage at the company was relatively minor, lasting for less than a minute. A few calls identified the cause of the power failure to the local telephone company placing new underground cables, and frequently cutting the electric cables in the process. As the frequency of the power outages increased, so too did the duration of each outage.

The production group began to feel the impacts of the power failures in terms of lost productivity, delayed schedule, and corrupted data. It was decided that something must be done, but in order to demonstrate the long-term benefits of 'doing something', the 'cost' of not doing anything had to be spelled out.

Several people were enrolled to identify the process that occurred each time the power failed, and what was involved in order to bring the production group back online. To the group's astonishment, a significant amount of collective time was consumed each time, regardless of the duration of the power failure. First, a process map was created, and each step in the process was given a time estimate. Based on standard operating procedures, the people involved in each step of the process had a certain hourly wage associated with their labor. This was calculated for the entire process. Next, the opportunity cost of not gaining any additional revenue (from work that could have been done) was calculated across the enterprise. Then, the cost of lost production work, in terms of re-doing work and searching for corrupted data, was calculated across the enterprise. Another component to the cost-of-quality analysis was in quantifying the cost of production schedule delays and customer satisfaction due to the frequency of power failures.

All of this data was collected, compiled and collated for a single occurrence of a power failure. Then the team estimated, based on historical evidence, the annualized number of power failures that the production group would be forced to endure. Once the annual impact was estimated, the annual costs were calculated, and the team was shocked; power failures alone were causing the company Rs. 68, 64,000 per year.

The COQ team then prepared an action plan intent on preventing or alleviating the costs of power failures in the future. This plan included the purchase of a robust network backup system, UPS's for every workstation and server, and the revision of operating procedures with risk avoidance as a central theme. The entire preventive action plan was estimated to cost approximately Rs. 5, 60,000, and take two months to implement. The ROI on that preventive action investment would yield 1225 % (or 12.25 times) over a one-year period.

This COQ analysis was presented to the executive management, and a cheque was issued for Rs. 5, 60,000 the very same day.

Review Questions

1. What are the learning points from this case study?
2. Why was a cheque issued for Rs. 5, 60,000 the very same day?
3. Which two costs of quality are discussed in this case study?

CASE STUDY 2

Plan-Do-Check-Act Cycle

PLAN-DO-CHECK-ACT PROCEDURE

1. *Plan*—Recognize an opportunity and plan a change.
2. *Do*—Test the change. Carry out a small-scale study.
3. *Study*—Review the test, analyze the results and identify what you have learnt.
4. *Act*—Take action based on what you learned in the study step: If the change did not work, go through the cycle again with a different plan. If you were successful, incorporate what you learned from the test into wider changes. Use what you learned to plan new improvements, beginning the cycle again.

PLAN-DO-CHECK-ACT CASE STUDY

The Pearl River, NY School District, a 2001 recipient of the Malcolm Baldrige National Quality Award, uses the PDCA cycle as a model for defining most of their work processes, from the boardroom to the classroom.

PDCA is the basic structure for the district's overall strategic planning, needs-analysis, curriculum design and delivery, staff goal-setting and evaluation, provision of student services and support services, and classroom instruction.

Figure 1 shows their 'A+ Approach to Classroom Success.' This is a continuous cycle of designing curriculum and delivering classroom instruction. Improvement is not a separate activity—It is built into the work process.

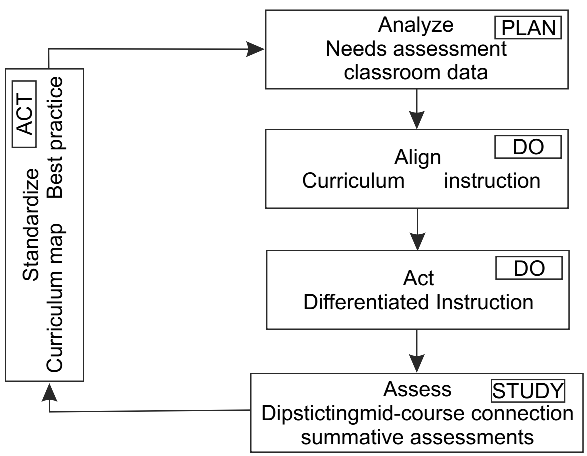


Figure 1: Plan-do-check-act example

Plan

The A+ Approach begins with a 'plan' step called 'analyze'. In this step, students' needs are analyzed by examining a range of data available in Pearl River's electronic data 'warehouse,' from grades to performance on standardized tests. Data can be analyzed for individual students or stratified by grade, gender or any other subgroup. Because PDCA does not specify how to analyze data, a separate dataanalysis process (Figure 2) is used here as well as in other processes throughout the organization.

Do

The A+ Approach continues with two 'do' steps:

1. 'Align' asks what national and state standards require and how they will be assessed. Teaching staff also plan curriculum by looking at what is taught at earlier and later grade levels and in other disciplines to assure a clear continuity of instruction throughout the student's schooling. Teachers develop individual goals to improve their instruction where the 'analyze' step showed any gaps.
2. The second 'do' step is, in this example, called 'act.' This is where the instruction is actually provided, following the curriculum and teaching goals. Within set parameters, teachers vary the delivery of instruction based on each student's learning rates and styles and varying teaching methods.

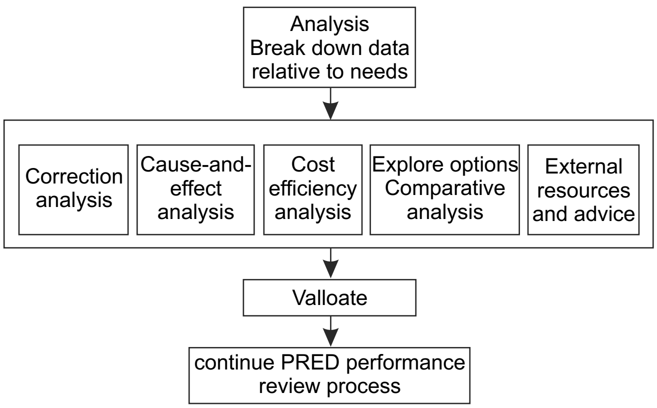


Figure 2: Pearl River: analysis process

Check

The 'check' step is called 'assess' in this example. Formal and informal assessments take place continually, from daily teacher 'dipstick' assessments to every-six-weeks progress reports to annual standardized tests. Teachers also can access comparative data on the electronic database to identify trends. High-need students are monitored by a special child-study team. Throughout the school year, if assessments show students are not learning as expected, mid-course corrections are made such as re-instruction, changing teaching methods and more direct teacher mentoring. Assessment data become input for the next step in the cycle.

Act

In this example the 'act' step is called 'standardize.' When goals are met, the curriculum design and teaching methods are considered standardized. Teachers share best practices in formal and informal settings. Results from this cycle become input for the 'analyze' phase of the next A+ cycle.

Review Questions

1. When can you use PDCA cycle?
2. Can any step be skipped?
3. What are the learning points in the case study?

CASE STUDY 3

Quality in Services

Most food-service providers strive to deliver quality service, but for Shiva Restaurant in USA, it boils down to a commitment to people above processes, and people does not just mean customers. The mission of 'delighting every guest' begins with a deep commitment to nurturing each team member by providing certified trainers and individual development plans, conducting monthly life-balance classes on topics such as financial management, stocking a corporate library—employee benefits virtually unheard of in the restaurant business. The deeply embedded philosophy that staff is truly 'who we are' means an investment in resources most organizations are unwilling to make, but it brings results most organizations don't achieve either: outstanding success in every measure. The company's turnover rate is less than half the restaurant industry average, and Shiva has been lauded nationally as one of the most effective performers of its kind.

Approximately 480 employees work in the company's combined seven locations. Shiva was formed in 1993 based on the proprietor's common love of excellence and good food. Their goal was to create and operate restaurants where freshness, quality, cleanliness, hospitality, and consistency would be taken seriously. Their commitment to excellence is so serious that their registered trademark is *Quality Is Everywhere*. Their dedication has paid off. Today, Shiva is the number one restaurant in food sales per square foot of approximately 67,000 total restaurants in USA. For a mere four years, Shiva is one of the most successful start-up fast casual concepts in the nation with more than Rs. 200 million per year in single-unit sales and world-class guest satisfaction ratings.

Shiva's proprietors came into the restaurant business from the commercial insurance industry with expertise in risk management. While acknowledging that Shiva invests a lot of money into every phase of the people side of the business, Ganesh, the proprietor, simply says, 'How can you not?' He believes the risk of keeping under-trained employees on the payroll is far worse than the risk of losing good employees after they've been trained and developed. Ganesh's background meant that he was used to studying how companies function. He worked to identify trends he saw in prosperous organizations and watched how they successfully made themselves stand out. At Shiva that experience has translated into standard measures senior leadership constantly monitors:

- Food quality
- Speed of service
- Hospitality
- Cleanliness
- Order accuracy

Shiva's management team consists of one owner, seven senior leaders or directors, and a general manager for each location. The group meets each month to monitor key measures. Ganesh says, 'If something is impacting our guests, we pay attention to it.'

