

QUALITY ASSURANCE IN CONSTRUCTION



A dissertation submitted in partial fulfillment of
the requirement for the degree of



MASTER OF SCIENCE
IN
CONSTRUCTION ENGINEERING

by

KHALID . ALSHAFEI

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September 1990

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*"Quality is never an accident. It is always the
result of high intention; sincere effort, intelligent
direction, and skillfull execution.
It represents the wise choice of many alternatives."*

ABSTRACT

This dissertation deals with the terminology and elements of Quality Assurance and discusses the relevance of quality assurance to construction. Then follows information on the standards for quality systems and the schemes which are operational or being developed. Guidance is given on developing and implementing a quality system and various aspects of the application of quality assurance to construction are discussed. The report concludes that quality assurance in construction is essential and worth the costs.

This dissertation is not a comprehensive treatise on quality assurance. Those experienced in the theory and practice may find the detail and terminology oversimplified. Nevertheless, it is believed that the dissertation will enlighten those with less knowledge of quality assurance and encourage informed debate on its application to construction.

ACKNOWLEDGEMENT

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ABBREVIATIONS

QA	Quality Assurance
QC	Quality Control
BS	British Standards
BSI	British Standards Institution
UK	United Kingdom
NACCB	National Accreditation Council of Certification Bodies
ISO	International Organisation for Standardization
ASCE	American Society of Civil Engineers
BCSA	British Construction Steelwork Association
FCEC	Federation of Civil Engineering Contractors
NEDO	National Economic Development Office

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CHAPTER 1



JOHN Q. QUALITY

John Q. Quality is the silent partner who is always with us when we are at our best. He isn't really a person or a thing. He's kind of a state of mind ... an ideal ... part of each one of us. A terribly important part.

INTRODUCTION

1.1 GENERAL

The 'industrial revolution' took place in the last century. Perhaps the 'computer revolution' happened in the early 1980's, but we are now, without doubt, in the midst of the 'quality revolution' a period of change affecting every type of business, enterprise, organisation and person.

In any competitive economy, cost reduction and quality improvement are essential if an organization is to stay in operation. Competitiveness is measured by three things: quality, price and delivery. In today's business climate the pursuit of quality must be recognized as one of the most important objectives of any enterprise. Quality is a prime determinant of competitiveness in contract award, relationships and overall profitability.

Many organisations have realized that quality assurance is the new way of managing for the future, it is a way of managing the whole business or organisation to ensure complete customer satisfaction.

1.2 BACKGROUND

Attainment of acceptable levels of quality in the construction industry has long been a problem. Great expenditures of time, money and resources, both human and material are wasted each year because of inefficient or non-existent control procedures. The manufacturing industry has developed a quality assurance concept, first applied in

Japan and in recent years used in the United States, Western Europe and the UK.

What is Quality Assurance?

Despite the name, it is not a system for guaranteeing the quality of products and services; QA is the name given to a management philosophy which leads to improved quality and based on the concept that 'prevention is better than cure'. The concept has produced many positive effects including increased productivity, decreased product cost and high levels of product reliability. See Section 2.1 for full definition of this concept.

1.3 FAILURE IN THE CONSTRUCTION INDUSTRY

Some of the most significant failures of the last twenty years have been: the Kansas City Hyatt Regency; the Ferry Bridge 'C' Power Station Cooling towers in the UK; the Silver Bridge over the Ohio River; Ramp C of the Riley Road Interchange in East Chicago. These occurred because of design mistakes, bad details, construction errors or lack of adequate inspection and maintenance programmes.

Judging what stands constructed today, we know how to design, we understand the materials being used. We know how to build the structure we design, as well as how to inspect and maintain them. Why, then these occasional failures? The answer is simple. Poor quality of design, construction, inspection and maintenance in the original buildings is highlighted in our aging and deteriorating structures well enough.

These catastrophic failures were a consequence of misunderstood responsibilities, unclear communication and the lack of supervisory control and feedback, rather than mistakes in judgement.

One very positive approach, therefore, would be to implement a detailed quality assurance programme early in the project.

1.4 THE NEED OF QA IN CONSTRUCTION

The causes of poor quality are numerous and can run all through the engineering process from siting and investigation, through design and specification, contract and construction management.

Civil Engineering projects involve a number of organisations, disciplines, skills and people of widely ranging experience and background. This promotes communication problems. The existing system of contracts, drawings, specifications, method statement, etc, seeks to overcome these problems by the precision and (relative) permanence of printed or written documents. But, in general, the system is of one-way communication with little or no feedback from construction or design.

Quality assurance aims to reinforce the existing significant interfaces and to ensure that consultation (two way communication) has been carried out in a structured system.

Construction utilising quality assurance principles require an additional investment of time before construction begins. This investment is paid back by the reduction of delays during the construction phase when the rate of expenditure is, perhaps, an order greater and a better final product, cooperation and confidence are generated because communication is precise and responsibilities are clearly defined.

1.5 RESULTS OF IMPLEMENTING QA SYSTEM

A large proportion of construction defects are a result of shortcomings of management, either on the part of the client or the designer or of the builder. Whatever the origin, the costs are substantial and include expenditure on repairs, replacement materials, delays, compensation to clients, litigation and so on. There is also the sheer waste of management time which could be more profitably spent on useful work. These costs are not inevitable. Defects arising from inadequate management can be prevented.

Quality assurance systems bring a rational approach to reducing the costs of defective work and can provide confidence and assurance to all the parties involved that their buildings, and their future are secure. Implementation of QA will result in higher quality, lower cost and increased productivity in the construction industry and the most important is that "all parties sleep better" since the owner is assured of a well-constructed project.

Quality in construction is too important to be left to chance. To achieve quality, the variables which may affect quality and which can result from the actions of men, the nature of materials, and the performance of machines must be controlled. Quality has to be managed - it does not just happen. Understanding and commitment by senior management, effective leadership and teamwork are fundamental parts of the recipe for success.

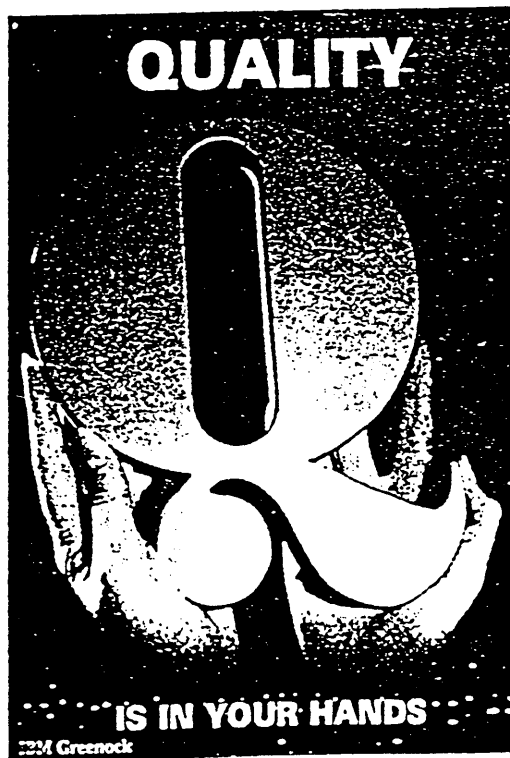
It is the writer's firm opinion that quality assurance is a medicine which will work for everybody and its success is guaranteed "but only if the patient takes it as prescribed."

1.6 PURPOSE OF DISSERTATION

This dissertation is designed to identify the essential and desirable elements of quality function in construction and explain what can be done to manage them effectively. It features modern organisational concepts, new participative resolutions and prevention of quality problems.

Excellence in construction is achieved through a team effort of the owner, engineer, contractor, construction manager, inspectors, testing firms, site staff and technical consultants as they are involved in the project. The intent of this dissertation is to acquaint the owner with his responsibilities and with those of his project team in executing a quality assurance programme. The dissertation offers general and specific definitions of critical words and phrases and also emphasizes and stresses the importance of concepts and practices that improve quality in construction projects.

CHAPTER 2



UNDERSTANDING QUALITY

2.1 DEFINITIONS

2.1.1 Quality

Quality is a term that is easily misunderstood. In everyday language its synonyms range from luxury and merit to excellence and value. Different companies also appear to mean different things when they use the word, even to different groups within the same firm. Without further refinement, continued ambiguity and confusion are inevitable. A better understanding of the term is therefore essential.

If we are to define quality in a way which is useful in its management, then we must recognize the need to include in the assessment of quality, the true requirements of the customer.

Quality then, is simply consistently meeting the requirements of the customer and this has been expressed in many ways by different authors:

'fitness for purpose or use' Juran

'the totality of features and characteristics of a product or service, that being on its ability to satisfy stated or implied needs.' BS 4778

'The total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectation of the customer.' Feigenbaum.

Designers have often used a 'fitness for use' definition for quality. By contrast, a "quality is conformance to established requirements" definition is more appropriate for the construction phase project. The requirements may include availability, delivery, reliability, maintainability and cost effectiveness. If the defined requirements

are met, quality has been achieved. This definition is unambiguous and measurable provided the requirements are clearly specified.

2.1.2 Quality Assurance and Quality Control

When quality assurance is introduced, people sometimes have difficulty in understanding what it is and how it differs from quality control and inspection. The following explanation may help:

Inspection is the examination or measurement carried out during construction to check that the contract requirements are met, it provides a measure of how well the job is being done, but on its own inspection does not prevent mistakes, merely identifies them, nor does it guarantee that the job is done correctly.

Quality control is the activities and techniques employed to achieve and maintain the quality of a product or service. It involves a monitoring activity.

'... to worry whoever thought up the term "quality control" thought if we didn't control it, it would get out of hand'.

Jane Wagner (1987)

It is not really quality that gets out of hand, it is the absence of quality that creates problems and quality control is only part of the solution. Quality control is a system of checking any defects before the product goes out of the door. Quality cannot be attained through quality control inspection methods alone but from improvement of the process.

Whereas quality control is designed to catch defects, quality assurance is designed to prevent them. Defect prevention in a project is not the purview of a reviewer, but of every project participant.

Quality assurance is more comprehensive than quality control. Quality assurance is a systematic way of guaranteeing that organized activities happen in the way they are planned. It is a management discipline concerned with preventing problems from occurring by

creating the attitudes and control that make prevention possible. An airline pilot running through his pre-flight checks is an excellent example of quality assurance. Quality assurance is a way of life; it is concerned with changing attitudes and skills so that the culture of the organisation becomes one of preventing failure and the norm is operating right first time and every time.

It doesn't make any difference how sophisticated we get with measurement, or how sophisticated we get measuring the fact that we are drowning, we still drown. Quality control is just the measurement of drowning people, it is not preventing people from drowning.

Quality assurance is not just a matter of super quality control, it is an entirely different thing. It is based on prevention rather than containment.

The concept of quality control is that we cannot get things right first time. It is statistically impossible. We have to learn how to contain it to an acceptable quality level. If we do something wrong for years, the perception is that maybe we ought to look at something else, so we have to learn how to do something right instead of let's learn how to contain how much wrong there is.

The emphasis, therefore, changes from defect detection to defect prevention.

Quality assurance must be applied across the board, encompassing planning (planning what we want); designing (designing what we planned for); specifying (specifying what we design); constructing (producing and building what we specify); inspection, sampling, and testing (evaluating the product to see if we are buying what we specified); maintaining (maintaining what we build to provide optimum performance); and monitoring (analysing performance of what was constructed and feeding this information back into the system). Reduced to its simplest terms, quality assurance requires proper answers to the following five questions:

1. What do we want?

2. How do we order it?
3. How do we determine that we got what we ordered?
4. What do we do if we don't get what we ordered?
5. If there is a fault how do we ensure that the fault doesn't happen again.

In short, quality assurance involves the criteria and overall methodology, while quality control involves the specific control procedures and test programmes.

2.2 EVOLUTION OF QUALITY ASSURANCE

The evolution of quality assurance concept can effectively be traced by studying its development in the manufacturing industry, which parallels that of the construction industry. There is extensive documentation on quality assurance in the manufacturing of various construction materials. Some articles give broader treatment to comprehensive quality programmes in specialized areas such as the nuclear power industry. However, general trends in the evolution of quality assurance are much more extensively documented for the manufacturing industry than for the construction industry. (See Fig. 2.1)

There have been five stages in the evolution of quality assurance

1. Craftsman quality control was inherent in manufacturing up to the end of the nineteenth century. During that time, one craftsman, or at least, a very small number of craftsmen, were responsible for the manufacture of a complete product, and each craftsman exclusively controlled the quality of his work.
2. Foreman quality control occurred during the industrial revolution when the large-scale modern factory concept developed. During this stage, many craftsmen performing similar tasks were grouped together and supervised by a

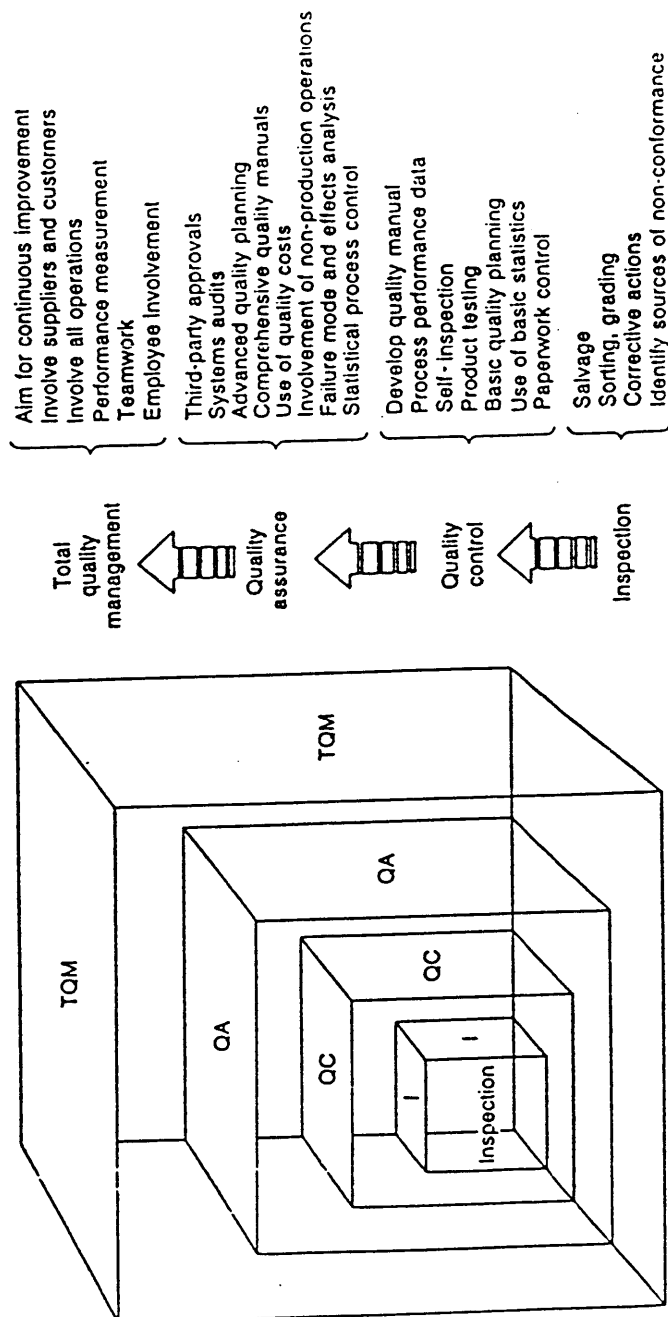


Fig. 2.1 Evolution of Quality Management

foreman, who then assumed responsibility for the quality of their work.

3. Inspection quality control evolved during World War I when the manufacturing system became more complex. Because a large number of craftsmen reported to each production foreman, full-time inspectors were required.
4. Statistical quality control flourished during World War II when tremendous mass production was necessary. In effect, this step was refinement of the inspection step and resulted in making the large inspection organisations more efficient.
5. Quality assurance evolved in the early 1960's. A dramatic increase in user quality requirements resulted in increasing customer demand for higher quality products, leading the manufacturer to recognise the inadequacy of existing in-plant quality practices and techniques. These all contributed to excessive quality cost due to such items as inspection, testing, laboratory checks, scrapping and reworking imperfect products, and customer dissatisfaction. Statistical quality control could never meet the challenge. Thus a totally new concept was developed based upon the principle that in order to provide genuine effectiveness, control must start with the design of the product and end only when the product has been placed in the hands of a customer who remains satisfied.

2.3 QUALITY ASSURANCE AND THE CONSTRUCTION INDUSTRY

While the evolution of quality assurance in construction is parallel to that of the manufacturing industry, many dissimilar characteristics distinguish the two industries. These differences, some of them significant, must be considered when applying a manufacturing quality assurance programme to construction:

1. Almost all construction projects are unique. They are single-order, single-production products.

2. Unlike other industries, which usually have a fixed site with similar conditions for production, construction production sites have no fixed/controlled environment.
3. The life-cycles of construction projects are much longer than in any other production industry, so that projects evolve according to time and circumstances throughout the life-cycle.
4. Since construction projects are a single-order design product, the owner usually directly influences the production.
5. The project participants: the owner, designer, contractor, material supplier, etc. differ for each project.

Because of these distinguishing characteristics, it has generally been considered that quality assurance procedures that work effectively in a mass production industry are not considered suitable for the construction industry. It is only in the past few years that some major contractors have begun to recognize and adapt to construction the quality assurance principles that have been employed successfully in manufacturing.

The traditional approach to quality control in the construction industry is inadequate. The time has come to adopt the quality assurance principle used successfully in the manufacturing sector to meet the need in the construction industry.

Fig. 2.2 represents a typical traditional construction project quality control flow chart. This process results in the following trends:

1. Quality is designed into and evaluated for each individual project each time. There is no comprehensive quality policy employed to establish quality assurance for the entire industry.
2. No feedback system exists for re-examining quality control work.

3. As a result, it is difficult to establish a data collection system to build on an information base that could lead to early identification of defects.
4. No system exists to manage quality throughout the design/construction process. While a "construction management" block appears in Fig. 2.2, it is only the execution of the construction plan and does not contain a quality assurance component.

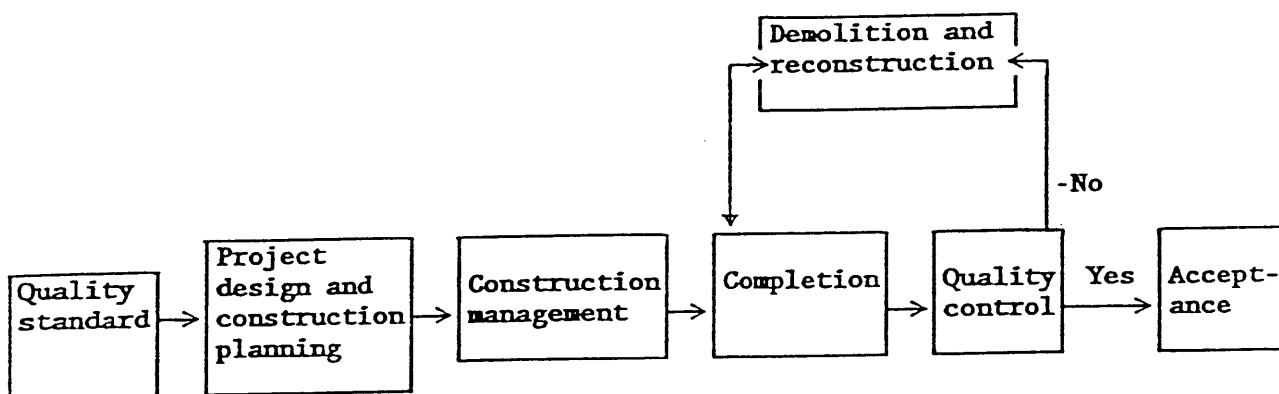


Fig. 2.2 - Typical Construction Project Quality Control Flow Chart

A quality assurance chart (see Fig. 2.3) demonstrates the following characteristics for a properly organized quality assurance programme in the construction industry.

1. The quality assurance standard is derived from a current data base created through feedback from previous projects, providing a more uniform and comprehensive standard.
2. Design and planning, construction and evaluation phases are integrated through the quality assurance system.
3. Defects are identified and corrected early.
4. Feedback expands the quality data base to eliminate repetition of the identified defects.

Feedback

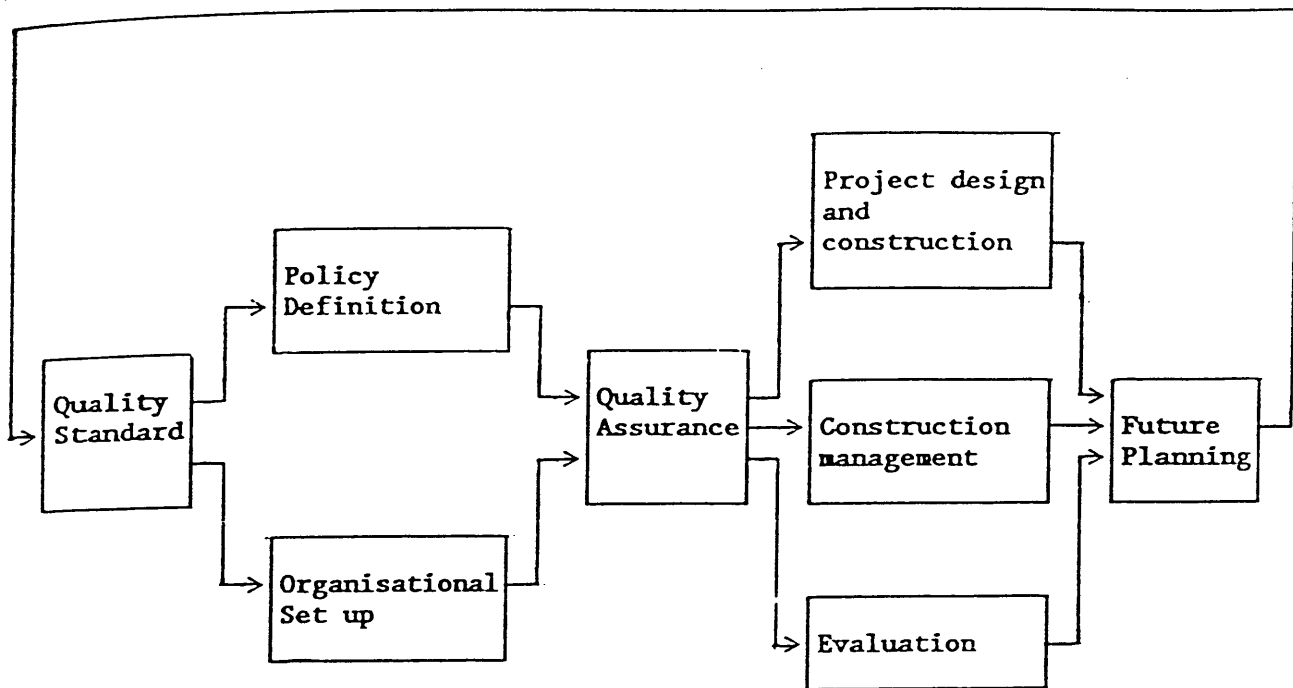


Fig. 2.3 Quality Assurance Flow Chart

Information analysis, standardization and statistical approach, all have been utilized separately in the traditional construction project. Effective unification of these activities through the concept of quality assurance is essential to improving quality.

2.4 BASIC PRINCIPLES OF QUALITY ASSURANCE

1. Involvement

Quality is not the responsibility of any one person or department, it is everyone's job. We may have procedures and systems in place. We may have manager commitment, but still, the message is not getting across - quality involves everyone. Only by involving everyone in a practical way can we start to change people's attitudes and really see the benefits of improving quality throughout the Organisation. People are the source of ideas and innovation and their expertise, experience, knowledge, and co-operation have to be harnessed to get

those ideas implemented. After all, the company is only as good as the people in it.

2. Commitment

Within each and every department of the Company, basic changes of attitudes will be required to operate quality assurance programmes. The owners and directors of the organisation should recognize and accept the responsibilities of initiation and operation of Quality Assurance for the necessary changes to take place. Controls and techniques are important in Quality Assurance, but they are not the primary requirement. It is more an attitude of mind based on pride in the job, and requiring total commitment from the top, which must then be communicated to all the employees at all levels and in all departments.

3. The 'Right First Time' Concept

Instead of the 'it shall not pass' philosophy of the historical inspection activity, the theme of quality assurance is, 'make it right the first time'

What is the 'Right first time' philosophy?

- a. An understanding that it is always cheaper to do it right the first time.
- b. A commitment that every job will be organized and planned with a goal of no errors.
- c. A recognition that the majority of defects and errors are caused by management.
- d. A belief that every error has a cause which can be identified and eliminated.
- e. Planned and measurable improvement towards a goal of error-free performance.

- f. Quality assurance is a journey not a destination that is, 'Make it right the first time, every time.'

4. Communication

If Quality Assurance is to succeed in any organization it is important for all managers, supervisors and staff to recognize the value and influence of good communication as a vital link in creating and maintaining standards of quality.

Failure to communicate effectively creates unnecessary problems, resulting in confusion, loss of interest and eventually in declining quality through apparent lack of guidance and stimulus.

2.5 COST OF QUALITY

In many companies, scrap, rework and similar quality failure costs, absorb a vast amount of money, thereby seriously reducing the profitability and sometimes even the viability of a concern. Quality costs spread into almost every activity, and hence there are many opportunities for improvement. Quality Assurance costs little to operate, compared with the considerable savings achieved, improved reputation and greater market share.

Quality cost and productivity are usually interrelated. Quality is raised and costs are lowered, while at the same time, productivity is enhanced.

CHAPTER 3



Are your records preventing prevention?

SYSTEM FOR QUALITY

3.1 INTRODUCTION

Definition

A quality system may be defined as an organisational structure of responsibilities, activities, resources and events that together provide procedures and methods of implementation to ensure the capability of an organisation to meet quality requirements.

Quality systems concentrate on prevention, looking at the process, identifying the opportunities for error and taking action to eliminate them. The concept of quality assurance systems could be depicted as an umbrella which protects the organisation from the rain of problems which could descend upon it. Fig. 3.1 shows such a concept. Beneath the umbrella are the various elements of a typical organisation.

The Need for a Quality System in Construction

In recent years a number of quality assurance schemes dealing with construction materials and components have been set up. Surveys of building defects, however, tend to show that the majority of such defects arise not so much from poor materials or components as from errors in design and specification, and from poor workmanship during construction. Construction companies are now being asked to demonstrate a formal quality assurance capability as a condition of tender or contract. There is therefore a need for those involved in construction to develop a quality system. (See Fig. 3.2)

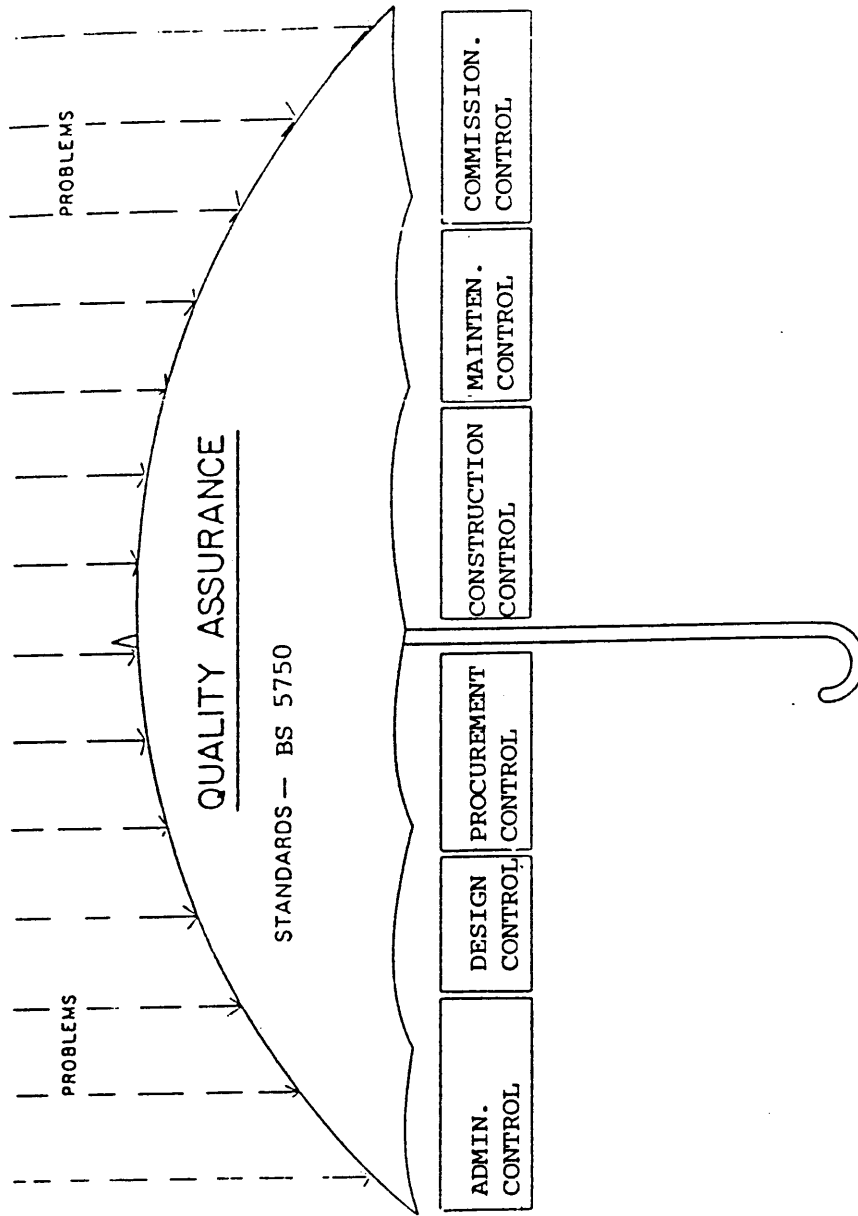


Fig. 3.1 The Quality Assurance Umbrella

The Quality system seeks to provide objective evidence that the required quality has been achieved. These objectives are: first, to control what is produced to make sure it complies with requirements (quality control) and secondly, to provide confidence that compliance has been achieved and will continue to be achieved (quality assurance). This assurance is needed by both the client and the builder, the former so that he knows he is getting what he is paying for, and the latter so that he knows his system is working satisfactorily.

The ground rules of a quality system are laid down in British Standard BS 5750: 1987 which is the basis of both the International Standard ISO 9000 and the European Standard EN 29000. The standard is applicable to all fields of manufacturing and service industries. Some degree of interpretation is therefore required for particular industries such as design and construction.

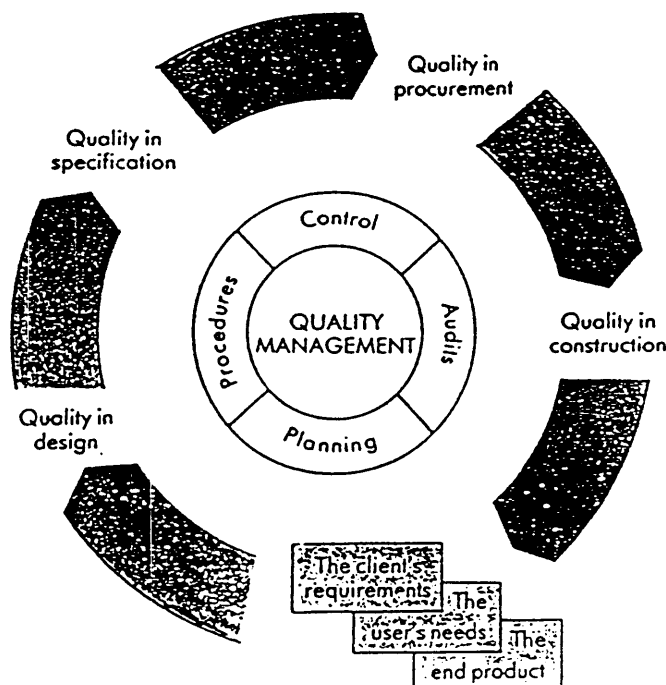


Fig. 3.2 The Need For Quality Throughout the Construction Process

3.1.1 Evaluation of Quality Standards

Quality standards are not new; they have been defined or implied for centuries. One of the earliest recorded inspection systems was that of the superintendent of the Necropolis in Ancient Egypt. His job was to inspect and approve all goods going into the tombs of the Pharaohs, the approval being indicated by his mark on each item. In the case of Tutankhamun, the marks show that the horizontal members (beams of blocks) of two of the beds were transposed, confirming what still applies today, that things are most likely to go wrong when you are in a hurry!