Shiva's fundamental commitment to quality, combined with Ganesh's natural interest in managing processes, made it perhaps inevitable that the company would pursue the nation's highest honor for performance excellence. The Malcolm Baldrige National Quality Award (MBNQA) Program was established by the US government to enhance the competitiveness and performance of Indian businesses. The award is given to role-model organizations that demonstrate exceptional performance in all areas of management:

- Leadership
- Customer service

- Workforce focus
- Process management
- Data analysis
- Business results
- Strategic planning.

The judging process includes a review of the application and a comprehensive site visit, during which a team of examiners spend days verifying every aspect of the applicant's quality approach.

CONTINUOUS DEVELOPMENT

All Shiva management team members are evaluated on a consistent basis using a job scorecard that focuses on core competencies. Individual development plans also facilitate continuous improvement. Team members are encouraged to make use of professional development materials available through the corporate library and to pursue pertinent outside training, the cost of which is usually reimbursed by the company.

DEALING WITH CHANGE

Ganesh says Shiva will continue its quest for quality and excellence. "We're never going to get to a point in which there's nothing left to learn," he said. "All change begins with a vision of becoming something better." Shiva plans to continue its MBNQA by holding periodic benchmarking sessions to monitor performance. When change is needed, it's up to the senior leadership team to convey the information to the rest of the staff. "If people understand why you're doing something, they'll buy into it," said Ganesh. Ganesh also works hard to give back to the community by sharing best practices with organizations that request information. Occasionally, the company even hosts foreign delegations that wish to benchmark their operations against Shiva's high standards.

Review Questions

1. List the lessons learned in this case study.
2. What do you think is the most important contributor to the success of Shiva Restaurant?
3. What is the relation between TQM and MBNQA?
4. Is there any difference in approach towards excellence between manufacturing and service industry?
5. Find out the USP of Shiva Restaurant .
6. List the quality metrics used by the organization.

CASE STUDY 4

Deming Prize

The case examines the quality initiatives taken up by leading Indian air-brakes manufacturer Sundaram Clayton to win the world's highest award for quality, the Deming Prize.

The leading manufacturer of air-braking systems in India, Sundaram Clayton Ltd. (SCL) is the flagship company of the US$1.6 billion TVS Group. Named after its founder, TV Sundaram Iyengar, the TVS Group began its journey with a small transport business in Chennai (India) in the year 1911. Over the years, the group diversified into two-wheelers, automotive components, automotive spares, computer peripherals and financial services. In the year 2001, the TVS group had 29 globally recognized companies and an employee base of over 30,000.

SCL was established in 1962, in collaboration with UK-based Clayton Dewandre Holdings Plc. (renamed WABCO Automotive), a division of American Standards Inc. for manufacturing air-assisted and air-brake systems for commercial vehicles in India. Over the next few decades, SCL went on to become the principal supplier of air-brake systems to the heavy and light commercial vehicle segments of the Indian automobile sector.

The company was the Original Equipment Manufacturer (OEM) for Ashok Leyland and Tata Engineering and Locomotive Company (TELCO). Other major clients of the company included Hindustan Motors, Maruti Udyog and Bharat Earth Movers. OEM sales contributed 60% to the company's total sales while the replacement market accounted for an estimated 25%.

SCL used 65% of the castings produced by its foundry division and supplied the remaining (35%) to the group companies or other companies. The company's vast network of over 205 wholesale dealer outlets, situated across the country enabled it to become the leader in the automotive air-brake systems market in India and garner a 70% market share.

SCL has a full-fledged R&D center that enables design, development, simulation and testing processes of products. By focusing on R&D, the company was able to substitute its imports by its indigenously developed components. SCL was also able to indigenously manufacture some components for the export markets. These initiatives were expected to help the company achieve its goal of becoming the leader in the automotive air-braking business in Asia.

In spite of the slump in the automobile sector during the late 1990s, SCL registered improved revenues year after year between 1998 and 2000. Industry analysts largely attributed the company's success to its focus on quality.

According to TVS sources, the group as a whole had always aimed at competitiveness without compromising on quality. This belief was proved when the company adopted Total Quality Management (TQM) in all its manufacturing companies, including SCL. SCL followed the core principles of the TVS group—Quality, Reliability and Service. Quality measures at SCL were not only applicable to the product but also to systems, operations and processes at all levels of manufacturing.

As a result of its company-wide quality control over the years, the company won the Deming Prize for CWQC (Company Wide Quality Control) in 1998. SCL was the first Indian company and the fourth non-Japanese company to receive the prize in the 50-year history of the award. One of the three highly recognized and coveted quality awards in the world, the Deming Prize, was established in Japan, in 1951, by the Union of Japanese Scientists and Engineers (JUSE).

SCL had decided to apply for the Deming Prize in the early 1990s itself. This decision was the result of management's belief in the total quality control efforts that had started in 1979, after Venu Srinivasan (Srinivasan) became the CEO (1977). A SWOT analysis conducted by Srinivasan in 1997 revealed that though the company had a 90% share of the air-brake systems market in India, it was not competent enough to deliver world-class quality products. This analysis prompted the company to seek excellence through total quality control/management. As a part of this initiative, SCL managers were introduced to the concept of Total Quality Control (TQC) and exposed to the quality control practices of the world's leading companies.

The managers were also trained in modern manufacturing techniques. By the mid-1980s, the TQC culture was well established at SCL. Famous Japanese quality control experts like Yoshio Kondo and Washio trained managers and employees extensively in TQC. The company also introduced the concept of quality circles. To remain focused on quality control and to keep the employees interested in quality-control practices, external targets such as winning national quality awards were set, following which the company won the Quality Circle Award of the Confederation of Indian Industry (CII) in 1989 and the Quality Circle Federation of India awards successively for the next few years.

The defect rate in the manufacturing process at SCL decreased substantially and customer returns came down as a result of these quality-control initiatives. New-product development time was reduced from 24-to-30 months to12-to-14 months. The turnover per employee increased by an estimated 18% annually whiles the gross value addition by every employee increased by 12% per annum. The quality practices in the company also reflected in its financial performance. Between 1992 and 1997, sales grew at an annual rate of 35% while its net profits grew at an annual rate of 83%.

Review Questions

1. What steps were taken by SCL to bag the Deming Prize?
2. What benefits did SCL reap because of TQM?
3. Are TQM and Deming Prize independent?
4. What do you understand about the Deming Prize?

CASE STUDY 5

ISO 9000 Implementation in a Machine Shop

This case study gives details of how a machine shop, with the help of a consultant, implemented ISO 9000 within 9 months and obtained the ISO 9000 certification.

THE ORGANIZATION

The organization is a machine shop catering to a large customer base, and 20% of its turnover comes from exports. The management has a plan to increase the export turnover. The organization's staffing is as follows: top management, 4; middle management, 14; supervisory staff, 28; operators, 2106. The current assessment showed that there was no documented system followed in the shop. So the work started by interacting with the top management. Some of the main points are described in the following sections.

Top-management Involvement

Top management's commitment and involvement were first assured for the planning of the implementation of ISO 9000. The management realized the need for proper planning, maintenance and control in implementing the system. The following activities were taken up:

- Planning for development and implementation of the system and distribution of the plan to all management staff—this was finalized after discussion with the management staff
- The appointment of a Management Representative (MR) and a management committee consisting of the Managing Director (MD) as chairman, the MR as convener and heads of departments as members with responsibility and authority for system implementation
- The formation of a task force for developing and implementing the QS

- Ensuring employee participation in the formulation of quality policy and objectives
- Planning for required training programmes
- Enabling the management staff and supervisors to understanding the different clauses of the standard, their interpretation and relevance to the organization
- Helping management, staff and supervisors to develop the system through continuous review
- Discussion on internal-quality audit findings and encouragement of the task force members to remove the deficiencies

Training Programmes

The next step taken by the management was to impart necessary training to all employees. The management identified the training needs of personnel at different levels through discussion with the consultants, and a training programme schedule was prepared. The training programmes were conducted by the consultant. It was ensured that all employees attended the relevant training programmes.

Documentation

The management planned to implement the ISO 9001 model, as it was the most appropriate to the organization's activity. Different activities carried out by the organization were reviewed, and it was found that only a few formats were used for recording necessary data. There were no documents available for any activity, and generally it was carried out based on practice or on verbal instructions. It was decided to follow the standard practice of documentation with minor modifications. It may be noted that the document structure has been modified by developing standards for raw material, finished and semi-finished material, etc., and making it a separate document. The idea was to respond to the changing environment and customer demand effectively. Standards were prepared based on the organization's requirements, and due care was taken to achieve this during system development. Various levels of documents were prepared by the concerned task performers themselves and reviewed by the head of the departments.

Continuous Review

To ensure effectiveness, the system-implementation process was continuously reviewed by the management committee and task force, starting with development. Before any review, task performers were asked to ensure the correctness of the documentation.