In the first instance standards were evolved so that those failing to meet requirements would be punished, in modern times meeting the requirements has become an indication of pride in the work.

3.1.2 The Quality Standard

BS 5750: 1987 is published in the following parts (references given in brackets refer to the identical part in the ISO 9000 series):

Part 0 (ISO 9000), Principle Concepts and Application:

This provides guidelines on the selection of the other parts of the standard, and clarify some of the basic concepts used in QA.

Part 1 (ISO 9001), Specification for Design/Development, Production, Installation and Servicing:

This part is for use when the supplier has to demonstrate conformance to specified requirements from design through to production, installation and servicing.

Part 2 (ISO 9002), Specification for Production and Installation:

This part covers production and installation only (where the design is not carried out by the supplier).

Part 3 (ISO 9003), Specification for Final Inspection and Test:

This part covers the procedures necessary to assure a client that the final inspection and testing has been carried out properly.

Quality Standards and the Construction Industry

Part 2, "Specification for production and installation" is more applicable to the construction industry because most contracts are set on the basis of designs produced by architects and engineers. Where contractors are responsible for design as well as construction, then they also need to satisfy Part 1.

Some basic explanations are however, necessary throughout BS 5750 to apply it to the construction industry. Under the BS the client or customer is referred to as the 'purchaser', and the contractor is referred to as the supplier. The word 'product' is used to refer to whatever the supplier (ie. the contractor) is producing. 'Product' for a contractor can therefore mean the whole of, or a section of the project. For a specialist constructor, architect or consulting engineer, the 'product' would be the service he provides. When reading BS 5750, contractors will need to bear these interpretations in mind.

Companies looking at the introduction of a quality system for the first time would be advised to examine all aspects of a system outlined in Part 2 of the standard, they should also bear in mind that in the Introduction (Part 0) it is stated:

"it is intended that these International Standards will normally be adopted in their present form, but on occasions they may need to be tailored for specific contract situations."

Thus the Standard itself gives contractors leave to agree with their clients that the requirements of the standard may be modified in certain circumstances.

3.2 DEVELOPING A QUALITY SYSTEM

3.2.1 Initiation

The first step in the development of a system for quality is to establish the philosophy which will provide a sound foundation for

what is to come. Action is required by the chief executive and his board of directors since these are matters which only they can articulate. A statement of sound quality policy, together with the organization and facilities to put it into effect must be made. At the same time they should appoint a "management representative" whose task will be to initiate and monitor the operation of the quality system.

Every organization should develop and state its policy on quality, together with arrangements for its implementation. The content of the policy must be known to all employees. One of the principal aims of an effective quality policy is to ensure that quality becomes everyone's concern (see Appendix 1 for a typical example of quality policy).

The Basis of a Quality System

The Quality system uses as its basis the British Standard 5750: 1987, but recognises that the best way of approaching quality assurance is to work from the company's existing good management and technical policies towards the documentation and procedures required by the standard. The Quality system in use must be appropriate to the type of activity and product or service being offered.

When a company is going through the initial process of introducing quality assurance, it may need a complete "cultural" change and the burden of the job of a quality management representative is to provide the drive for this change.

The quality system should be a living thing, not a bureaucracy or a paper-work model. Applying BS 5750 and writing procedures and manuals does not mean we have achieved quality. To make the system come to life requires the involvement of every person in the organization. This can only be achieved by effective communication about what the system is, how it operates, and what role each individual plays in it. These insights are developed by staff training.

Aim of the Quality System

The aim of setting up a quality system is to lay down in accordance with established criteria, procedures which will assist those who do the work to achieve the required quality and to monitor the results. Thus not only will quality be achieved, but it will be seen to be achieved.

In its early stage, a new quality system can be over formal, there may be too much rigidity and it will take time before the system matures and operates smoothly and efficiently by the staff. However, progress will be gradual and evidence of its achievement will come when it is realized that certain activities are no longer the problems they were.

3.2.2 Organization

To be effective the quality system requires an organization which clearly defines 'who does what' and how the responsibilities and the authorities contributing to quality are delegated. This delegation and definition of responsibilities is most effectively achieved by documenting and issuing appropriate:

- _ job descriptions
- _ organizational charts - identifying the primary position and reporting routes of the company.
- _ procedures - which clearly define responsibilities for specific activities.

Effective delegation and clear reporting and decision-making responsibilities will minimize problems and confusion and help to motivate staff who should clearly know what they are supposed to do and how they are to do it.

The recommended organization is shown in Fig. 3.3. This places the quality assurance function as a staff function directly responsible to the managing director.

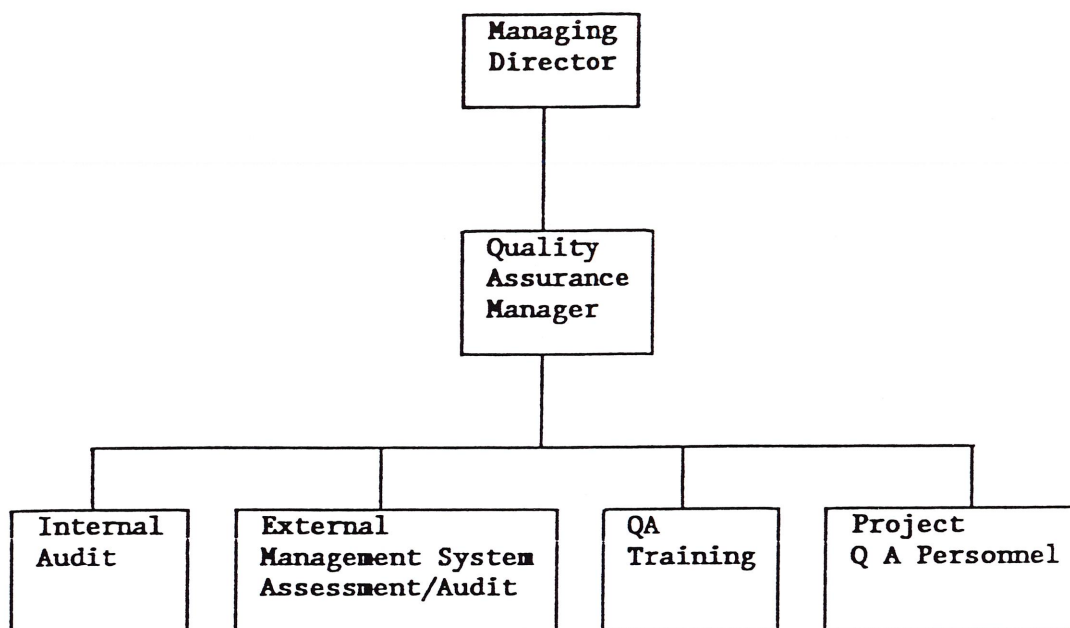


Fig. 3.3 QA Department function structure

3.2.3 Quality Assurance Department

The Way It Is

In some construction companies there is a department which is given the responsibility of quality. Usually this department is only responsible for the control of the quality of the constructed items and has no responsibility for verifying that all activities which precede the execution of the works are correct.

The Way It Should Be

Companies should look towards the total integration and control of all activities. This cannot be achieved solely by the efforts of the department responsible for quality control or inspection, as the result will be only increased activity in inspection and testing, probably resulting in increases in the costs of putting things right.

It is, therefore, necessary to appoint in an executive position, a person who is to be responsible for the quality assurance function. This person should have management capabilities and will be expected

to be the guide and philosopher of the quality system. It is essential that this person should occupy a senior executive position in the organization and has independence of action in order that he should have the authority to install and maintain the quality system.

The QA Department's Responsibilities

The responsibilities of the QA Department will be:

1. To verify the implementation and adequacy of the quality programme.
2. To identify any deficiencies within the programme.
3. To verify that corrective action has been taken to correct deficiencies and that action has also been taken to prevent a recurrence.
4. To verify that personnel operating in the quality assurance function are adequately trained to carry out their activities.
5. To develop objectives, policies and budgets.
6. To make systematic use of all resources to achieve QA objectives.

Returning to the umbrella analogy, which is shown in Fig. 3.1, the quality assurance department would, during verification activities, identify 'leaks' which may occur and would be instrumental in verifying that these 'leaks' are patched up by the appropriate department to prevent further 'leakage'. These leaks could occur anywhere - in administration, design, construction, or elsewhere. Hence the requirement that the person responsible for quality should be independent of the other functions.

However, the management should bear in mind that setting up a QA department will not take care of quality. Quality objectives can only be achieved if everyone is responsible for quality, with the quality department acting mainly as a co-ordinating function.

3.3 ELEMENTS OF A QUALITY SYSTEM

The elements of a quality system appropriate for construction are illustrated in Fig. 3.4. These are divided into two parts:

1. The company's quality manual
2. The particular quality programme, quality plans, work procedures and instructions for a specific contract.

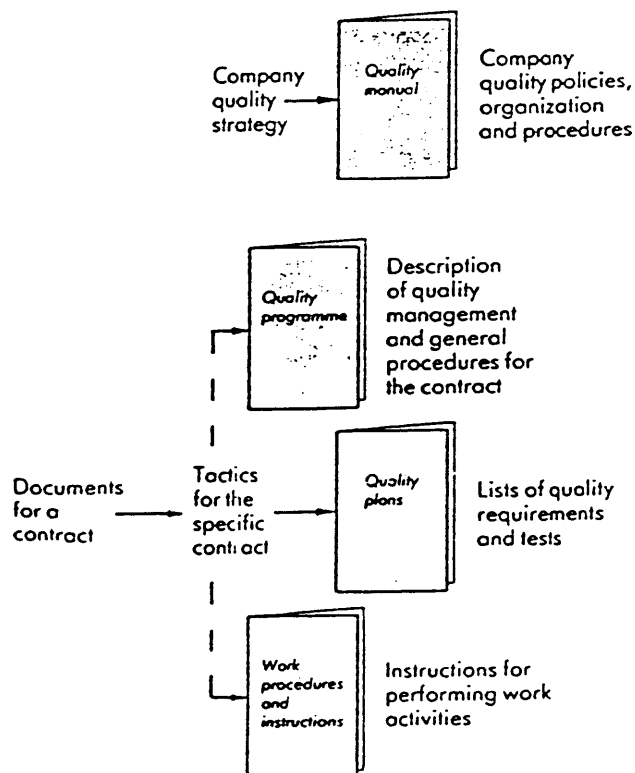


Fig. 3.4 The Documentation for a Quality System

3.3.1 Quality Manual

The quality manual sets out the general policies, procedures and practices of the organization in a well-organized and comprehensive

manner. It is a management tool to keep employees aware of their responsibilities within the quality programme; it can thus become an effective training document. It is a document of intent, describing what is done to assure quality.

In writing the quality manual, the following questions should be asked with regard to each requirement being met:

- What is done? (to meet the requirement)
- Why is it done? (or why is it done that way)
- Where is the requirement met?
- When is the requirement met?
- Who is responsible for ensuring that it is done?
- How is it done?

3.3.2 Quality Programme

A quality programme is the written description of the quality system for a specific contract stating the organization and responsibilities. It will also list appropriate general company procedures and contain a commitment to meet the specific work procedures required for the contract, such as concrete production and pre-concrete operation.

The stages of developing a quality programme from the appointment of the QA group to the implementation of the system are best described in flow chart form. (Fig. 3.5)

3.3.3 Quality Procedures

A procedure can be defined as a "document that describes how an activity is to be performed and by whom".

Procedures provide instructions to all levels of personnel which:

1. ensure uniformity of understanding, consistency of action and continuity of performance when personnel changes occur.

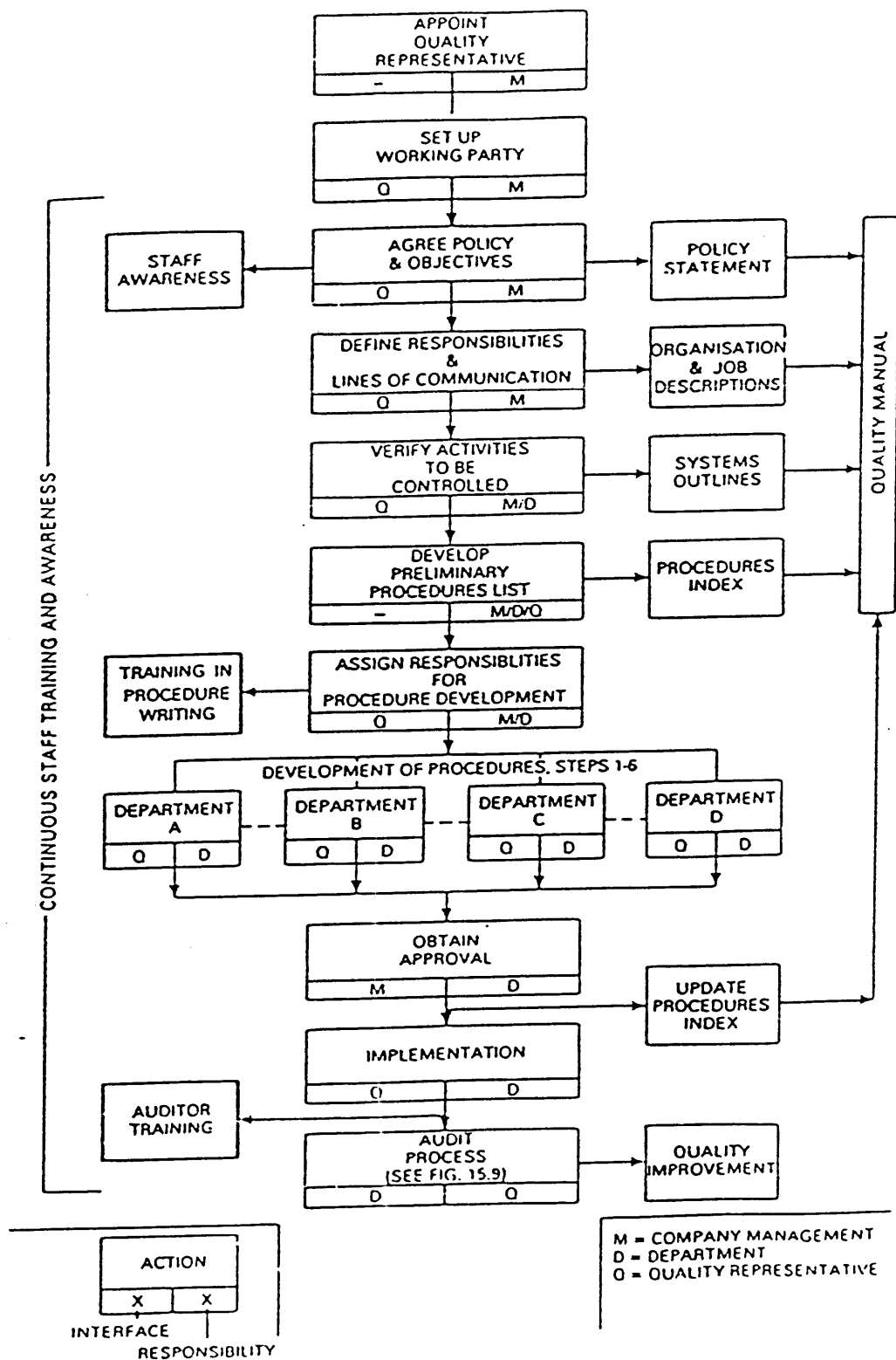


Fig. 3.5 Planning and implementation of the quality programme.

2. can be used as a basis for control, audit and review of the system and their effectiveness.

Procedures should be brief and to the point. They should be confined to routines which the management wants to be treated as obligatory. They should not be confused with technical specifications. It is to be expected that they will require amendment from time to time.

The chief engineer has to arrange the writing of the quality procedures which govern the immediate items of work, such as excavation, pre-contract inspections and post concrete inspection. Other procedures will then follow as required. It is essential that these procedures should be written by the parties responsible for carrying them out, ensuring that they intend to satisfy both the specification and the assurance requirements.

The QA department role here is to be only one of guidance, recommending procedural requirements in consultation with the department or discipline concerned.

3.3.4 Quality Plan

A quality plan summarizes the quality requirements for a particular item of work and identifies relevant contract documents, procedures and any certification, inspection or hold points required. It provides a check list of what needs to be done to attain, verify and document the specified quality of the item concerned.

The first issue of a quality plan must be made before work starts on site. Preparation should be commenced at the tender stages as part of the normal routine of construction planning.

Quality plans should include the following:

1. Quality objectives.
2. Allocation of responsibilities and authority.
3. Procedures, methods and work instructions.
4. Inspection and testing.

5. Review and update.
6. Record.

3.3.5 Work Instructions

A work instruction is a written or verbal instruction detailing how a specific task is to be done. Examples of work instructions would be those for use of re-inforcement couples, sampling concrete, making concrete cubes.

3.4 QUALITY SYSTEM REQUIREMENTS FOR CONSTRUCTION

The requirements of BS 5750, Part 2, the part relevant to general contracting, are presented here, with explanatory notes as applicable to the construction industry. The interpretation is intended to be explanatory only and does not convey the full contractual significance of the original text. For more detail on this matter, the reader may refer to "CIRIA Report 74: 1990" and to "Quality Assurance for Contractors" issued by the Federation of Civil Engineering Contractors:

BS 5750 Part 2 identifies:-

1. Management responsibility -
Management should state its policy and objectives. They should specify who is responsible for quality functions as set out in the quality manual.
2. The quality system -
Management should establish, document and maintain a quality system.
3. Contract review -
The contractor should review the client's requirements as set out in the drawings and specifications. This review should be carried out before tendering.

4. Document control -
The contractor should operate a procedure for ensuring that drawings, specifications and other working documents are properly controlled and kept up to date.
5. Purchasing -
The Contractor should ensure that construction materials and sub-contracted work complies with specified requirements.
6. Client supplied products or service -
The contractor should ensure that all parts of his construction work are clearly identifiable with particular drawings, documents, etc.
7. Product identification and traceability -
The contractor should ensure that all parts of his construction work are clearly identifiable with particular drawings, documents, etc.
8. Process control -
The contractor should plan and control the work on site and prepare written method statements defining how work is to be done.
9. Inspection and testing -
Verification of compliance with specifications should take place on receipt of materials, at intermediate stages and when work is complete. The criteria for compliance is defined in the contract specifications.
10. Inspection and test status -
The contractor should establish a system whereby the work-force can distinguish between work which has been inspected and found acceptable and that which has not.
11. Control of non-conforming product -
The contractor should establish a procedure to identify, segregate, repair or remove defective materials or workmanship.

12. Corrective action -

This is applicable to any failure to conform with requirements. It is essential to ensure that corrective actions are effective in preventing a recurrence of non-conformities.

13. Handling, storage, packaging and delivery -

The contractor should operate procedures to prevent damage or deterioration to construction materials during construction and after completion prior to hand over to the client.

14. Quality records -

The contractor should identify the records to be maintained to show that work has been carried out in accordance with specification. Documentation of records should be agreed with the client when necessary.

15. Internal audits -

The contractor should carry out independent internal checks to ensure that his quality system is achieving its objectives.

16. Training -

The contractor should provide proper training to personnel who are to undertake any work which needs special skills. Records should be kept of people with specific skills.

17. Statistical techniques -

Statistical techniques should be used to establish conformance with specifications, as in the case of interpreting the results of concrete cubes.

3.5 AUDITS

A good quality system will not function without adequate audit and review. Audits are carried out to make sure that actual methods comply with the documented procedure. The main purpose of auditing is to provide an impartial professional assessment of management and operating efficiency, to identify opportunities for improvement and to make recommendations for more cost-effective operations.

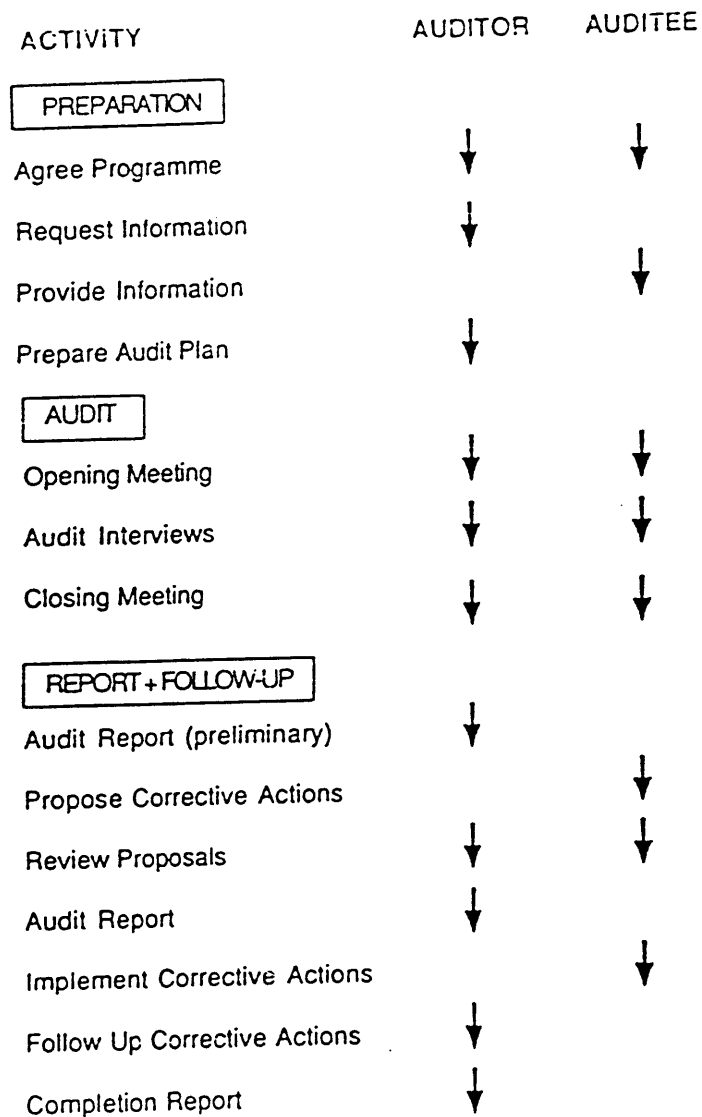


Fig. 3.6 Audit Flowchart

BSI QA Services, Lloyds, and Yarsley Quality Assurance Firms Limited.

Independent third party certification ensures that the QA system of the firm is organized in line with modern practice, it improves product design and saves money. Feedback from the certification process itself often leads to an improvement in the product standards themselves. For the user, third party certification gives greater confidence in both the management system of the supplier and the integrity of the product, it saves product inspection and failure costs, it improves design and helps to improve overall quality performance.

There are two main benefits of the certification of quality system.

1. Pre-qualification
Third party certification may become a condition of pre-qualification for certain classes of work.
2. Internal discipline.
A programme of audits by a third party is a valuable aid to internal discipline.

3.7 QUALITY SYSTEM BENEFITS

The benefits of installing a quality assurance system in a construction company are quoted as:

- Greater efficiency
- Less remedial work and defects
- Better control of operation
- Greater management confidence and client satisfaction
- Improved quality and quality awareness
- Engineering efficiency and awareness.
- Improved administration of change control and achieving information services.
- Market stability and increased business opportunities.,
- Improved job satisfaction.
- Easier integration of new staff.

CHAPTER 4

"The material is often used without the knowledge of the supervising engineer."



PROJECT TEAM: ROLES AND RESPONSIBILITIES

4.1 THE PROJECT TEAM

Most construction projects are developed by a team consisting of an owner, consultant and contractor. There are, of course, many other professionals who play significant but more limited roles within the overall project. The major participants (owner, consultant, contractor) are involved in nearly all phases of the project.

Each member of the team must be dedicated to quality and must assume a share of the responsibility for quality. Overlapping areas of responsibility must not be ignored by any team member. The failure of any of the team to perform properly will defeat the effort of the whole team. An equation for this characteristic of quality might be written:

$$\text{Owner quality} \times \text{Engineer quality} \times \text{contractor quality} = \text{project quality}$$

where poor quality by any member of the team lowers the overall project quality.

Quality is measured by the satisfaction of all the parties involved. The satisfaction of the owner at the expense of the satisfaction of the contractor would diminish the quality of the project. Similarly, the protection of the engineer and owner to the detriment of the user would negate the quality.

4.1.1 Determining Project Team's Roles

Role clarification is required for the project team to function properly. A considerable amount of time can be saved and misunderstanding averted, if roles and responsibility are clearly defined at the outset.

Some of the factors which inhibit the project team are:

- * Poor communication of information to the other teams or individuals in time for it to be useful.
- * Lack of understanding of where decisions are taken or goals set.
- * Low involvement of other teams in reaching decisions.
- * Failure to identify and use systems, methods or techniques for specific activities.
- * Absence of corrective action.

Therefore, to achieve quality, it is essential that each participating organisation understands in advance, exactly what the roles, responsibilities and activities of all parties will be (see Fig. 4.1)

4.2 THE OWNER'S ROLE

A successful project begins with the owner. The broad responsibilities of the owner on construction projects include two major factors that contribute to a quality project. The first is the development, by the owner, of a complete, clear and documented statement of his requirements and objectives for the project. The second factor is to promote a thorough understanding to other team members of the role and responsibilities of the owner.

Owner Objectives

An owner usually states his objectives in this way: "I want a good job, on time, and within budget." This generalized objective is not enough.

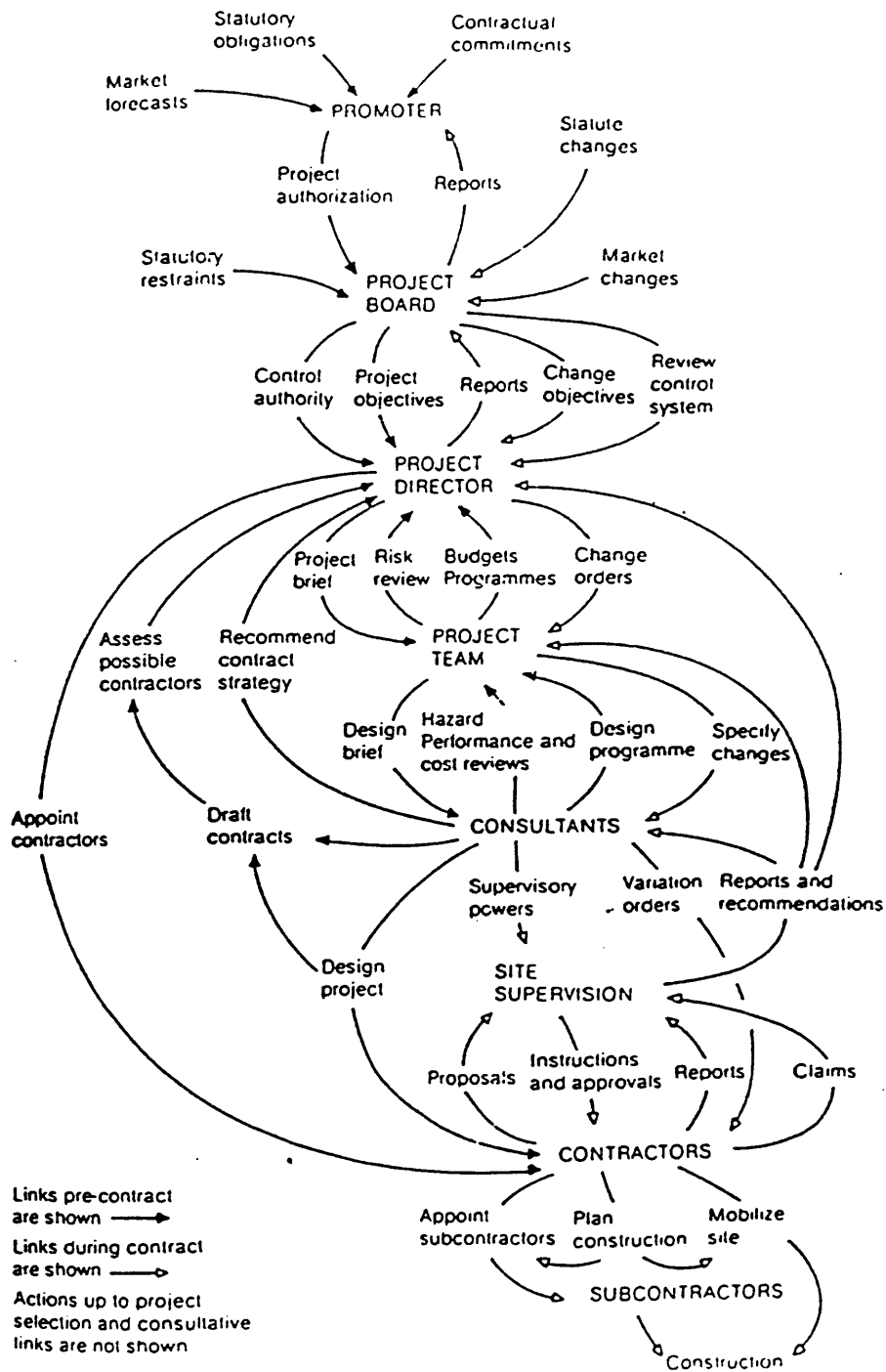


Fig. 4.1 Responsibilities for Construction

Actual objectives for a particular project must be more comprehensive. Objectives should be detailed and refer to specific aspects of a project, such as function, operation, programme, technical matters, quality, aesthetics, administration, fiscal and management requirements.

An owner cannot expect poorly communicated objectives to be fulfilled. The owner and consultant should develop good lines of communication and agree on how the objectives will be achieved. They should realize that thorough analysis of all relevant factors will greatly enhance the probability that set objectives will be fulfilled.

4.2.1 QA Requirements

A QA System requires full owner commitment prior to the selection of the consultant and contractor. The owner cannot assume that these organisations will automatically implement their own QA because each is under pressure to reduce costs and construction time. The owner can only assure that they actively participate in the QA effort by ensuring that specific requirements for quality are included both in his contract with the Consultant and in the Contractual documents. The owner, however, should also bear in mind that it is not sufficient for him to rely on contract provision to achieve well-managed QA. He should himself monitor and audit the designated QA responsibilities, in order to ensure that they are met in accordance with the contract requirements.

4.2.2 Selection of Consultant

The owner should establish a policy and procedure for procurement of professional engineering services.

The selection of a consultant engineer based solely on price rather than qualification and experience may result in the owner receiving less than perfect professional services.

Through useful consultant selection and the adoption of specific contract clauses, the owner can minimize potential difficulties and

capitalize on the consultant's experience in design and construction QA Programme.

For optimal results, the owner should:

1. Select the consultant with careful consideration given to his capabilities in design and field operation.
2. Require the use of a specialized consultant for functions outside of the designer's expertise.
3. Establish the authority and responsibility of the consultant to perform contract administration and QA functions.
4. Establish specific requirements for full documentation and reporting of all changes in project design and scope.

Appendix A shows a sample of an engineering firm questionnaire and a consultant selection rating form.

4.2.3 Selection of a Contractor

Contractors should be selected based on competition, where criteria includes experience and qualifications, rather than cost alone.

In order to identify a preferred contractor, it is necessary to assess his capabilities in a number of areas:

1. Engineering: Does the contractor have the professional capabilities to carry out the work?
2. Quality system: Does the contractor have an efficient and effective quality system and good track record in this field?
3. Economics/programme: Are the contractor's prices right?
4. Financial stability: Are the contractor's finances in order?

4.2.4 Degree of Influence of Quality during Project Life

The control of quality is strongly influenced during the early life cycle of a project. Fig. 4.2 illustrates this concept. Decisions made in the initial stages of design are more difficult and costly to change once detailed design and construction begins. In this context, it is strongly recommended that the owner should make good use of the design phase rather than make changes during the construction phase. (It has been shown that in the early design phase, monthly cost may be only 10% of those during construction phase. The significance of ensuring that all major decisions are made during the design stage is therefore obvious.)