Involvement of Employees' Union

The organization had two registered unions. Although the unions differed on many issues, for the implementation of system they were together in cooperating with the management. The management recognized the role of unions and interacted with them at various stages. Training programmes on system implementations for operators were arranged by them. During training programmes, union leaders as well as other members played active participation and had their doubts clarified in connection with system implementation. In the later stages, union leaders played an active role, explaining to the workers their role in implementing and maintaining the system. It is worth noting that unions worked hand-in-hand with the management to fulfill the organizational goal.

Internal Quality Audit

Necessary training was provided to selected members on Internal Quality Audit (IQA). Before training, twice an audit was carried out informally to give hands-on experience and a grip on auditing. Audit checklists were prepared by the management committee members. Auditors were selected from the participants of the training programme on IQA and were asked to audit by using the checklists. Initially, all the departments were audited twice, and then a formal audit took place. Non-Conformity Reports (NCRs) were raised and closed within a week. This was verified in the same week. In IQA, 78 NCRs were raised and six of them were major non-conformities. Maximum NCRs were raised with respect to document control and quality records. All NCRs were discussed during management review, and the management committee ensured that the right corrective and preventive actions were taken.

Certification (Initial) Audit

Four months after the trial implementation, an audit leading to certification was carried out by a leading certification agency. Thirteen NCRs were raised by the auditors, and they were closed during the audit period itself. At the ‘closing meeting’, the auditors recommended the organization for certification.

Follow-up

During development and implementation of the system, the management realized the benefits of the system. In order to achieve organization performance excellence, they are moving towards total quality management. Some of the steps already taken are

- Continuous review to maintain, sustain and improve the QS
- Imparting statistical knowledge to the executives for problem-solving
- Making studies into quality and productivity improvement
- Auditing the system for its effectiveness
- Review of customer feedback and corrective action

Review Questions

1. Is ISO 9000 certification a step to TQM and why?
2. What are the major steps involved in implementation of ISO 9000 standards?
3. How does a consultant help in preparation?
4. What is the role of the top management in this case study?
5. Why is documentation important?
3. Do trade unions impede quality certification. Why?

CASE STUDY 6

The Honeywell Six Sigma Story

In June 1999, AlliedSignal, a US-based aerospace and auto parts company announced its merger with Honeywell, another US-based aerospace and industrial controls major. The merger, valued at $15.5 billion in stock, created a Fortune 50 company, with $24 billion in revenues and over $45 billion in market capitalization. Slated to function under the name ‘Honeywell International Inc’ (Honeywell), it was a truly global technology company, with technical and product leadership in various industries. Besides cost savings of over $500 million annually, the merger was expected to offer many business synergies to the two companies.

The combined financial, technological, managerial, cultural and operational strengths of both the companies were expected to drive the growth of the new company. Savings were to be made by way of rationalization of overhead costs, integration of research and development (R&D), quality initiatives and purchasing efficiencies.

The merger was completed in December 1999 and Bonsignore became Honeywell's CEO. By this time, the company had identified many revenue and growth synergies, and opportunities from integration of businesses and resources. It had also increased its cost-savings estimate from $500 million to $750 million annually by 2002.

To reap further benefits from the merger, Honeywell decided to integrate the quality management initiatives of both the companies. Thus, in December 1999, it announced plans to build on AlliedSignal's existing efforts in order to implement a world-renowned quality initiative, known as Six Sigma.

Commenting on this, Bonsignore said, "We will perpetuate a broad and far-reaching Six Sigma discipline throughout the new Honeywell to create added value for our shareowners and our customers." The decision to create a broad Six Sigma discipline which was not just confined to processes, but to the various functional areas as well resulted in the creation of the Six Sigma Plus System.

This unique system was formed by the integration of both AlliedSignal's and Honeywell's quality systems, viz. Six Sigma and Honeywell Quality Value (HQV), respectively.

According to industry observers, AlliedSignal's growth owed much to the top management's focus on improving operational efficiency. Foremost among such initiatives was the Six Sigma Initiative introduced by Bossidy in 1994. AlliedSignal implemented the Six Sigma. Breakthrough Strategy, aimed at increasing productivity by 6% every year.

As the company began realizing the benefits of Six Sigma implementation processes, it decided to broadbase the Six Sigma implementation exercise by applying it to other processes such as product-development and innovation.

According to Barry Siadat (Siadat), AlliedSignal's Chief Growth Officer, Six Sigma greatly increased the efficiency of the product development process. The application of Six Sigma tools helped the company identify potential risks and their impact, define the probability of occurrence, evaluate the independent variables, reduce variability and maximize results. Thus, the initiative enabled the company to make much more accurate product-development decisions.

After the merger, Honeywell decided to integrate the best of both Six Sigma and HQV and form a new, comprehensive quality-management system. According to company sources, the integration of these strong sets of quality disciplines was expected to result in huge cost savings and in creation of a customer-centric culture. This new quality-management system created from combining Six Sigma and HQV was referred to as Six Sigma Plus. Six Sigma Plus was identified as a strategy aimed at measuring quality, improving growth and productivity and achieving performance breakthroughs.

Results and Problems

According to Honeywell sources, the most significant benefit of the Six Sigma Plus initiative was that it enabled the company to understand the needs and requirements of its customers. For instance, a tool named 'Voice of Customer' helped gain feedback from customers, which helped the company design a new customer relationship management system in 2000.

Putting Honeywell back on Track

As part of the restructuring exercise, Honeywell focused on five areas—growth, productivity, cash, people and enablers. Under these areas, the company mainly focused on cost cuts (through lay-offs and closing unprofitable businesses), increase in productivity, new product/service development, growth, effective cash-flow management and healthy customer and employee relationships.

Initiatives such as Six Sigma Plus and Digital Works (formerly Digitization) were classified under the area enablers.

In mid 2001, Honeywell decided to reinvigorate the Six Sigma Plus exercise. In line with this, the company put its 3,000 plus base of Black Belts, Master Black Belts and Lean Experts on priority projects where they could improve processes, reduce redundancies and cut costs. Apart from this, the company also renewed its focus on training and certifying hundreds of Black Belts and thousands of Green Belts every year.

What Lies Ahead?

In 2003, Honeywell was operating in the following businesses: aerospace products and services (such as turbofan, turboprop engines, landing systems and flight safety), control technologies for homes, buildings and industry, automotive products, and specialty materials (such as semiconductors, polymers for fibers and electronics and specialty friction products).

By early 2003, the company had integrated Six Sigma Plus into the way its employees thought and worked — thus making Six Sigma Plus an integral part of the organization's culture—a way of life. In fact, Six Sigma Plus became more of a mindset than a series of productivity projects.

By now, about 60% of Honeywell management was trained in Six Sigma Plus basics (i.e. in DMAIC). The company aimed at having 100% of its management trained in Six Sigma Plus by the end of the year. Apart from this, it also aimed at having 100% of its engineers trained in the Design for Six Sigma (DFSS) program by that time.

Review Questions

1. What steps were taken to integrate QMS of both the merged organizations?
2. What improvements were the result of Six Sigma initiative?
3. What is meant by Six Sigma Plus?
4. What benefits occurred on account of merger of the two companies?
5. Do you see any strategic planning in this case study?
6. Which constitute the major portion of the quality improvement effort?

CASE STUDY 7

Use of Seven New Management Tools

A CMMI level 5 software development organization was finding that the customer requirements grow with time while the product is under development. The following table gives the number of original software requirements agreed with the customer and the number of requirements implemented by the software development organization at the end of the project.

A brainstorming session was held to find out the possible causes of requirement growth so that they could be addressed in a systematic manner. A large number of causes emerged and a look at the list was not giving a clear picture.

Project Number	*Original Number of Requirements*	*Number of Requirements Implemented at the End of the Project*
1/2010	86	128
2/2010	987	1567
3/2010	678	987
4/2010	123	234
5/2010	88	155
6/2010	97	120
7/2010	111	113

Use of Affinity Diagram

An *affinity diagram* is a tool that gathers large amounts of language data (ideas, opinions, issues) and organizes them into groupings based on their natural relationships. The affinity process is often used to group ideas generated by brainstorming. The affinity process is a good way to get people to work on a creative level to address difficult issues. It may be used in situations that are unknown or unexplored by a team, or in circumstances that seem confusing or disorganized, such as when people with diverse experiences form a new team, or when members have incomplete knowledge of the area of analysis. Therefore, the problem-solving team constructed an affinity diagram to help understand the requirements-growth issue in their organization with the following group headings:

Benefit

Once the various causes were grouped as above, it gave a clear picture for the management to work further. This resulted in identifying causes due to Men and Methods as given below:

Men

1. The software analysts who were given responsibility to elicit requirements needed training.
2. The analysts were lacking in domain knowledge and hence the requirements given by customers were not understood clearly by the analysts.