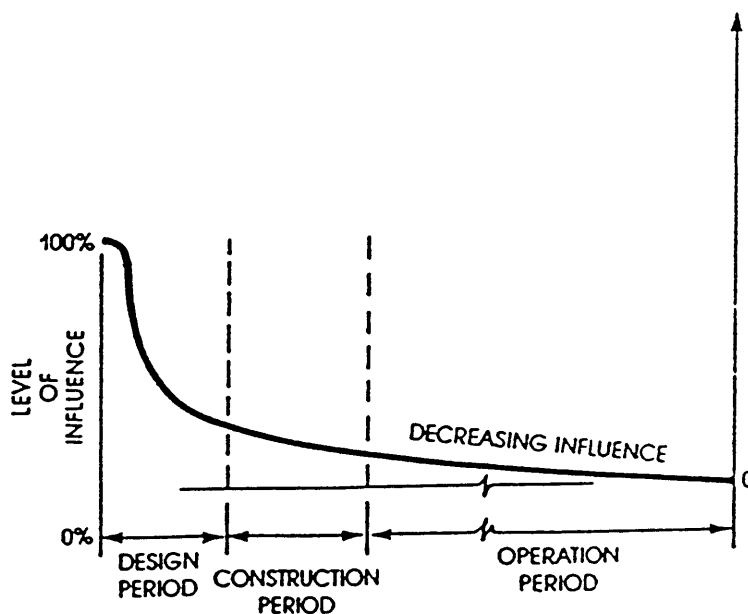


Fig. 4.2 Opportunity to Influence Project Quality and Cost

4.2.5 Other Responsibilities

There are other responsibilities of the owner, in addition to those already mentioned which contribute to achieving quality. These include:

- * to fully disclose facts
 - * to be truthful
 - * to be realistic in the assumption of risks and liabilities.
 - * to make timely decisions.
 - * to ensure that the project is funded properly: providing timely and correct payment for work completed is critical for contractors. One significant task of project administration is predicting, monitoring and controlling project cash flow.
 - * if possible, to avoid concurrent design and construction.
- This situation frequently causes expensive and embarrassing rework with adverse impact on quality, particularly if these two functions are being carried out by separate organisations.

4.3 CONSULTANT ROLE

The consultant has the responsibility and the duty of setting the appropriate quality level to fulfill the project requirements, to promote safety for the user and public, to develop built-in durability and to minimize maintenance.

Whereas the owner's role is important as the "initiator", the consultant role is equally important as the "implementor". Without an experienced skilled designer, the project cannot proceed.

4.3.1 Design Assurance

"Design Assurance" is defined as 'those planned and systematic actions taken to provide confidence that the completed design will satisfy the requirements of its intended use.'

A typical design assurance programme covers all phases of engineering associated with the project, including the definition of requirements, drawing and specification control, verification of design adequacy, control of changes and supporting documentation.

This approach focuses on preventing errors or defects in the engineering activities. Table 1 adapted from a text on design

TABLE 1. Evolution of Design Assurance (Burgess 1984)

Program Element (1)	No Program (2)	The Start of a Program (3)	Early Program Maturity (4)	A Working Program (5)	Fully Integrated Program (6)
Design requirements	The engineer relies on his experience.	The salesman sends spec sheets to the engineer.	Engineering and Sales meet occasionally to discuss new developments/marketplace happenings.	Engineer and salesman work together on bid/contract reviews.	Sales and Engineering use interactive review process; timely feedback
Drawing control	The engineer makes sketches and notes for the site.	Drafting prepares drawings per the engineer's instructions.	Engineer's supervisor reviews selected drawings.	Technical specialists review and sign selected drawings.	Ongoing series of design reviews with multidisciplinary signoff are used routinely.
Control of changes	Engineer gives verbal instructions for changes.	Drawings/specs are marked up by engineer.	Engineer issues written change notices.	Engineering management reviews/approves written changes.	Technical specialists review written changes to evaluate impact and approve as appropriate.
Engineering calculations	Components are sized by handbook and the engineer's experience.	Engineer performs written calculations based on personal methods.	Engineering calculations for selected items are reviewed by supervisor or lead engineer.	Standard methods based on analysis and test data are developed and tailored for specific applications.	Latest state-of-the-art interactive CAD systems are in place with necessary support specialists.
Control of non-conformances	Nonconformances are not controlled.	The site foreman decides if a problem needs to be corrected.	The engineer is consulted if problems are found.	The engineer is on the job site to decide if a non-conformance is acceptable.	Technical specialists review/disposition non-conformances.
Engineering records	Formal records are not prepared or maintained.	The engineer keeps informal records and notes.	A department clerk collects and files the drawings and records.	Records procedures and centralized files are used to control and retain records.	Engineering records are controlled as integral part of company records management program.
Management evaluation	The engineering department works independently from other departments.	When a problem occurs, management wants to know who goofed.	When a problem occurs, management wants to know what went wrong.	Management hires or designates a knowledgeable person to review the engineering activities every few years.	A planned program of internal audits by engineering and other departments are conducted regularly for refinement and improvement of the engineering processes.

assurances (Burgess 1984), presents an insight into the evolution of the various elements from virtually no control to a fully-integrated approach.

4.3.2 Action by QA Manager

During design stage, the QA Manager should follow up and expedite all missing or ambiguous information until he is satisfied that each section engineer knows what has to be done within his own department (civil, electrical, geotechnical, structural, etc.) and that he has the necessary tools with which to do it. It is helpful of each section engineer to compile, from the contract, a checklist covering what he considers to be lacking or not understood. These checklists are then reviewed with both project management and client.

During tendering stage, the QA Manager's responsibilities are to review each tender for compliance with the quality system, quality acceptance criteria, inspection and test plan, certification and monitoring all comments made by others prior to selection of the contractor.

For the QA manager's responsibilities during construction stage refer to chapter 3.

4.3.3 Social Factors

There are social factors or forces which are as relevant as the technical factors in affecting the overall quality of a project. These need to be considered by the consultant prior to the starting of design work. These factors are: political, social pressures of various groups, legal problems, the human environmental factors and the pressure of 'rush' (pressure to finish the project in a rush).

The best way to handle these problems is for the engineer to recognise these activities during the formative stages, and compensate for this as far as possible in design and planning.

When assurance of quality is viewed as a system, every activity - political considerations, social pressures, preliminary planning, economic factors, financing, human and environmental factors, design, drawings, specifications, bidding, training of field personnel, inspection, testing, product control and feedback - becomes an essential factor in the overall achievement of quality.

Only in such an overall system concept, giving due weight to each factor as the case may require, can the quality desired be achieved at minimum cost, and society be best served.

4.3.4 Consultant Role During Construction

The system for control of quality during the construction phase must be fully designed and operational before construction commences. Control in the field may be divided into two aspects which fit in with the two basic responsibilities during construction:

1. Product control and inspection by the contractor to assure the work will meet the requirements that he has contracted to produce.
2. Acceptance of completed works at various stages, by the Engineer. This acceptance signifying to the owner that the works conform to the contract.

4.4 CONTRACTOR'S ROLE

The contractor has direct control of the quality of construction of the project. His primary responsibility, both contractually and morally is to meet the standards specified by the designer. Quality can be seriously eroded if the contractor does not carefully review the contract documents at the start and evaluate specific requirements and unforeseen risks.

4.4.1 Bid Preparation

In planning a job for bidding purposes, the contractor first encounters the control of quality. If the contractor's planner or estimator fails to recognize the potential problems and to make allowance for them, then the groundwork is laid for reduction of quality. On the other hand, if the drawings and specifications are carefully appraised and comprehensive planning and realistic estimates are made, then the quality required will be attained.

4.4.2 QA Requirements for Contractors

The contractor should be required to show a quality assurance plan. This plan will be a contractor's statement of intent to perform the required construction and associated quality assurance tasks. The plan should be approved by the owner and engineer prior to contract award. The implementation of the plan should be monitored by the engineer/owner during the construction phase.

Quality assurance for the contractor is a way of approaching a project:

- by thinking about the end result from the beginning, and creating plans.
- by ensuring the works are satisfactorily carried out and inspected systematically.
- by producing documents to demonstrate that the specification for materials and workmanship have been met.
- by auditing the procedures used to demonstrate that the planned approach has been observed and has been successful.

The end result should be a client with greater confidence in the project he has financed and greater confidence in the contractor who built it.

4.5 OPERATION AND MAINTENANCE OF THE COMPLETED PROJECT

Project team members should cooperate to produce a project which can be reliably, safely, and efficiently operated and maintained. These activities are important in providing a quality project.

For best results, the owner should involve experienced operation and maintenance personnel to advise on project design early in the planning/design phase.

The designer is responsible for preparing plans and specifications according to the owner's needs, incorporating operation and maintenance consideration learned from prior experience and from the owner of O&M personnel. The designer should include the contract documents provisions for equipment performance criteria, repair and replacement warranties and adequate manufacturer supplied O&M manuals.

The contractor should document significant elements of the work including changes made during construction to assist the owner or designer in preparing record drawings for the completed project.

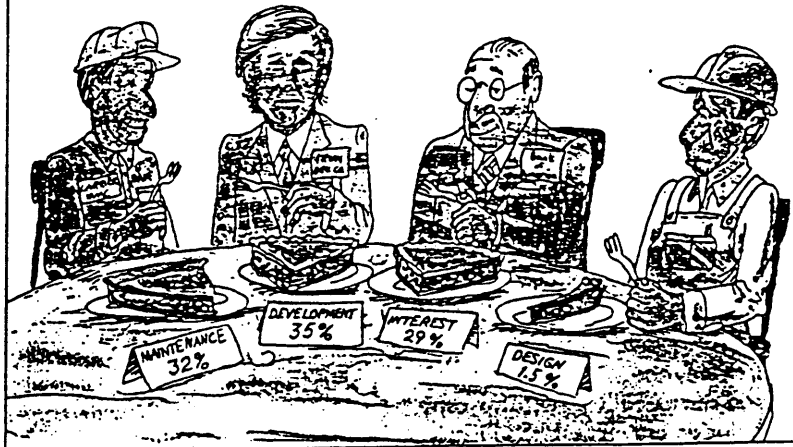
4.6 SUMMARY

A successful and good quality project can be characterized as follows:

- The owner has a good definition of what is to be built and how it is to perform.
- Competent professionals are retained by the owner to study, plan and design the project to serve the owner's need, and to minimize the risk of problems and failures.
- An experienced contractor concerned with providing a good job is selected to carry out the work.
- Good communication attitudes create a team who co-operate in producing quality construction promptly and resolve problems.

CHAPTER 5

A fundamental question is whether the consulting engineer should bear unlimited risk in light of his limited benefits.



COMMUNICATION AND SUPERVISION

5.1 THE IMPORTANCE OF COMMUNICATION

For a QA system to function effectively, a construction company must have communication systems of different types: interpersonal, interdepartmental and interorganizational. Communication systems are the central nervous system that make it possible for hundreds of people to do dozens of tasks in an integrated and orderly way, and to coordinate their efforts and skills toward a common goal. It is important therefore for all managers, supervisors and staff to recognize the value and influence of good communication providing a vital link in creating and maintaining standards for quality. All must learn the characteristics of the various methods of communication - verbal, non-verbal, written, graphic and electronic communications - and select the most appropriate for each situation.

5.1.1 Communication-related Problems

As mentioned in Chapter 1, many of the construction failures are due to communication/coordination problems. These problems occur between owners and designers, various design disciplines, designers and contractors, owners and contractors.

Some of the most common construction problems were outlined in a survey carried out by ASCE in various parts of USA . Table 5.1 describes the type of problem, consequences and remedies, the technical cause and the 'basic cause' (the root of the problem). These are found to be fairly commonplace problems associated with many projects, large and small. These problems were not generally the

TABLE 5.1 Description of Structural Problems Due to Communication/Coordination Failures

Location (1)	Type of problem (2)	Projected consequences/remedial actions (3)	Technical cause (4)	Basic cause (5)
Great Lakes	Cracking and failure of pilasters supporting roof girders	Could have resulted in roof collapse; rebuilt girder supports	Inadequate reinforcement for girder support	Switch of designers in midstream, without orientation of new designer to status of work
Southeast	Masonry walls of HVAC room which cracked and moved when system pressurized	Could have collapsed inward; reconstructed reinforced masonry	Failure to design for internal lateral pressures	Lack of communication between mechanical and structural/architectural designers
Southeast	Walls not designed for blast pressures as required for process safety	Would have failed at design blast pressure; reconstructed reinforced concrete	Intended function of walls not understood by designer	Lack of communication between owner's process engineer and structural designer
Northeast	Rapid corrosion of roof bar joists and tower supports by chlorine fumes	Near collapse of roof, rebuilt with protected structural members	Unrecognized corrosive atmospheric conditions of plant	Lack of site visit by designer or communication with plant management
Midwest	Severe oscillation of tall process stack during periods of moderately high winds	Could have resulted in stack collapse in high winds; changed bracing, added strakes	Von Karmen vortex-shedding not considered in stack design	Failure to communicate a chronic, known problem to a new designer
West	Ineffective wind bracing, as constructed on tall steel frame	Could have resulted in frame failure; redesigned and rebuilt bracing	Bracing point altered by field for needed equipment clearance	Lack of communication between designers and field/design
Midwest	Precast double T supporting stub column which cracked and moved	Could have failed under load; provided reinforcement of double T	Column improperly located by field erection forces	Lack of understanding by field; poor communication with designers
Northeast	Distress of roof due to snow loading	Near collapse of roof; installed new, stronger girders and joists	Drifting effect of parapets on snow. Not recognized by codes and design practices	Failure to communicate a chronic, known problem
East Central	New steel between 6th, 7th, and 8th floors which produced a leaning effect on building	Reset steel and modified the connections to adjust to 1 in. difference	Steel misfabricated based on poor field measurements	Lack of cooperation in getting field measurements for structural members
South Central	Cracks in elevated structural floor slab of packing room	Collapse was a possibility; performed epoxy treatment of cracks and added structural steel	Platform designed for handtrucks; fork lifts actually used	Lack of communication between owner's representative and designer

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result of new technology technical incompetence but rather of a communication/coordination breakdown.

5.2 THE IMPORTANCE OF SITE MANAGEMENT

Site management is more likely to be successful in achieving good quality when lines of authority and responsibility are clearly defined and understood. Also, when the site staff have the opportunity to contribute to and take responsibility for quality achievement.

This chapter discusses the role of site representatives who are directly connected with construction. It also discusses material quality management on site, construction workers and subcontractors/suppliers.

5.2.1 Need for On-site Representatives

Adequate representations on site from the organisations involved is important for both the quality and the efficiency of construction.

Depending on the size of the project, the complexity of the materials and difficulty of construction operations, site representatives from at least four types of organisations are recommended. First, an owner's representative is required to manage and coordinate the work of several contractors at the site, to manage the owner's QA activities, to give quick direction if unanticipated conditions are encountered, and to approve changes.

Second, representatives from agencies with jurisdiction over the project or inspection and testing agencies that will check for conformance to requirements. Their involvement includes in-process inspection and testing, documentation and the timely resolution of problems so that they are corrected before they become serious.

Third, representation from the ~~he~~ consultant who prepared the design is necessary to achieve quality and avoid reconsidering faulty works.

Among the many of his activities on site, the following are especially important in meeting quality requirements.

- . Interpreting the plans and specifications.
- . Identifying technical requirements and anticipated risks.
- . Updating plans and specifications and predicting changes during construction.
- . Offering recommendations, advice and suggestions to the contractors.

Finally, a representative from the contractor whose job is to supervise and direct the work competently and efficiently and ensure that proper techniques and procedures are used. One of the main qualifications which he should possess is the ability to deal productively with the many people on site of diverse education, training, experience and skills.

Site representatives should support construction operations and avoid or quickly resolve problems or conflicts in order to expedite the construction process. Appropriate site representation is a key means of providing continuity in construction. The owner should analyse the project early and identify special requirements that influence the need for site representatives from designers, suppliers and others.