Methods

1. Although the customers were eager to bring out the requirements, the analysts were unable to capture them since they did not have a proper tool to capture them.
2. The analysts were unable to communicate in the same language the end user was comfortable with.

Review Questions

1. What are the key points of the case study?
2. When can we not use the affinity diagram?
3. What is the next step to be taken by the management after the affinity diagram has been constructed.?

CASE STUDY 8

Customer Satisfaction: McDonald's™* India's Business Strategy

This case study discusses how McDonald's India managed to buck the trend in a struggling economy, its early years and business strategy to get more out of its stores in India. The case also briefly discusses how McDonald's adapted to local culture in India, its localization and entry strategy, its strong supply chain and pricing strategy.

- ***World's Leading Food-service Retailer***—McDonald's has more than 32,000 restaurants serving over 50 million customers each day in more than 119 countries.
- ***McDonald's Competitors in India***—McDonald's competes with fast-food chains like Pizza Hut, Domino's Pizza, Papa John's, Nirula's and KFC in India.
- ***McDonald's Supply Chain***—McDonald's has a dedicated supply chain in India and sources 99% of its products from within the country. The company has strong backward integration right up to the farm level.
- ***Quick Service Restaurants in India***—By October 2009, McDonald's India had more than 170 quick service restaurants in India. Domino's Pizza, which began operations in India in January 1996, has over 275 stores across 55 cities in the country. KFC has 46 restaurants across 11 cities in India. (KFC is one of the 5 brands owned by Yum!. KFC is a $12 billion global brand and a leading Quick-Service Restaurant (QSR) in many countries.) Nirula's, one of India's oldest food chains (completed 75 years in service in March 2009), has a network of around 62 outlets in five states across northern India. Nirula's, established in 1934, has interests in hotels, restaurants, ice-cream parlours, pastry shops and food-processing plants. Nirula's was the first to introduce burgers in India.
- ***Food Industry in India***—In India, the food industry, and particularly the informal eating-out market, is very small. In India, over quarter of a million customers visit McDonald's family restaurants every day. The Indian fast-food market is valued at $1 billion (Rs 4,547 crore) approximately.
- ***MFY (Made for You) Food Preparation Platform***—MFY is a unique concept (cooking method) where the food is prepared as the customer places his/her order. All new upcoming McDonald's restaurants are based on MFY. This cooking method has helped McDonald's further strengthen its food safety, hygiene and quality standards. McDonald's has around 10 MFY restaurants in its portfolio.
- ***How McDonald's Manages to Keep its Prices Down*****—**Fast-food chains face a tough time balancing between margin pressures and hiking prices which can hurt volumes. Consequently, the chains have to increase rates or rework their strategies. Affordability has been the cornerstone of McDonald's global strategy. Some of its measures to achieve this include *bulk buying, long-term vendor contracts, and manufacturing efficiencies*.
- ***McDelivery Online***—In India, McDonald's first launched home delivery of meals in Mumbai in 2004. McDonald's now has plans to launch web-based delivery service in India (across 75 McDelivery cities) in 2010, a pilot for which has already been tested by it in Hyderabad. The company hopes to add 5 per cent to sales via Web delivery. McDonald's Web-based delivery model will be based on serving the customer quickly wherein the drive time does not exceed seven minutes because its food has to be eaten within ten minutes of preparation. The footfalls in India are amongst the highest in the world, but the average bill is amongst the lowest. At present (March 2010), Domino's Pizza (operated by Bhartia Group-promoted Jubilant Foodworks under a master franchise agreement) has a 65% market share in the **home-delivery segment**.

*McDonald's™: Registered trademark of McDonald's Corp. All rights reserved.

- ***Most Preferred Multi-Brand Fast-Food Outlets***—In 2009, McDonald's India won the CNBC Awaaz Consumer Awards for the third time in the category of the Most Preferred Multi-Brand Fast Food Outlets.
- ***McDonald's India in 2010***—In 2010, McDonald's India plans to open 40 more outlets. The company has also earmarked a budget of Rs 50–60 crore to market its new products and initiatives for consumers. Its new marketing campaign is titled **'Har Chotti Khushi Ka Celebration'**—in other words 'celebrate little joys of life' where it positions McDonald's as a venue for enriching the lives of consumers. In South India, McDonald's has 29 outlets and plans to add 10 more by the end of 2010.
- ***Local Vegetarian Menu***—In India, McDonald's does not offer pork or beef-based products. Its menu is more than 50 per cent vegetarian. The fast-food retail chain has separate production lines and processes for its vegetarian and non-vegetarian offerings.
- ***High Real-Estate Costs in India***—In many countries, in a Quick Service Restaurant (QSR) a customer comes in, buys and then leaves. This is known as a **revolving-door concept**. But an Indian customer believes in a **dine-in culture**. This adds to the real-estate costs which go as high as 20–25 per cent as compared to 10–15 per cent globally.
- ***The Most Important Meal for QSRs: Morning Meals (Breakfast)***—According to a market research company, the NPD Group, breakfast accounted for nearly 60 per cent of the restaurant industry's traffic growth over the past five years in the US. Quick-service restaurants sold 80 per cent of over 12 billion morning meals served at US restaurants for the year ending in March 2010.
- ***OOH Branding***—According to Rameet Arora, Senior Director (marketing), McDonald's India (West and South), McDonald's India may be the largest Out-Of-Home branding (OOH) in the country. McDonald's India has restarted OOH (out-of-home branding) after a 7 to 8 year break to reach to their target group.
- ***Employees and Customers***—In India, McDonald's employs 5,000 people and serves half a million customers a day via its 169 family restaurants. McDonald's has 85,000 employees and serves 2.5 million customers a day in the UK.

Review Questions

1. McDonalds has become the poster brand for recession-resilient business. What is McDonald's doing right in India?
2. What elements of its business strategy are working for it and how does it manage to get more out of its stores?
3. Does local adaptation contribute to business growth in a country? Explain McDonald's efforts to adapt to the local culture in India.
4. What challenges did McDonald's face in India?
5. Compare and contrast your experience with another quick-service restaurant or fast-food joint you visited earlier. How can McDonald's improve? Should it alter its strategy?
6. What are the lessons learnt from the case study?

CASE STUDY 9

Leadership for TQM

A major manufacturer in USA opened an assembly plant in Asia in the late 1980s to produce automobiles. Business boomed and the plant ran seven days per week with two shifts of twelve hours each. By the year 2001, however, the automotive industry in USA, and that plant in particular, was struggling to survive. Business at the plant was down and operations were reduced to one shift with lack of orders still forcing weeks of temporary lay-offs.

By early 2005, the local company's management and officials realized that they needed to bring in a new product if they were to insure the future of the plant. Fortunately, the plant was the newest facility in the company's collection and there was room for expansion because they also owned the surrounding property. Therefore, the plant was selected when the decision was made to increase the production of a new line of vehicles. With the expanded production facility, the local company and officials in the US expressed interest in a less adversarial relationship. The company decided to explore a team concept; after all, the Japanese were having fabulous success with it. When the local-company management approached union leadership, the union leaders realized that a cooperative relationship was also in their best interest; and necessary for the survival of the plant and the jobs that it provided. After much negotiation, and with much fanfare, the new operating agreement emphasizing total quality initiatives was born.

The team concept, as encompassed by the new operating agreement, allowed the work group more autonomy to make daily decisions dealing with meeting work group tasks. Rather than allowing the production supervisor to make all the manpower decisions, the team now had an equal vote in decision making, and the supervisor began to function as a coordinator for the team, providing it with assistance in resolving issues. The team elected a team leader; and the team leader was responsible for determining operation coverage, defect containment within the zone, scheduled days off, and training.

Union leaders saw the new team initiative as a way for the hourly employees to have more power and input into production decisions. The company saw it as a way to force accountability down to hourly workers and pull them into a mutually beneficial relationship instead of an adversarial one, as had been the history. In short, the change should have been a win-win agreement.

A Case of Miscommunication

After the agreement was made, some job-duty changes took place. The senior hourly employees from the old production division became the product specialists in the new division, managers from the old division filled the newly available senior management positions, and for the most part, people hired from outside the company became the new frontline supervisors to help avoid any preconceptions associated with the previous method of management. All product specialists and new supervisors were given extensive training on the team concept, and all new hourly employees were given extensive testing before being offered a job. This process of screening was known as 'best in class'. After employees were hired, they were then given an additional 40 hours of training. It was assumed that these practices would ensure the success of the new operating agreement, but one crucial element was overlooked: middle and upper management. They did not understand nor accept the new team concept. Most senior managers had spent their entire careers under the old regime and saw no incentive to accept the new system.

When the new supervisors started turning decisions over to the teams, they were belittled by their managers and dismissed as weak. The product specialists also had difficulty accepting the new method of operating and were often reluctant to make decisions. Ultimately, most of the original product specialists returned to the traditional operating system already established in the older production division.