5.2.2 Site Management-related Problems

There are many obstacles and problems which face the site representatives in carrying out their duties. These obstacles were identified in a survey made and published in the 1987 NEDO report on "Achieving Quality on Building Sites". The key findings of this report concluded that:

- . Site management spends too much time chasing late drawings and other project information.
- . Contractual arrangements, as such, have little influence on the quality achieved, but management structures have considerable influence.
- . Inadequacies in the quality, completeness and accessibility of

the project information are a major handicap in the achievement of project quality.

- Site managers often have to spend time dealing with technical queries to the detriment of other aspects of management.

5.3 MATERIALS QUALITY MANAGEMENT

Material quality management is an essential part of construction quality and requires the same degree of planning, prevention, appraisal, and corrective action as design engineering and construction.

There are high costs associated with poor quality of materials and equipment, including schedule delays, rework, loss of productivity and loss of competition. Fig. 5.1 shows the quality process for materials.

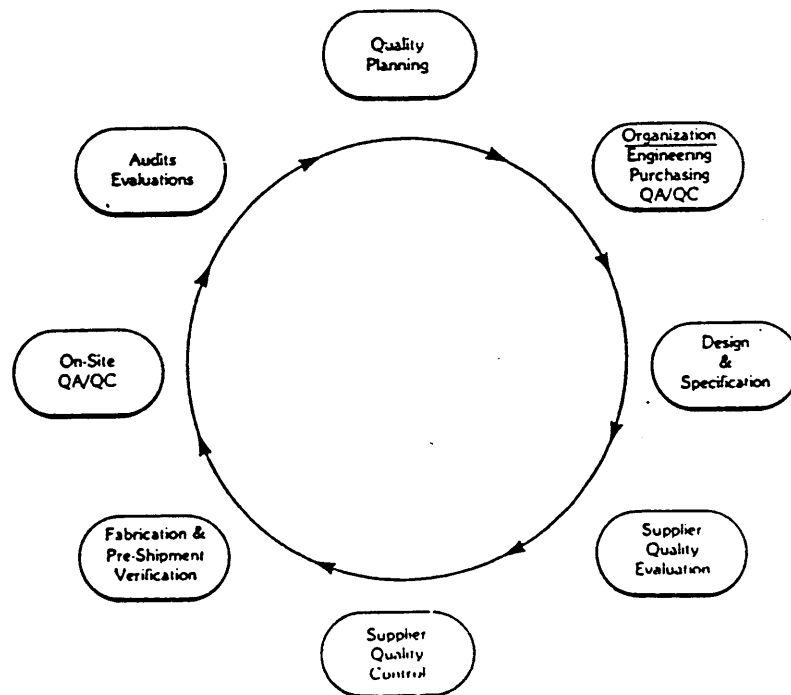


Fig. 5.1 "Quality Process" of Construction Materials.

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Achievement of the correct levels of construction quality should be a major factor in the selection of subcontractors and suppliers. The application of the supplier's quality assurance programme is very important to prevent shipment of non-conforming materials. As in every construction system, QA starts with the owner, but extends to the engineer, who is responsible for standards and specifications, and to the contractor, who requires quality products of suppliers and subcontractors.

One of the factors to assure quality in materials is planning. Good planning can avoid unpleasant surprises and delays due to quality breakdown in the materials management system. Poor planning leads to changes of suppliers and poor suppliers performance, both of which adversely affect project quality.

5.3.1 On-site QA for Materials

The key to effective on-site control of incoming materials is pre-establishing responsibilities. One individual, probably the site engineer or materials manager, should be responsible for determining whether materials can be accepted, returned or replaced.

Field quality assurance of materials should occur prior to receipt and include the following:

1. Planning: Purchase orders for materials must be available and inspection criteria should be developed prior to the start of materials deliveries.
2. Visual checks; materials must be checked for shipment damage, improper making and shortages.
3. Document review: documentation required specification should be reviewed to ensure the materials meet the documented requirements.
4. Notification of supplier: suppliers must be notified of deficiencies in quality or quantity delivered.

5. Installed equipment protection: The contractor must have plans and procedures to protect installed equipment during the construction activities.

A form of documenting field quality problems is shown in Fig. 5.2. It indicates cause, status, and proposed corrective actions. Also a checklist of times relating to QA/QC is shown in appendix 2.

5.4 CONSTRUCTION WORKERS

Construction workers include carpenters, bricklayers, pipejoiners, steel fixers, crane and machine drivers and labourers. The skill and care in execution of the work of these people will determine whether the required quality is achieved first time.

To achieve the required quality, the feeling of responsibility must be built in all workers:

- To follow the agreed written procedures.

- To use materials and equipment correctly and as instructed.

- To draw attention to existing or potential quality problems and report all errors, defects and wastes.

- To suggest ways in which risk of errors or quality problems could be reduced.

To get the best out of workmen, they must be given freedom and responsibility to act on their own initiative within defined limits. They must have quick communication with one another, and their areas of action must be clearly defined.

5.5 SUBCONTRACTORS/SUPPLIERS

Contractors occasionally purchase items or services from others. Therefore, it is necessary to have control over these activities since they affect the quality of contractor's finished work.

QA programme standards require that the main contractor should ensure that the subcontractor's quality system is effective. He should

OFFICE CHECKLIST:
FIELD QUALITY NOTICE

Project: _____
Contractor: _____ Date: _____ Report No. _____
Problem: _____
Item Identification: _____ Vendor: _____
Drawing No.: _____ Specification No.: _____
Date Found: _____
Work Category: _____ Date Needed: _____
Work Area: _____

Demolition ☐	Earthwork ☐	Concrete ☐	Steel ☐	Sheet Metal ☐	Welding ☐
U/G Pipe ☐	A/G Pipe ☐	Equipment ☐	Painting ☐	Insulation ☐	Electrical ☐
Instrumentation ☐	Roofing ☐	Other ☐			

Possible Cause:

Owner Change ☐	Vendor Change ☐	Transportation Error ☐
Design Change ☐	Vendor Error ☐	Other _____
Design Error ☐	Construction Error ☐	_____
Design Omission ☐	Construction Change ☐	_____

Problem Found: Receipt Inspection ☐ Has Vendor _____ Carrier _____ been notified? Yes ☐ No ☐
Before Installation ☐ Contact: _____ Date _____ N/A
During Installation ☐ Correction to be made by: Contractor ☐
After Installation ☐ Vendor ☐

Description of Problem: _____ _____ _____ _____ _____ Representative: _____
--

Description of Solution: _____ _____ _____ _____ _____ Contractor _____ Date _____

Remarks: _____

Fig. 5.2 Field Quality Notice

request the detail of their system and then determine what checks he should still carry out to ensure compliance. A supplier with a consistent quality programme will usually provide a superior, long-lasting product that is more economical over the project life cycle.

5.5.1 Subcontractor's Selection

Main contractors must maintain an accurate list of subcontractors and a measure of their performance to develop 'approved supplier' lists. Fig. 5.3 shows a sample form of supplier performance rating system evaluation in which suppliers are rated according to some weighted average by project staff, which could include engineering, quality assurance, material management or construction.

A well-documented, clearly written purchase order or subcontract is necessary to ensure that the design requirements are conveyed to suppliers or sub-contractors. Contractors must emphasize the quality requirements, including warranties, tests and procedures for acceptance, rejection, repair and replacement.

5.5.2 Supplier Relationship

The supplier should create a relationship with the contractor that assures that the product will meet fitness for use requirements with a minimum incoming inspection or corrective action.

A subcontractor/supplier with a long-term relationship is thought to be more likely to keep to delivery promises frequently at the expense of short term relationship with other companies.

Major development in the long-term contractor-supplier relationship will also include.

- . Establish programme activities
- . Joint problem solving activities
- . Less paperwork
- . On going quality improvement based on open exchange of information

- . Less schedule disruption
- . Lower stock level.
- . High priority of their order
- . Gives the supplier a greater sense of security.

VENDOR QUALITY APPRAISAL
(To be used in developing supplier lists)

Name and Address:		Commodities Supplied:		Date of Appraisal

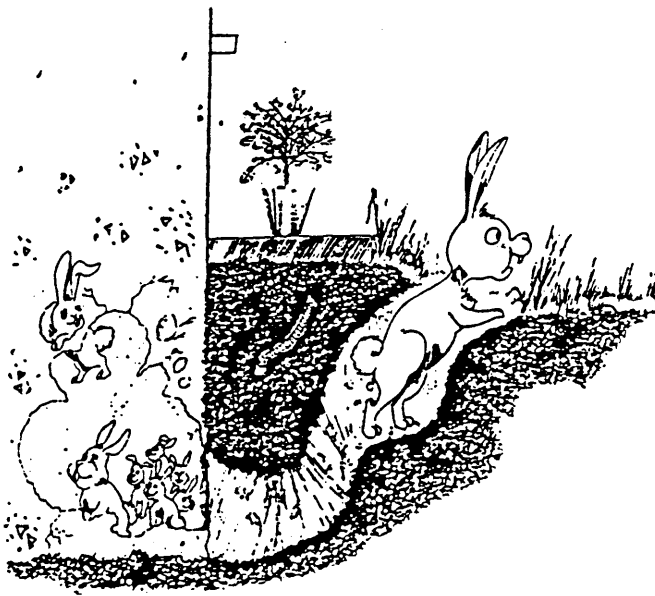
Rating categories	Weights	Rater A	Rater B	Rater C
Experience	.20			
Technical personnel	.10			
Facility/housekeeping	.10			
Quality-observed	.10			
History	.15			
Schedule/delivery	.10			
Service organization/parts	.05			
Financial	.05			
Location	.02			
Labor relations	.03			
Attitude, cooperation	.05			
Overall reputation	.05			
TOTAL	1.00			

Notes and Recommendations:	Overall Rating:			
	Excellent	Good	Satisfactory	Unsatisfactory
	Prepared by: _____			

Fig. 5.3 Vendor Quality Appraisal Form

CHAPTER 6

"One never knows whether concrete has formed a homogeneous mass without honeycombing or large voids."



QUALITY IMPROVEMENT AND PRODUCTIVITY

6.1 QUALITY AND PRODUCTIVITY

There is a positive correlation between quality and productivity. Quality is achieved by improvement of the process. Improvement in the process increases uniformity of output of product, reduces rework and mistakes, reduces waste of manpower, machine time and material and thus increases output with less effort.

Reduction of waste transfers man hours and machine hours from the rework of defectives into the improvement of the work which is in process. In effect, the level of production will increase.

6.2 QUALITY IMPROVEMENT

'Improvement' is defined as the attainment of a new level of performance that is superior to any previous level.

Fig. 6.1 shows successive levels of increasing quality awareness and the resultant actions within an organisation. This hierarchy provides an indication of a company's cultural climate and steps that may be taken to improve quality and productivity.

6.3 EDUCATION AND TRAINING

To perform quality design, quality engineering and quality construction, we need quality people. People who are intelligent, success oriented, technically skilled, trained in the latest technology, and able to communicate effectively. This can be achieved through education and training.

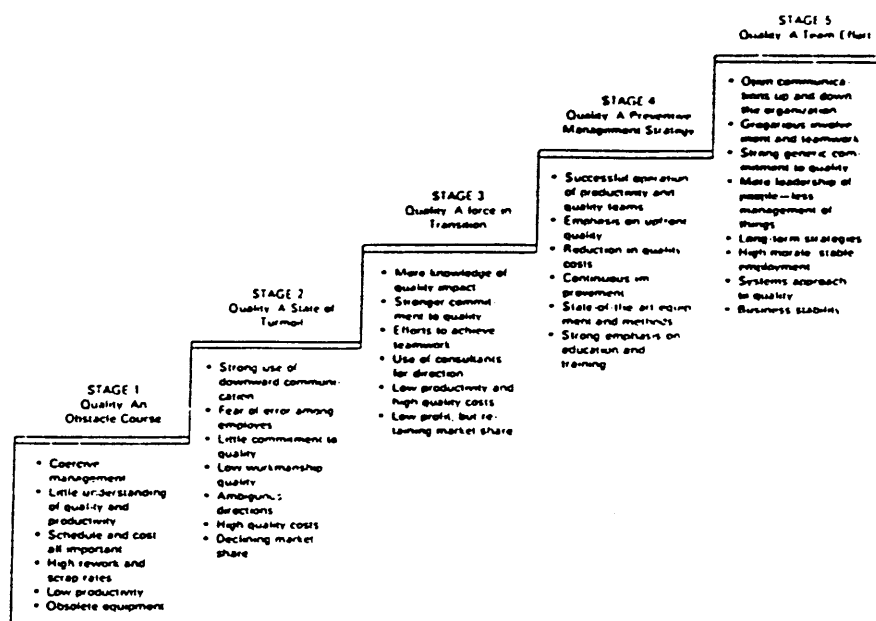


Fig. 6.1 Up the Staircase to Quality and Productivity Improvement

6.3.1 Education for Quality

Education for quality should start early. Young engineers should be taught the importance of quality. Quality management courses should be made as part of the formal academic curriculum.

Elements of QA Education

Quality improvement is not a goal but a direction. It is part of the cultural change of the organisation that it will not see itself stable or static but will rather regard itself as a dynamic and growing concept in this ever changing market place.

For any change within an organization to have long term success, four elements must be ensured:

- Attitudinal change
- leading to
- Altered action
- leading to
- financial Benefit to the company
- leading to
- perceived improvement in the trading position

This element chain is vital. Without the earlier elements as prerequisites, each stage is difficult to achieve. The relationship between attitudinal, task, finance and trading position is important and the steady flow from one to another is necessary to maintain a momentum of change.

6.3.2 Training for Quality

Training is the second most important factor in improving quality. For training to be effective, it must be planned in a systematic and objective manner. Quality training must be continuous to meet not only changes in technology, but also changes involving the environment in which an organisation operates and its structure.

Training of workers should go beyond the basic skills to do the job. They should be equipped with problem solving skills, use of initiative and perhaps, most important of all, team work.

Quality training activities can be considered in the form of a cycle shown in Fig. 6.2.

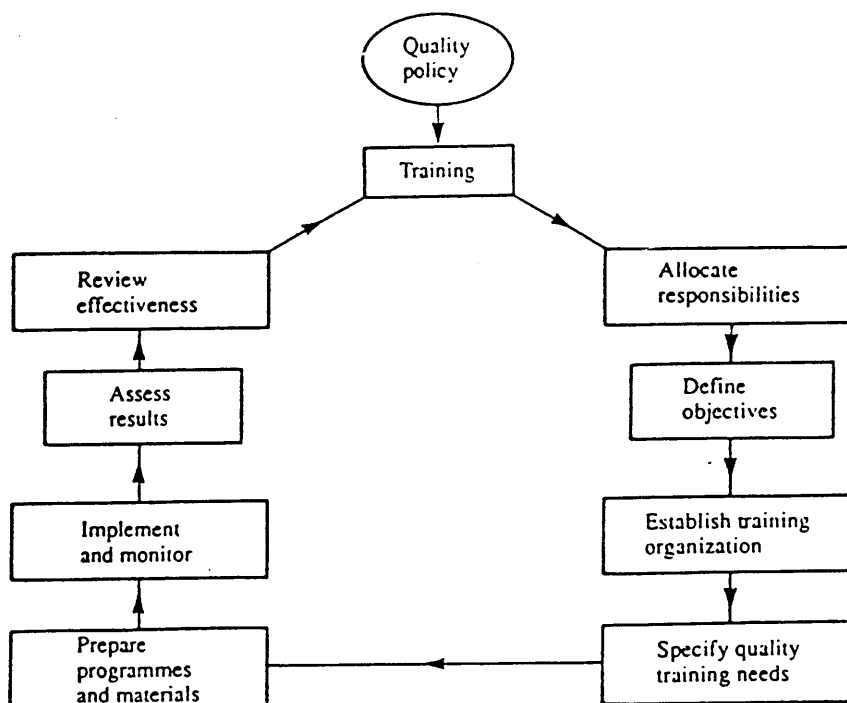


Figure 6.2 The Quality Training Cycle

The main elements of effective and systematic quality training are:

- . Error/defect/problem prevention
- . Error/defect/problem reporting and analysis
- . Error/defect/problem investigation
- . Review

Training Records

Cl. 4.18 of BS 5750 requires that all organisations should establish and maintain procedures for the identification of training needs. These procedures should be designed and documented to include all personnel.

6.4 SPECIFICATIONS AND STANDARDS

Specification is a form of communication between the designer and the contractor, and, as such, forms one of the bases of the construction contract. It is considered as the principle document in respect of attaining quality. Quality specification means better projects, less valid claims, and in the end, higher net earnings for the designer and lower ultimate project costs to the owner.

6.4.1 Writing Specifications

The specification writer must be familiar with contract administration, materials, the variability of workmanship, material sampling and testing needs and construction methods.

Specification Writers must promote open communications not only with contractors, manufacturers and suppliers, but also with inspectors. Feedback from inspectors who may have suggestions for minimizing construction problems, should be encouraged.

A good specification must be fair, reasonable, realistic and brief. To be realistic, quality level should include tolerances based on the natural variability of the material characteristics being considered. Poorly written specifications result in confusion, poor quality

construction, poor quality material, and problems in contract administration.

Quality assurance is deciding what has to be measured and who is going to do the measuring. Quality assurance is already in the specification if they are done properly, if they are not, then the designer gets whatever it was that was specified.

6.4.2 Specification Requirements

Quality specifications should be an on going continuous improvement. One thing that must not be forgotten is that clients' standards are constantly improving. Tolerances which were accepted yesterday might not be acceptable today. Therefore, specifications and standards should not be static but should be open to review and should over a period of time be rewritten to match new requirements.

6.5 THE JAPANESE APPROACH TO QUALITY ASSURANCE

QA in Japan is characterized by company-wide participation extending from top management to the lower-ranking employees. It is an activity centred not only in design and construction but also in management functions such as planning, accounting, business and personnel. QA concepts and methods are used for solving problems in the construction process, for incoming material control, product control, for analyses assisting management to decide on company policy and for checking if top management policy is being carried out.

The results of these company wide QA activities are found to be rewarding, not only in ensuring the quality of product but also in their great contribution to the company's overall business.

What differentiates Japan from other Western countries is that their innovation is not in the product, but in the production process. In other words, what the Japanese have achieved is process innovation rather than product innovation. It is important here to notice that human factors have greater influence on the former than on the latter.

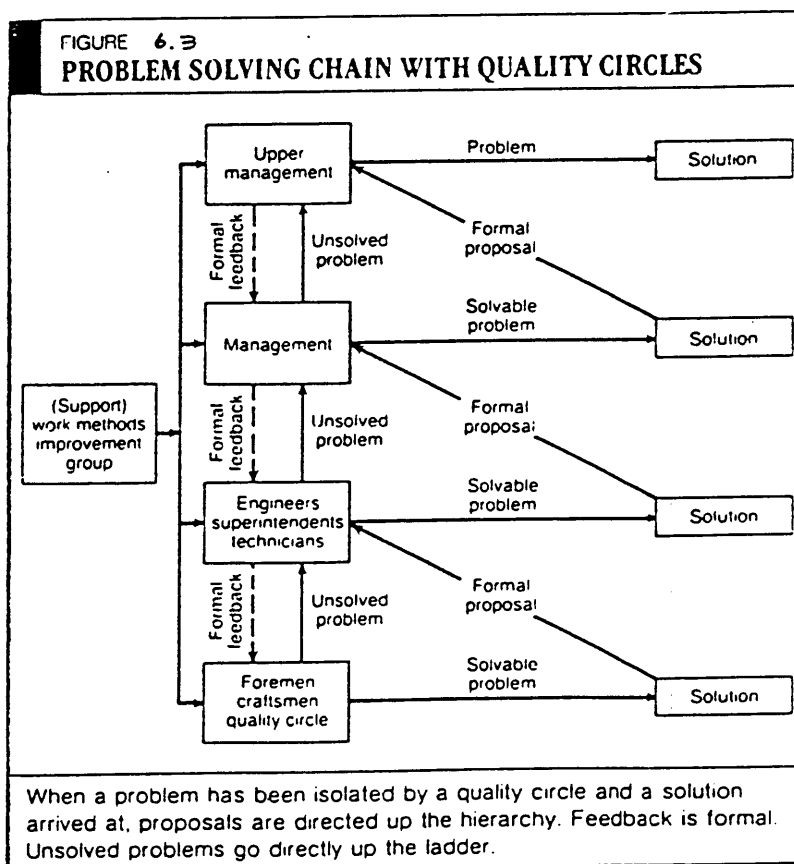
Two of the most publicized aspects of the Japanese QA system have been quality circles and just-in-time concepts. These are briefly explained below.

6.5.1 QUALITY CIRCLES

Definition

Quality circle is a problem solving management concept in which employees or workers from all hierarchical levels meet to discuss their problems, isolate them, assign them priorities and find solutions. Each circle is composed of workers who are working in the same areas and functions (ie track drivers, cement masons). As the project progresses, the number of circles is increased and most of the project activities will be covered by quality circle programmes.

If the workers cannot make the necessary correction, the problem is passed up to the appropriate level of management. It is a bottom up approach to problem solving (see Fig. 6.3). This approach gives upper management more time to make upper management decisions.



Objectives of Quality Circles

- . Develop an effective problem-solving team
- . Improve communications
- . Improve experience, skills and morale
- . Reduce conflicts
- . Improve motivation, productivity and quality
- . Provide a form of continual education in the craft
- . Build in the workers a sense of dignity and a sense of participation in the decision making.

6.5.2 Just-In-Time Concept

Definition

Just-in-Time (JIT) is a management concept credited to the Japanese who developed it and began to use it in the late 1950s. Basically JIT is a disciplined programme for improving overall productivity and reducing waste. This leads to cost-effective production in operation and delivery of only the required goods or services at the right time. This is achieved with the minimum amount of resources - facilities, equipment, material and people. JIT fits well under the QA umbrella, for many of the ideas and techniques are very similar and moreover, JIT will not work well enough without QA in operation.

The real objective of Just-in-Time is "we have only got one piece (equipment or material) so it better be a good one or the work in progress has got to stop!" This way everybody pays more attention to the work in hand. The operator ensures that his machine does not break down and the worker pays more attention to the handling of the material and fixing it right first time. Japanese industry produces small quantities "Just-in-Time" Western industry produces massive quantities "Just-in-Case".

JIT Techniques

Some of JIT main characteristics are:

1. Reduction of inventory level to the minimum: By reducing the inventory level, there will be:

- . Low scrap cost, since defects will be detected early.
- . Fast detection of defects since supply will be frequent and outlots will be small.
- . Reduction in stock and the space it occupies
- . More control on changes during construction

2. Increase the flexibility of the workforce: one of JIT principles is to train people in the workplace to do different tasks so they can be moved around easily.

3. Preventive maintenance: JIT systems rely on preventive maintenance programmes with the aim of preventing breakdown of machines and equipment rather than repairing them once they occur. Unreliable machines cause quality problems, delay and increased amounts of work in progress.

6.6 QUALITY AND SAFETY

Accidents affects crew quality and productivity in that the workers work more slowly and become more cautious. The effect of job accidents on the workforce are both physical and psychological. Closer job control by company management means job accidents and field problems will be minimized. A smooth running job is a safe job. This job control eases the pressure on the field personnel and enables them to feel secure and to work with less frequent interruption. Consequently, this will help the workers to concentrate their attention on their quality of work.

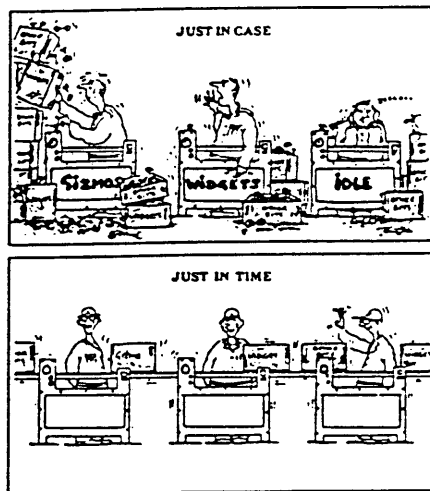
6.7 LEARNING FROM FAILURES

The concept of learning from failures to improve quality is fundamental to the practice of engineering. Codes, standards and design and construction procedures have evolved primarily through a process of trial and error.

Failure usually leads to better understanding of physical behaviour of materials and products. Communication between designers about lessons learned from failure has always been an important component in the advancement of the engineering profession.

Lesson learned from experience, however, should be combined with mathematical theories to predict the behaviour of engineered systems with a greater degree of confidence.

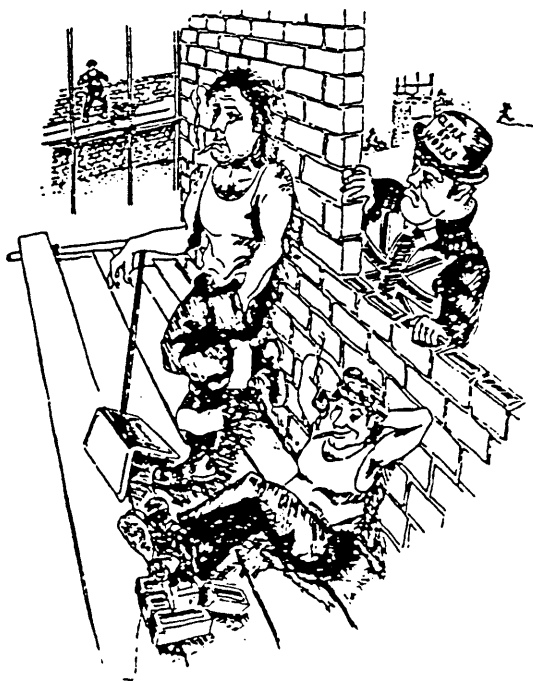
Coordination and recording of failure information will result in improved professional practices and quality in the built environment.



The joys of JIT

CHAPTER 7

*"One wonders if the old breed of watchdog
Clerk of Works is rapidly becoming extinct."*



COST OF QUALITY

7.1 DEFINITION

The term 'quality cost' has different meanings to different people. Some equate 'quality costs' with the cost of attaining quality. Other equate the term with costs of running the quality department (development cost). While others equate 'quality costs' with cost of poor quality (operational cost). These definitions will be explained in this chapter.

7.2 COST-EFFECTIVE QA

Constructing a quality project with a high degree of fitness for purpose, is not enough. The cost of achieving that quality must be carefully managed so that the long-term effect of quality costs on the business is a desirable one. These costs are a true measure of the quality effort. A competitive product or service based on a balance between quality and cost factors is the principal goal of responsible management. This objective which is highlighted in Fig. 7.1 is best accomplished with the aid of competent analysis of the costs of quality. The balance works like this as quality goes down, costs go up, and as quality improves, cost will fall.

Effective QA helps reduce the cost of projects by ensuring that work is done right first time. And because it helps to produce projects that conform to requirements, effective QA in turn helps boost customer-perceived quality. Likewise, quality improvements may

directly increase profits by providing the basis for customer acceptance of higher prices. This is illustrated with the chain reaction in Fig. 7.2.

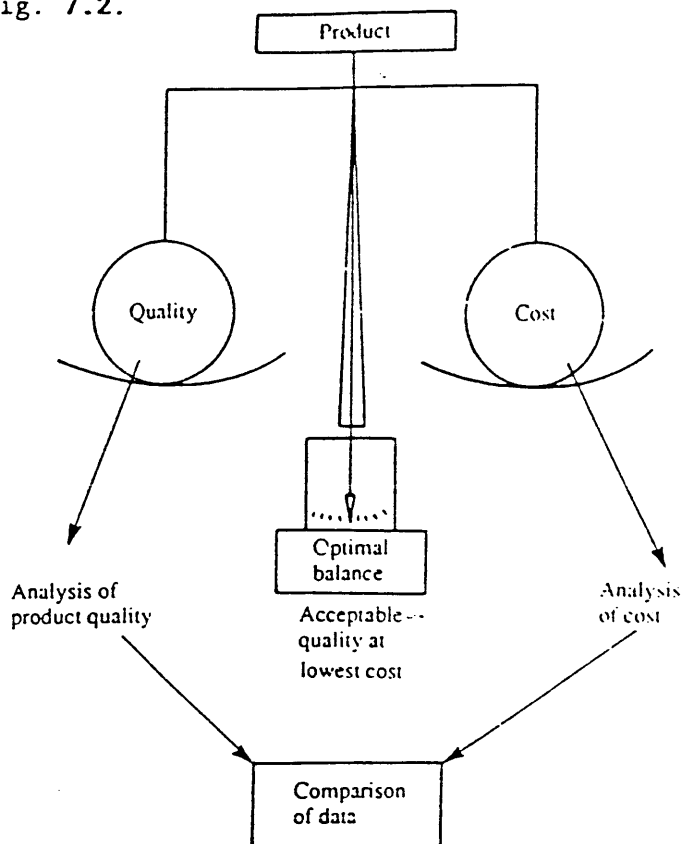


Fig. 7.1 The balance between quality and cost

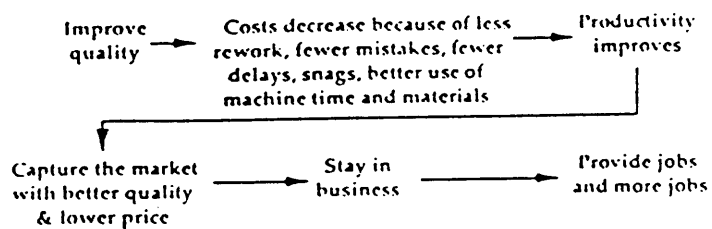


Fig 7.2 Chain Reaction of Quality Improvement

7.3 OBJECTIVE OF EVALUATION

The main objectives which lead companies to go into programmes of evaluating quality costs are:

1. Quantifying the size of the quality problems in language that will have impact on upper management.
2. Identifying major opportunities for cost reduction.
3. Expanding budgetary and cost control.
4. Stimulating improvement through publications.

Evaluation costs should address:

- . Developmental costs
- . Implementation costs
- . Operational costs
- . Certification and assessment costs
- . Saving achieved

The implementation of a quality system requires the investment of time, money and resources. It is essential, therefore, that these costs are known and reported to provide the basis for evaluating the resulting benefits.

7.4 DEVELOPMENT COSTS

Development cost is an investment cost. It is the cost of the resources committed to develop the quality programme. Resources may include , but are not limited to, personnel, external services and supporting facilities. It is difficult to give estimates of costs, as these will depend on the size of the company and the complexity of its operations and how many procedures are to be written and implemented.

There are two categories of these costs: Measurable and hidden.

1. Measurable costs

It is the cost of the appointment of staff to implement the quality system. The appointment of a quality manager may be full time or part time depending upon the size of the company and the number of QA staff required. He may be an external appointment or somebody delegated the responsibility with the Company. In the latter case the cost of training should be considered. If a full time manager is employed then the cost to the company will be in the region of £30,000 - £35,000 per annum. Other costs may occur, if more staff are required to be present on the construction site. Costs of documentation preparation are to be included as well.

2. Hidden costs

These are the costs of time and lost production of the personnel involved in QA programme. This being the value of the work that they would otherwise have contributed to the Company.

7.5 IMPLEMENTATION COSTS

Implementation programmes include the requirement to set up education and training sessions, technical library and to improve the existing filing system to cope with the increase in documentation. It as been noted that, initially, these costs will be high but then decline rapidly and remain at a reasonable level.

Little published data has been found for quality development and implementation costs in the construction industry. However some large companies reported that these costs are in the region of 1% - 3% of construction costs.

7.6 OPERATION COSTS

These are the costs of poor quality. They can be divided into three categories:

1. Prevention costs
2. Appraisal costs
3. Failure costs

7.6.1 PREVENTION COSTS

These are the costs of all activities undertaken to prevent mistakes from happening in the first place. These include: quality and reliability of administration, quality data, quality plans, contracts procurement and supplier appraisal, programming; process capability studies, quality audits, tool control, general cleanliness on site and preventive maintenance.

7.6.2 Appraisal Costs

These are the costs incurred to determine the degree of conformance to quality requirements. These include the costs of checking during design and development; supervision; inspection and testing during and on completion of construction.