The team leaders were members of the newly hired group, however, so the new system worked much more smoothly at the lower levels. Eventually, the demand for production increased, and a new shift and crew were added. Unfortunately, by the time the initial problems involving hiring, training, assigning and managing an entire new shift and crew had been resolved, annual manpower reductions were requested by corporate headquarters. Manpower reductions are losses in time authorization to build the product because of gains in operator efficiencies brought about by doing the same task repeatedly. That resulted in a reduction in the number of operations required to assemble the product, but not the number of employees at the facility. According to the new operating agreement, the teams were expected to take an active role in determining where work previously done at one work station would be moved, or combined with another operation. But, no hourly employees were to lose their jobs; once an operation was reduced, employees would be assigned to another position, or as extra manpower when others have days off. The union hierarchy, however, decided that in spite of the agreement, that "no union brother would help eliminate the job of another". This effectively put a halt to the original intent of the new process. Frontline supervisors did not have the support of their managers and the union forbade their ranks to participate. These contradictions between the new operating agreement and directives from the US plant prevented the team leaders from being successful. What had started out as a win-win situation was rapidly becoming a lose-lose situation.

Shortly after the turmoil caused by the annual manpower reductions had passed, the company introduced a new product line. Everyone had to be trained to build the new vehicles, but the new production managers—none of whom had training or experience in quality systems, the team concept or the new operating agreement—made the decision to eliminate the team trainers from each team as an additional manpower reduction. This change was made with the launch of the new product line, further eroding team autonomy. Now, each operator was skilled in his or her own job, but not of others. The team leaders and supervisors had to go to the department manager to make a case for additional training, though this was usually disallowed. Despite the problems, the launch was considered an enormous success and another shift and crew were added. Employee numbers rose from just under 2,000 to more than 6,000. In spite of the increase in the number of employees, the training system from the original launch was abandoned, and employees were given no training on the new operating agreement or in team concepts. Though not abandoned altogether, the teams were not functioning in the manner originally specified in the operating agreement.

What Went Wrong?

Ultimately, the change was not completely successful because upper management of both the company and union did not accept the change and communicate it to all levels of the organization. Therefore, culture has to change for a change initiative to be successful.

Review Questions

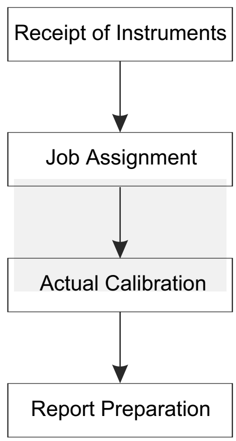
1. Summarize the moral of the case study.
2. What went wrong and what was a gap area for quality improvement?
3. How important is top-management leadership?

CASE STUDY 10

Business Process Reengineering

The Proficient Calibration Laboratory, Chennai, came to know from its customers that another laboratory located in another region elsewhere in the country was considered to be the *numero uno* in calibration services. This laboratory carries out calibrations of 2000 instruments per annum. The management of the Proficient Calibration Laboratory approached the other laboratory for help in benchmarking their processes. The chosen benchmarking partner immediately accepted their request and gave a time schedule to the employees of the Proficient Calibration Laboratory to plan a visit to their premises. The top management of the Proficient Calibration Laboratory formed a small benchmarking team and requested the team to find out the average time taken in each step in their laboratory and compare the results when they went onsite to the other laboratory for benchmarking.

The benchmarking team made a process flow chart for their organization which is given in below:



Then they calculated the average time taken in each step, based on their past data. They visited the benchmarking partner with this data and studied in detail how the calibration jobs were carried out there.

The team could get some data on the time taken at various steps of calibration by the benchmarking partner. A comparison of the times taken by the Proficient Calibration Laboratory and the benchmarking partner is given below:

Average Time Taken	*Proficient Calibration Laboratory*	*Benchmarking Partner*
Transfer of items from Customer Service department to Calibration department	3 days	2 hours
Typing of reports	7 days	same day
Time for actual calibration	3 days	1 day
Total cycle time	14 days	3 days

They observed the following in particular:

- Extensive automation
- Average time taken per job was between 3–4 days

- Absence of full-time typist
- Extensive standardization of work

The benchmarking team was quite surprised at the data and they returned to the laboratory with a determination to improve their services. They also realized that the gap between the performance of their organization and that of the leader was quite large.

The top management of Proficient Calibration Laboratory studied the data collected by the benchmarking team. It observed the following three weak areas in their laboratory:

- Undue time delay in sending the instrument received from the customer from Customer Service department to the Calibration department
- Too much time in typing of reports
- Time taken for actual calibration was also very high.

These three reasons contribute to high cycle time. The top management also came to the conclusion that incremental improvements would not improve the process and dramatic improvements were needed. Hence they realized that incremental improvement may not be the right approach in the current scenario. They approached a leading quality consultant for advice. The consultant also proposed that they should carry out business process reengineering and he could help them in the task. The results achieved by the leader served as a target. Under the guidance of the consultant, the Proficient Calibration Laboratory carried out business process reengineering. The following steps were taken, in particular:

- Investment was made in IT infrastructure.
- Job-handling mechanism in the Customer Service department was simplified.
- Standardization of procedures for calibration of each model was carried out.
- Employees were trained in calibration techniques, use of SPC tools and teamwork.

All these steps and assistance provided by the consultant improved the process dramatically. The Proficient Calibration Laboratory reported the following metrics at the end of the next year.

Average Time Taken	*Proficient Calibration Laboratory—Before BPR*	*After a year*
Transfer of items From Customer Service department to Calibration department	3 days	4 hours
Typing of reports	7 days	2 days
Time for actual calibration	3 days	1 day
Total cycle time	14 days	6 days

Review Questions

1. Do you think the approach taken by Proficient Calibration Laboratory was appropriate?
2. Was the benchmarking process in order?
3. What are the learning points in this case study?
4. What do you think is the next logical step?
5. Why did Proficient Calibration venture into BPR?
6. What factors do you think necessitated employing a consultant for carrying out BPR?

CASE STUDY 11

Use of the Taguchi Loss Function

According to four times Deming award winner Taguchi, 'loss to society' occurs when any of the following happen.

When a product's characteristics do not meet the

- customer's tolerances
- performance measures
- serviceability
- expected life, etc.

The above are not only the customers' losses, but of the society as a whole.

Often these characteristics are not clearly known nor clearly specified to the supplier due to various reasons such as

- Lack of awareness
- Lack of clarity in methods of measurement
- Delays at various stages leading to lack of time and resources for carrying out the measurements of the product/system characteristics

This study was undertaken with the cooperation of a manufacturer of temperature control devices to determine whether the concept of Taguchi's loss function could be applied to a specific product, and how the use of this cost function would compare with the 'conventional' method of estimating quality costs.

The 'conventional' method assumes that there are no 'losses' unless the product characteristic falls outside the customer's specified tolerances, whereas the Taguchi cost function assumes that there is a 'loss' (quality cost) whenever the product characteristics deviate even an iota from a stated target value.

A specific model temperature-control device was selected (one of a large family of such devices) for which the product history was available. This data included an average year's production of this device as well as the number of items returned by customers as not performing to warranty specifications, the average factory cost of manufacturing the product, and the average rework costs per unit for items rejected at final inspection.

Samplings of specific temperature measures were analyzed and found to be approximately normally distributed. The population mean and standard deviation were estimated, and using these estimates projections were made as to the expected number of devices to be reworked based on the manufacturer's acceptance sampling plan used at the final assembly stage.

The total expected annual in-house costs due to rework (not meeting customer tolerances) plus those of the expected costs of warranty returns as well as the expected cost of loss of customer goodwill for products not meeting specifications and not identified by the acceptance sampling plan were compared to the expected rework and return costs using the Taguchi cost function and his proposed production tolerance desired from his cost function.

It was found that by using the Taguchi quality tolerances (deviation from a target value), almost 98% of all products would be rejected in-house and subjected to rework. Almost no out-of-tolerance products would be shipped to the customer. The total expected annual cost thus incurred would vastly increase the cost of producing each unit over the procedure using the customer tolerances wherein no expected losses would occur unless the product exceeded the customer's specifications.

It was proposed that experiments be conducted to reduce the standard deviation of the temperature-control device since six standard deviations slightly exceeded the customer's tolerances. At this time, the company was actively considering such experiments.

Conclusion: Even though the exact form of the 'societal' loss function may never be known, it is possible to follow a simple step-by-step methodology to determine

1. Whether the product performance natural tolerance limits exceed or fall within the customer's tolerance
2. Whether a formal investigation of customer tolerances should be undertaken
3. Whether it would be economically feasible to conduct experiments to identify the significant causes of the natural variance of performance measures
4. Whether it is economically feasible to reduce those sources of variation

This study suggests that the use of the Taguchi loss function provides an excellent base to provide a manufacturer with facts to enable him to continue striving to meet the goal of continuing quality improvement while reducing the costs of providing the improved product.

Review Questions

1. What are the various concepts proposed by Taguchi?
2. List the steps involved in estimating losses to society.
3. Bring out the difference between quality costs and loss to society.
4. Under what circumstances is loss to society considered to occur.?

CASE STUDY 12

Reliability Testing

Most Plastic Encapsulated Microelectronics (PEM) type devices are manufactured for and sold to the high-volume computer, consumer electronics and telecommunications industries. Therefore, the devices are designed to provide the maximum reliability and performance in the environments associated with these industries, more specifically an operating temperature range of –40 to +85 degrees C.

Other industries, such as the automotive, aerospace, military, etc., which need high-rel parts to operate in temperature ranges beyond the standard, are forced to test the limits of commercially available devices. This is commonly known as "Uprating". Uprating a device typically includes checking all the electrical characteristics of the device over the intended operational temperature range and other environmental conditions, such as Relative Humidity (RH), radiation, various corrosive conditions, etc. It is a time-consuming and costly evaluation, but it is needed to ensure that the devices perform reliably within the intended use environment. Unfortunately, most manufactures of a device being uprated do not recommend, support, guarantee and even warn users against using the devices outside their recommended operating environments for legal and liability reasons. Therefore, most companies doing upratings are on their own and looking for guidelines. In their search for guidelines, they will take an industry standard, such as J-STD-020, and borrow portions of it for their evaluation, even though it does not directly apply. However, they need guidelines and at least it is a start. In one particular case, Company D needed to evaluate Company E's devices for an aerospace program that would expose the devices to environments outside the recommended ranges. Naturally, Company E was not willing to provide technical support for the project, so Company D hired an independent lab F to uprate the parts for them. Part of the evaluation involved exposing the parts to an 85% RH and 85 degrees C environment (which is popularly known as ‘pressure cooker’ test) for a period of time and performing various electrical and physical tests, including AM evaluation. Devices were sent to independent lab G from the Lab F for AM evaluation per J-STD-020. Without having any pre-exposure AM images available, the analysis was performed and Lab F was informed that the devices did not pass J-STD- 020 due to delaminations over the entire length of the leads, even though the leads were small. Both Company D and Lab F were concerned and a teleconference call to discuss the situation was requested.

Company D and Lab F were informed that J-STD-020 does not consider or establish any accept/reject criteria for delamination at initial/time zero inspection, which they understood, but they needed some guideline for their evaluations. In the review of the AM data, they were informed that the PEM device was a ‘dead bug’ configuration, meaning that the die was mounted on the bottom side of the device, which they were not aware of at the time. Since the leads were completely delaminated over both the bottom and top sides within some of the devices, the devices would not qualify per J-STD-020. However, they were not completely clear why this would cause a problem with reliability. For these particular devices, there were two potential problems associated with the lead delaminations. The most common is that it provided a direct path for moisture and contaminates from the outside environment to the interior of the device. The big concern was premature corrosive failure of the device. The second concern was that the crack or delamination could intersect a wire bond or wire bonding surface, which could cause premature failure of the wire or the interconnection. Since they did not have any knowledge of the internal configuration of the device, this type of failure mode could not be ruled out. They would now need to re-evaluate their uprating procedures and decide to either ignore the J-STD-020 test data, retest the parts at more favorable environmental conditions or design the final product so that it incorporated some sort of environmental protection for this particular device.

The following lessons were learned from this experience:

- The internal construction of a device needs to be known before any uprating tests of the device are started.
- If you plan to adapt and apply other standards within your uprating process, you need to specify what it will be evaluating and the consequences of that evaluation.

Review Questions

1. What do you understand by uprating?
2. Discuss the pros and cons of uprating.
3. What do you understand by the term ‘pressure cooker’ test?

CASE STUDY 13

Application of Control Chart

This case study pertains to a small industry in India, manufacturing pressure gauges. This industry supplies pressure gauges to a number of high-value customers like Indian Railways, air-conditioner manufacturers, etc. The pressure gauges manufactured by them are in great demand due to their accuracy and reliability. They specified an accuracy of Class 1, which means the maximum permissible error of the pressure gauge manufactured by them will be less than 1% of the full scale. Their customers were giving a feedback that the accuracy of the part supplied by them was better than what was claimed.

Then on, the company started expanding very rapidly for a number of years. Their focus was on growth while quality initiatives were at the bottom of the list due to the high demands of constant expansion. After

4–6 years of the growth focus, they noticed some alarming statistics about quality in their facility. The first -pass yield was very low on some of their lines. One of the lines in question had a first-pass yield of 75%. Since no control charts or capability studies had been done on these machines in over two years, they didn't know why the first pass yield was so low.

A *control chart* is a tool which one can use to monitor a process. It graphically depicts the average value and the upper and lower control limits (the highest and lowest values) of a process.

All processes have some form of variation. A control chart helps one to distinguish between normal and unusual variation in a process.

Variation can exist for two reasons:

1. **Common causes** are flaws inherent in the design of the process.
2. **Special causes** are variations from standards caused by employees or by unusual circumstances or events.

Most variations in processes are caused by flaws in the system or the process, not by the employees. Once you realize this, you can stop blaming the employees and start changing the systems and processes that cause the employees to make mistakes. (It is important to remember, however, that some variations are not 'mistakes' introduced by employees, but, rather, they are *innovations.* Some variations are deliberately introduced to processes by employees specifically because these variations are found to be more practical. To make a control chart, one has to determine the sampling method and plan:

- Choose the sample size (how many samples will you obtain?).
- Choose the frequency of sampling, depending on the process to be evaluated (months, days, years?).
- Make sure you get samples at random (don't always get data from the same person, on the same day of the week, etc.).

The industry we are discussing, decided to take five samples at random from every lot produced and check the error and note it down.

The control graph was divided into zones as given below:

________________________________ Upper Control Limit (UCL)

________________________________ Standard (average)

________________________________ Lower Control Limit (LCL)

They noted the following points for interpretation of the graph:

- If the data fluctuates within the UCL and LCL, it is the result of common causes within the process (flaws inherent in the process) and can only be affected if the system is improved or changed.
- If the data falls outside the limits, it is the result of special causes (in human-service organizations, special causes can include bad instruction, lack of training, ineffective processes, or inadequate support systems).
- These special causes must be eliminated before the control chart can be used as a monitoring tool; for example, staff may need better instruction or training, or processes may need to be improved, before the process is 'under control'. Once the process is 'under control', samples can be drawn at regular intervals to assure that the process does not fundamentally change.
- A process is said to be 'out of control' if one or more points falls outside the control limits.

- The Cpk value is calculated to know the capability of the process. It is calculated when the process is under control.

The first order of any business is, therefore, to determine a baseline for process capability. Therefore, the company decided to calculate Cpk values. The measured Cpk numbers were very low, all below 1.0. Very little information was kept for maintenance records so it was hard to determine why the machines were in their current state. After some research it was determined that some mechanical parts had been replaced over the two-year period and, due to the lack of jigs, not all the factory calibrations were done. So the machines were calibrated and the Cpk values were checked. The values were now on a range of 1.5–2.5. The first-pass yield for the next week were 89%—a 14% overall improvement. The calibration only took 45 minutes and would save $35,000–$60,000 a month if applied to all ten lines. This doesn't even take into account the soft saving of reduced maintenance time and production down time.

Review Questions

1. What is the learning point from this case study?
2. What is the reason that the company decided to carry out process-capability studies?
3. What benefit accrued to the organization because of this exercise?
4. Bring out the steps involved in calculating the Cpk value for any process.
5. How important is the calibration process?

CASE STUDY 14

QFD for the Development of a Heat-Activated Tape Product

The Indian Polymer Group began using QFD in late 1997. A team consisting of representatives from Purchasing, Marketing, Process Engineering, Research and Development, and Quality Assurance was formed to use QFD to develop a heat-activated tape product. An interview guide with questions designed to elicit performance and excitement needs was developed and visits to several customer sites were arranged. Two members of the QFD team, along with an IPG sales representative, participated in the customer interviews. The survey questions were posed to several employees at each facility and their answers recorded verbatim. Employees were also observed as they processed the product through their operation. Those observations were documented on the survey as well. After all of the interviews were conducted, the customer needs, in the customer's own words, were organized and consolidated by the QFD team via an affinity diagram. This process of grouping similar needs together helped in terms of organization; however, even more importantly, it gave the team members who did not participate in the interview a chance to better understand the customer needs.

The initial customer participants were then enlisted to complete a customer competitive survey and importance ranking of the identified needs. All of this information was subsequently entered on the House Of Quality (HOQ) chart along with other items that the team felt were important but had not been mentioned by the customer. These were grouped together under the 'design/tech' heading. The next step was the establishment of the company measures. The company measures were organized into groups and entered into the HOQ. In our project, the customer need of 'once activated, stays adhered' was measured by the lead pull force test. A technical competitive benchmark study was performed on competitive products and that data added to the chart. Any conflicts between the customer competitive survey and the engineering survey were discussed and resolved at this point.

Next, the team developed the relationship matrix between the customer needs and the chosen company measures. In some cases, there was a blank row or a blank column. A blank row meant that a customer need did not have a company measure associated with it. In those cases, a company measure or new test was developed. A blank column indicated that a company measure was in place that did not relate to a customer need. These tests were removed from the matrix. The team then developed the preliminary targets for the company measures. This was done based on an understanding of the competitive technical assessment results as related to the customer competitive assessment. In our specific case for example, a target for lead pull force was based on Competitor 2's test results since the customer rated Competitor 2 as superior for the need 'once activated, remains permanently adhered'. Once the target values were developed, the correlation matrix (roof) was developed to determine the relationship of the company measures to one another. The team evaluated each company measure (how) by asking 'if I optimize this 'how', does it help or hurt his 'how'. For our project, it was determined that optimizing lead pull force helped 'visual test after activation" but hurt "probe transfer at X°F'. The analysis of the roof leads to discussions about how to deal with conflicts. One option is to turn strong negative relationships into either strong positives, positives, neutrals, or at least negatives. These transformations are achieved by design or technology changes. Other options for dealing with roof conflict are to compromise by adjusting target values or ignore them. In our example, a compromise was achieved that was acceptable to the customer.

The final steps in the completion of the Phase 1 HOQ were determining the degree of organizational difficulty, and establishing the absolute and relative importance of each company measure. In our project, we found it would be difficult to achieve the target of 0 set for 'number of splices per roll', but relatively easy to achieve the target set for lead pull force. Thus, the corresponding entries for organizational difficulty reflect this. The absolute importance weights were calculated by multiplying the degree of the importance of a need to the customer by a value assigned to the strength of the relationship between the need and measure. This is best illustrated by an example. Looking at our chart, lead pull force has a medium relationship (3-point weight)to customer need of 'holds components without bridging' which has a 5-point weight of importance to the customer. 5 times 3 gives 15 points. Lead pull force also has a medium relationship (3-point weight) to 'good conformability around components' with a 5-point importance for another 15 points. Lead pull force is strongly related (9 points) to 'once activated, remains adhered' which has a 5-point weight of importance to the customer for another 45 points. Finally, lead pull force has a weak (1-point) relationship to "holds components in place without burst through" which also has a high (5) customer importance ranking. This results in an additional 5 points for a grand total of 80 (15 + 15 + 45 + 5) for absolute importance. From the absolute importance, a relative importance can be calculated.

The importance ranking, in conjunction with other criteria, is used to determine which company measures should be deployed to Phase 2. In addition to highly ranked items, some of the other items to consider for further deployment include things that can be used as sales points, things that are new and different, things that are difficult to achieve (means that it is also difficult for the competition), things that will improve competitive position, things related to previous complaints, and in some cases, the team's gut instinct. For the QFD project, Phase 2 and Phase 3 were combined into one as both material and process characteristics directly influence the end-product characteristics. The choice to combine phases is project or process dependent. The first step in our combined Phase2/3 was to enter the Phase 1 'hows' (company measures which were chosen based on factors described above), their targets, and importance ranking from Phase 1 into the second HOQ. These now become, instead of customer requirements, design requirements. At this point, the R&D team began the design work with the customer needs and established requirements foremost in their minds. The team used *Design of Experiment* to determine the best combination of ingredients and process conditions to achieve the objectives on the HOQ. Once the material and process parameters were optimized, the ‘how’ section and the corresponding target values, and a measure of manufacturing difficulty were completed for the second house. The relationship matrix was completed in the same manner as the first house with the question being ‘if I control this process or ingredient parameter, how will it impact or satisfy the design requirement?’ In our case, the control of several process and ingredient characteristics, such as coating weight, resin type, and resin level, was found to strongly impact the design criteria for lead pull force. The chart was analyzed for blank rows or blank columns to make sure all of the design requirements had a corresponding ingredient/process characteristic and that all of the ingredient/process characteristics were related to a design requirement. The team also performed a reality check to confirm that the ingredients and process characteristics were measurable and controllable.

Phase 4 of QFD is production planning. This is the step that translates the initial customer requirements to the shop floor, quality assurance, maintenance and other departmental work instructions. After the importance analysis of the Phase2/3 chart is complete, the selected ingredient/process characteristics, along with their target values, are entered into a fourth chart. The team then determines the systems, procedures, instructions, training, and control mechanisms that need to be put in place to ensure that the specified ingredient/process characteristics will be met. These are entered on the fourth chart. Phase 4 deployment will vary depending on specific company practices and systems; however, the goal of ensuring that the voice of the customer is carried through to the operating personnel is the same for every company. In our example, coating weight, which related to lead pull force, was carried to Phase 4 and specific production requirements put in place. The appropriate process-control instructions for the online weight control monitor were established, the troubleshooting guidelines updated, and a calibration schedule established. If a QFD project is done correctly, each control mechanism put in place in Phase 4 will be easily traceable back to an original customer requirement found in Phase 1. In this case, a specific calibration requirement can be traced back to the customer’s spoken need (‘once activated, remains permanently adhered’) which was discovered during initial interviews.

Review Questions

1. What is the purpose of QFD?
2. Describe the various phases of building House of Quality (HOQ).
3. What other tools were used to construct HOQ.
4. Do you see the use of cross functional team for QFD in this case study?

CASE STUDY 15

Application of Quality Circles by Public Sector Organization in a Leading Hospital

This case study documents the planning, implementation, and the results of the energy conservation initiative implemented by Maharashtra Public Works Department (MPWD) at the Sir Jamshedji Jeejeebhoy Hospital (Sir J J Hospital) in Mumbai. Sir J J Hospital is one of the oldest and the largest hospitals in South-East Asia. This 1,352-bed hospital was established by Sir Jamshedji Jeejeebhoy almost 150 years ago and occupies an area of 65 acres in the heart of Mumbai. The hospital functions on a 24 × 7 basis and operation theatres, high-end medical equipment, lighting, HVAC systems, water heaters, elevators, and water pumps account for more than 75% of the energy consumption.

Maharashtra Public Works Department, responsible for the operation and maintenance (O&M) of the hospital campus, implemented an Awareness Campaign to reduce energy consumption throughout the hospital campus. The primary problem identified by the MPWD staff was a lack of awareness among hospital employees resulting in wastage of electricity. In addition, inefficiency due to deferred maintenance and replacement, sub-optimal operating schedules (equipment left on when not needed), and reduced emphasis on the importance of O&M led to excessive energy consumption. The situation called for drastic measures when the local electric authority, Brihanmumbai Electricity Supply and Transport Undertaking (BEST), issued a warning to disconnect the power supply as a result of unpaid energy bills.

PLANNING THE EFFORT

The Quality-Circle Concept

An innovative concept developed in Japan after World War II provided the framework to organize and plan the effort. Adopted initially by the manufacturing sector in India, each quality circle is a small group of 6 to 12 employees from similar work groups who meet on a regular basis to identify improvements in their respective work areas. Using established and proven techniques for problem solving in issues related to work quality, production and human efficiency, sustained excellence within the group as well as within the organization is achieved by the quality circle team.

Initial Impetus

The project got underway in response to the Prime Minister of India’s nationwide appeal in 2001 to all states to adopt and implement energy-conservation measures. A quality circle project team comprising of eleven members implemented the initiative. MPWD took the lead role in adopting and implementing the concept of quality circle for this energy-conservation awareness project. The Sir J J Hospital project team adopted a multi-faceted energy conservation strategy identifying effective methods and techniques to improve energy efficiency and reduce wastage. Consisting of members from different levels of the organization, the quality circle met every week to discuss issues and problems related to energy usage and efficiency. The team conducted several brainstorming sessions raising issues related to energy wastage and working together to find solutions. The goal was to devise ‘no- or low-cost’ methods to improve energy efficiency and conserve energy through education of the users through campaigns and posters. While the communication tools were targeted toward the end users, the project team made a very important decision during the planning stage to coordinate these educational and outreach activities by taking into confidence the management staff at each department. Further, the team conducted several brainstorming sessions using the Ishikawa (also known as fishbone) tool to assign responsibilities and delegate work to team members. The tool helped in the planning and subsequent execution by providing a framework to conduct a cause-and-effect analysis identifying the factors responsible for energy use and developing an effective strategy to use energy efficiently and minimize energy wastage at the Sir J J Hospital complex.

Design and Implementation

The primary challenge that the project team faced from the outset was in educating the primary users of the facilities and in creating awareness among hospital staff on the benefits of energy conservation and energy efficiency. The team overcame this challenge by interacting with the management staff, doctors, nurses, and students through direct interaction and through communication tools to reinforce the benefits of energy conservation on a continuous basis. The low- and no-cost O&M measures implemented to achieve effective solutions to minimize energy wastage and maximize savings are listed below:

- Catchy campaigns that made use of easy-to-remember slogans
- Use of various communication tools such as posters at strategic locations to inform staff of the steps that could be taken to conserve energy and minimize wastage

Although conserving energy by creating awareness was the main objective of the project, the following low- and no-cost measures were also implemented by the O&M staff at the hospital:

- Maximizing usage of natural light during the day through passages and corridors
- Turning off office equipment, fans and air conditioners during unoccupied hours
- Educating people about reasonable and efficient usage of water heaters and other electrical appliances
- Plugging air leakages in air-conditioned rooms such as office spaces, operation theatre
- Turning off water pumps when the tanks filled up

Through these efforts, a more responsible attitude towards the environment was cultivated among the hospital staff leading to substantial energy savings with little investment. To make these behavioral changes permanent, hospital staff was reminded about the benefits of energy conservation through the use of posters. Quality checks and analyses included use of checklists and other performance enhancement tools to record the electricity costs over the period and analyze the data to evaluate the performance of the project.

PERFORMANCE EVALUATION AND RESULTS

Energy Savings

There was a concerted effort to evaluate the performance of the team from time to time. Moreover, the project team also quantified the electricity reduction resulting from the awareness campaign by using metered electricity data from the buildings during 2001–2004. The simple energy-saving calculation and analysis was done by collecting metered monthly electricity consumption data and comparing it with the data for the corresponding month of the preceding year. Although a preliminarily energy audit was performed for the entire hospital campus at the time the project started, no intervention measures have been implemented that would lead to reduction in electricity consumption. During the period of 2001–2004, the electricity tariff structure has remained the same.

Fiscal Year	*Energy Savings (kWh)*	*Cost Savings (million Rs.)*
FY2002	473,000	2.13
FY2003	229,000	0.73
FY2004	110,000	0.99

Review Questions

1. What are the lessons learned in this case study?
2. What factors do you think contributed to the success of the project?
3. How is the case study related to TQM?
4. Why do you think that the energy savings are going down year after year?
5. Can you identify the multi-pronged initiative taken in this case study to achieve the objective?

Chapter 1

I.
1. b
2. d
3. e
4. d
5. c

II.
1. True
2. True
3. True
4. True
5. True
6. True
7. False
8. False
9. False
10. False
11. False
12. True
13. False
14. True
15. True
16. True
17. True
18. True
19. False

Chapter 2

I.
1. d
2. e
3. c

II.
1. True
2. True
3. False
4. False
5. True
6. False
7. True
8. True
9. True

Chapter 3

I.
1. d
2. d
3. c
4. a
5. c
6. b
7. d
8. d
9. c
10. a
11. c
12. e
13. a

II.
1. True
2. False
3. True
4. False
5. True
6. True
7. True

1. False
2. False
3. True
4. False
5. False
6. True
7. True
8. False
9. True
10. True
11. True
12. True
13. False
14. False
15. False
16. False
17. False
18. True
19. False
20. False
21. False
22. True
23. False
24. False
25. False
26. True

Chapter 4

I.
1. c
2. a
3. d
4. a
5. b

II.
1. True
2. False
3. True
4. False
5. True
6. False
7. False
8. False
9. True
10. True
11. True
12. False
13. True
14. False
15. False
16. False
17. False
18. False
19. False
20. True
21. True

III.
1. 3
2. 1
3. 4
4. 2
5. 5

Chapter 5

I.
1. b
2. d
3. d
4. c
5. a
6. c
7. c
8. c
9. c
10. c
11. d
12. c
13. b
14. d

II.
1. True
2. True
3. True
4. True
5. True
6. True
7. False
8. False
9. False
10. False
11. False
12. False
13. True
14. False
15. True
16. False
17. False
18. True
19. True
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35. False
36. False
37. False
38. False
39. True
40. True
41. False
42. True
43. True
44. True

Chapter 6

I.

1. d
2. d
3. d
4. d
5. b
6. d
7. d
8. b
9. a
10. d
11. d
12. d
13. b
14. d
15. d

II.

1. False
2. False
3. False
4. False
5. True
6. True
7. True
8. True
9. False
10. False
11. True
12. False
13. True
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37. True
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39. True
40. False
41. False
42. False
43. False
44. True
45. True
46. False
47. False

Chapter 7

I.

1. d
2. c
3. c
4. c
5. d
6. d
7. d
8. d
9. d
10. d
11. c
12. a
13. d
14. d
15. d

II.

1. True
2. False
3. False
4. True
5. False
6. True
7. True
8. True
9. False
10. False
11. True
12. True
13. True
14. True
15. True
16. True
17. False
18. True
19. True
20. True
21. True
22. False
23. True
24. True
25. True
26. False
27. True
28. True
29. True
30. True
31. True
32. False
33. False
34. True
35. False
36. True
37. True
38. True
39. True
40. True
41. True
42. True

IV.

1. 4
2. 5
3. 6
4. 1
5. 2
6. 3

Chapter 8

I.

1. a
2. b
3. c
4. c
5. a
6. a
7. d
8. d
9. c
10. d

II.

1. False
2. False
3. True
4. True
5. True
6. False
7. True
8. False
9. True
10. True
11. False

IV.

1. 5
2. 4
3. 1
4. 3
5. 2

Chapter 9

I.

1. d
2. c
3. c
4. b
5. c

II.

1. True
2. True
3. False
4. False
5. True
6. True
7. False
8. False
9. False
10. True
11. False

Chapter 10

I.

1. d
2. d
3. a
4. d
5. d

II.

1. True

2. True
3. False
4. True
5. True
6. False
7. False
8. False
9. False
10. True
11. True
12. True

Chapter 11

I.

1. c
2. d
3. a
4. b
5. d
6. c
7. a
8. b
9. c
10. c
11. a
12. d
13. c

II.

1. True
2. False
3. False
4. True
5. True
6. False
7. True
8. False
9. True
10. False
11. True
12. True
13. False
14. False
15. False
16. False
17. False
18. True
19. True
20. False
21. True
22. False

III.

1.

1. 4
2. 5
3. 1
4. 2
5. 3

2.

1. 5
2. 4
3. 3
4. 2
5. 1

Chapter 12

I.

1. b
2. b
3. c
4. d
5. b
6. b
7. a
8. b
9. b
10. c
11. a
12. c
13. b
14. a
15. a
16. c

II.

1. False
2. False
3. False
4. False
5. True
6. True
7. False
8. False
9. False

III.

1. 5
2. 1
3. 3
4. 2
5. 6
6. 4

Chapter 13

I.

1. d
2. b
3. d
4. d
5. d

II.

1. False
2. True
3. True
4. True
5. False
6. True
7. False
8. False
9. True
10. True
11. True
12. False
13. True
14. False
15. True
16. True

IV.

1. 4
2. 1
3. 2
4. 3

Chapter 14

I.

1. d
2. d
3. d
4. d
5. d

II.

1. False
2. True
3. False
4. False
5. True
6. True
7. False
8. True
9. True
10. False

Chapter 15

I.

1. b
2. d
3. d
4. b
5. d

II.

1. True
2. False
3. True
4. False
5. True
6. False
7. False
8. True
9. False
10. False
11. True
12. False
13. True
14. True
15. True

III.

1. 3
2. 5
3. 1
4. 2
5. 4

Chapter 16

I.

1. d
2. d
3. a
4. d
5. d
6. c
7. c
8. a

II.
1. True
2. True
3. True
4. True
5. True
6. True
7. True
8. True
9. False
10. False

Chapter 17

I.
1. a
2. c
3. b
4. b
5. a

II.
1. False
2. False
3. True
4. True
5. False
6. True
7. False
8. True
9. True
10. True
11. True

Chapter 18

I.
1. c
2. d
3. c
4. d
5. d

II.
1. False
2. True
3. True
4. True
5. True
6. True
7. True
8. True
9. False
10. True
11. False
12. False
13. True
14. True
15. True
16. False

III.
1. 6
2. 4
3. 1
4. 3
5. 5
6. 2

Chapter 19

I.
1. d
2. a
3. d
4. d
5. c
6. d

II.
1. True
2. True
3. False
4. False
5. False
6. False
7. True
8. True
9. False
10. True
11. True
12. False

Chapter 20

I.
1. c
2. d
3. d
4. d
5. a
6. c
7. d
8. d

II.
1. False
2. False
3. True
4. False
5. False
6. False
7. True
8. False
9. True
10. True
11. True
12. True
13. True
14. True
15. True
16. False
17. True
18. False
19. False
20. True
21. True
22. True

III.

1.
1. 3
2. 4
3. 5
4. 1
5. 2

2.
1. 2
2. 3
3. 4
4. 5
5. 1

Chapter 21

I.
1. c
2. d
3. d
4. d
5. a

II.
1. True
2. True
3. True
4. True
5. True
6. False
7. True
8. True
9. True
10. True
11. False
12. False
13. True
14. True

IV.
1. 5
2. 4
3. 2
4. 6
5. 3
6. 1

Chapter 22

I.
1. c
2. b
3. c
4. d

II.
1. False
2. False
3. True
4. True
5. True
6. True
7. False
8. True
9. True
10. False

IV.
1. 4
2. 1
3. 5
4. 2
5. 3