7.6.3 Failure Costs

These are the costs arising within and outside the organization of the failure to achieve the specified requirements in the most efficient manner. These include: scrap; rework; loss of production capacity; interference with construction schedule; time for investigation of the problem and complaints; replacement of material, transport cost; accounting costs; damage claim, legal costs,; increased insurance premium and loss of market.

7.7 DEVELOPMENT AND OPERATION COSTS RELATIONSHIP

In order to reach an optimum level of costs, a relationship between development costs and operation costs should be established. A model called SCORE (system cost optimization range estimate) is proved to be useful in this context. Of its three curves (shown in fig. 7.3) the first (curve 1) represents the development cost, initially low but increasing as quality rises. The second (curve 2) is the operation

costs, with initial high cost of a low quality product or service then it falls through reduction in failure and appraisal costs.

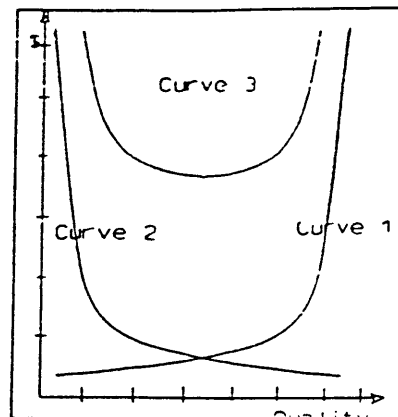


Fig. 7.3 The SCORE Model

The third (curve 3) represents the total cost curve for both development and operation costs, with a point where the relationship is optimal.

This model provides the theoretical framework for quantitative decision making and an opportunity to evaluate and present the development-operation costs relationship for each system.

The limitation of this model is that considerable data is required to construct such curves. However much of the value in the SCORE model is its ability to aid understanding of quality cost.

It has been observed, in a survey carried out by ASCE: 1985, that 7 $\frac{1}{2}$ % of construction dollars are wasted due to poor quality. Contractors spend up to 15% of their labour costs correcting mistakes. The cost of quality control is equal to the cost of correcting mistakes. They concluded that QA procedures can be set up for 1% - 1 $\frac{1}{2}$ % of a total project cost that will prevent between 15% - 40% of errors on the job.

7.8 CERTIFICATION AND ASSESSMENT COSTS

Certification is optional and costs may only be considered when the company have a documented QA system which is approved in accordance with the appropriate part of BS 5750.

The costs of certification include:

1. Application fee
2. Preliminary visit and assessment and travel costs
3. Certification fee
4. Internal costs incurred in preparing documentation
5. Any costs to verify corrective action before the award of a certificate
6. Routine assessment fees.

These costs vary according to physical size of organization, company/divisional split, range of products/services, off-site activities, number of non-conformities raised and complexity of written system.

Some of these costs have been published in the recent CIRIA report 72 (1989):

- Initial application fees vary from £300-£500
- Assessment fees are typically about £300-£400 per man-day
- Annual costs might be about £500-£2,000

There are also some guidelines published by the National Accreditation Council for Certification Bodies on typical time requirements for initial assessment. These are shown in table 7.1

	BS 5750 Part 1 LARGE	BS 5750 Part 1 MEDIUM	BS 5750 Part 1 SMALL	BS 5750 Part 2 LARGE	BS 5750 Part 2 MEDIUM	BS 5750 Part 2 SMALL	BS 5750 Part 3 ANY
Low	9.5	7.5	5.5	7.5	5.5	4.5	-
High	16.5	12.5	8.5	13.0	9.0	7.0	3.5

Notes

1. Large company : 600-1500 employees
Medium company : 100-400 employees
Small company : 15-60 employees
2. Travelling time excluded.

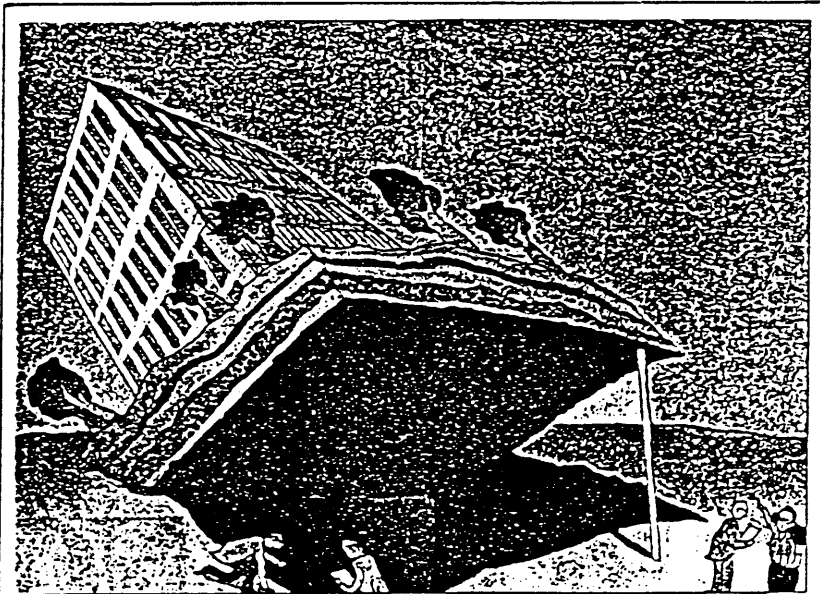
Table 7.1 Quality System Assessment Typical Times for Initial
Assessment to BS 5750 (man-days)

7.9 SAVINGS

The savings are almost impossible to quantify, because the same contract cannot be completed and costed, both with and without QA. But possible areas of saving costs can be indicated.

For the designer, these include less redesign and less overlap of inspection. For the contractor, they include less remedial work and less wastage of material. Both designer and contractor benefit from completion on time (lower overheads), easier settlement of claims and payment on time.

CHAPTER 8



Where did we go wrong?

IMPLEMENTATION AND PROBLEMS

8.1 PLANNING THE IMPLEMENTATION OF QA

In order to create and implement an effective QA system several steps should be taken. These are shown in Fig. 8.1. The preliminary stages of understanding and commitment are vital first steps which also form the foundation of the whole QA structure. Too many organisations omit these phases, believing that they have the right attitude and awareness, when in fact there are some fundamental gaps in their quality credibility which might lead to difficulties and the collapse of their programme.

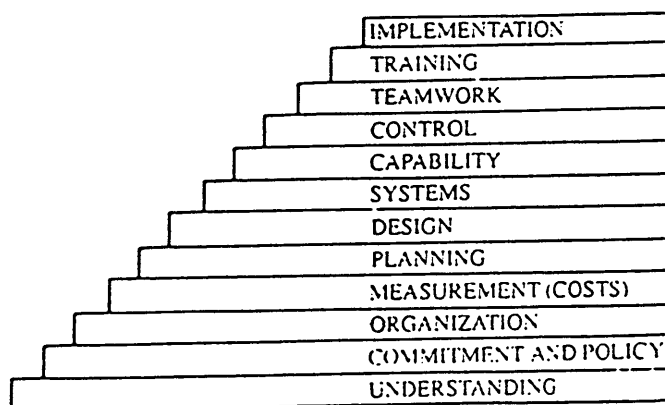


Fig. 8.1 The Steps to QA

Implementation begins with the quality policy statement and the establishment of the appropriate organisational structure, both for managing and encouraging involvement in quality through teamwork.

Collecting information on how the organisation operates, including the costs of quality, helps to identify the areas in which improvement will have the largest impact on performance. Planning involves putting quality assurance systems in place to drive the improvement process and solve the problems using corrective action procedures.

Once the plans and systems are in place, continued education, training and communication are important.

These major steps may be used as an overall planning aid for the introduction of QA, and they should appear on a planning or Gant chart (Fig. 8.2). Major projects should be time-phased to suit individual organisation's requirements. The main projects may need to be split into smaller sub-projects, which is true for quality system work.

The education and training elements will be continuous and draw together the requirements of all the steps into a cohesive programme of introduction. It may be useful at various stages to develop checks to establish the true progress.

The launch of quality improvement requires a balanced approach and the three major components (quality system, teamwork and process control) must be 'fired' in the right order to lift the campaign off the ground (Fig. 8.3). This figure shows that a quality system on its own will not work, it must have the boost of improvement teams and process control to increase its capability which in turn leads to increase of market share.

8.2 HOW LONG SHOULD THE IMPLEMENTATION TAKE

The time scale for implementing QA depends on many factors such as complexity of the organisation, culture, attitude of people and resistance to change. It has been mentioned earlier that QA is a philosophy that requires a fundamental change in behaviour, as sometimes even if all the necessary resources are made available, a company might not be able to implement QA in a short time. The

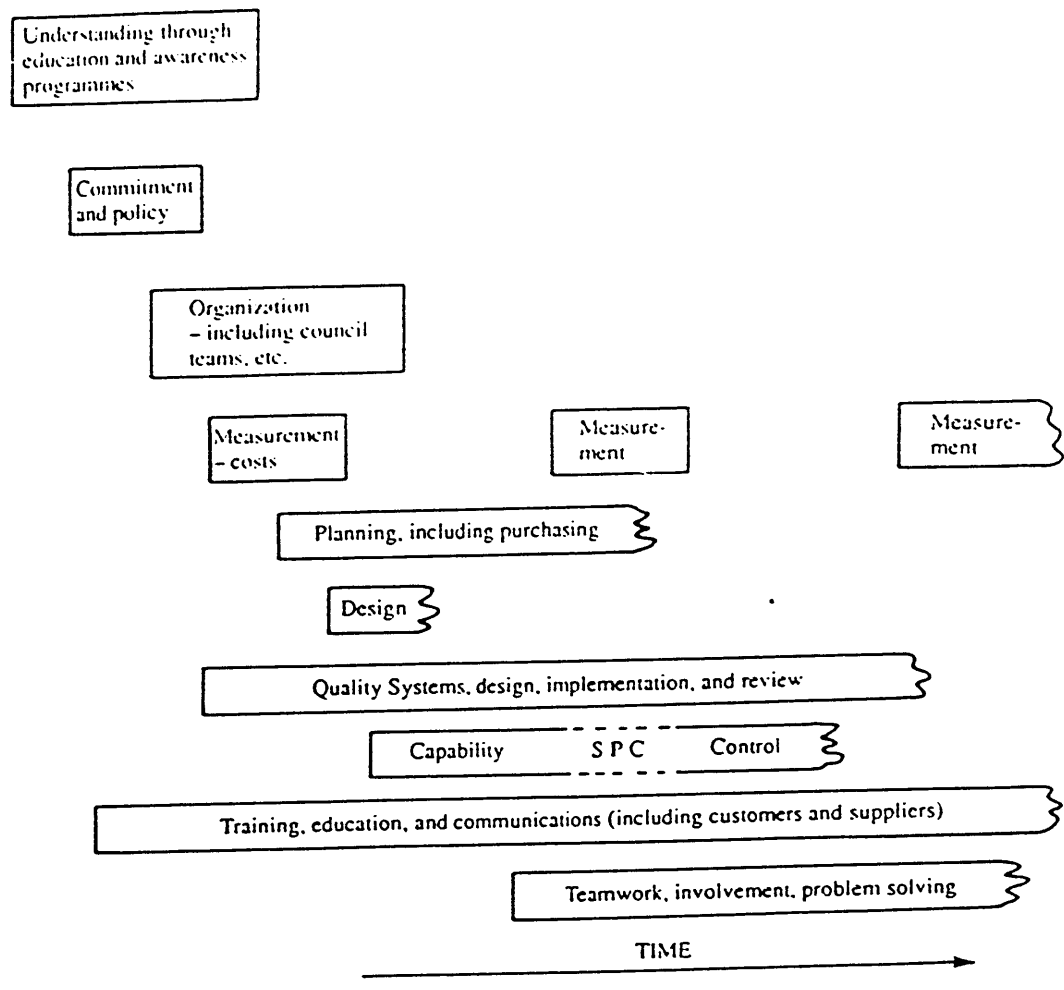


Fig. 8.2 Planning QA Implementation

changes are so fundamental that it takes time for the philosophy to be absorbed into the day-to-day running of the company.

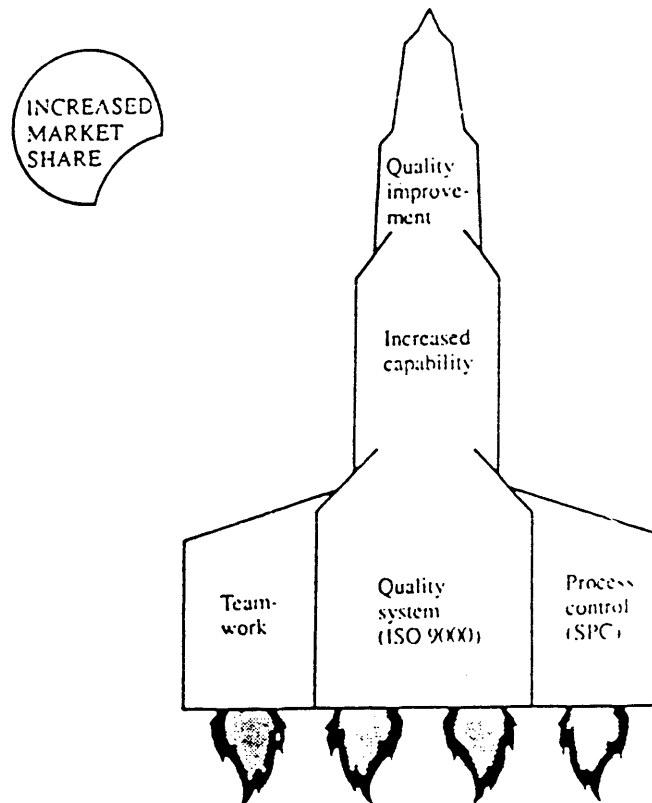


Figure 8.3 Launching Quality Improvement

Overall, companies that have successfully implemented QA have found a time scale of one year to be ideal. Why one year? First, there is little problem in obtaining the financial resources quickly. Second, a shorter time may not enable the necessary changes in attitudes to take place. Third, if longer than a year, there is a risk that enthusiasm for QA will wane since results will take longer to arrive. Furthermore, with a timescale longer than one year, key personnel, especially in the construction industry, are more likely to move on or be transferred from their posts.

8.3 PROBLEMS FACING QA IMPLEMENTATION

It has been reported by those who are implementing QA and those who are in the process of implementing it that it is not without its problems. Some of these problems that have been seen to be blocking the road to QA include:

1. Lack of penetration of QA concepts within the workforce. This is caused by:

- . no formal strategy
- . failure to provide incentives by recognition
- . lack of effective communication
- . narrowly based training

One approach which should not be used to correct these difficulties is a financial incentive; it does not form part of QA culture. Recognition and involvement are the only effective incentives.

2. Resistance to change: people are slow to change because they reject newness. This is the main obstacle which might face the implementation in that people often object to a revised work method. To overcome this problem, the following steps may be considered:

- a. Provide participation particularly by those members who will be directly affected by the change
- b. Provide enough time to allow them to evaluate the impact of the change.
- c. Treat people with dignity while introducing the system.
- d. Try a programme of persuasion.

3. Mobility of top management: in an environment where top management as well as other people have no root in the company and have moved around so often, will find difficulty to be committed to any policy.

4. Expectation of instant results: an important obstacle is the belief that improvement of quality is accomplished suddenly by

implementing QA system. All involved must be made aware of the 'long term' work required before significant Quality benefits are visible.

5. Inadequate external assistance: the actual implementation of QA system will be achieved by company personnel, but the problem is to assume that they have all the knowledge and experience necessary. The expertise of an external consultant will be, therefore, invaluable in the training and implementation.

6. Failure to view QA as an on-going process: Quality improvement should not be viewed as a short term effort but should be expected to produce returns for years to come. This will happen if education, etc. is maintained. The QA system should become part of the everyday life of the organisation.

To attempt to reduce some of these problems and difficulties, various sector schemes are being developed, the FCEC and BSCA schemes are examples.

6.4 LESSONS FROM QA IMPLEMENTATION

The basic lesson learned from those companies with most success in implementing QA can be summarized:

- . QA is hard work.
- . To establish a QA system takes longer than first thought.
- . QA needs to be 'driven' through the whole business.
- . Top and middle management commitment is vital.
- . QA staff must balance their enthusiasm with practicability.

8.5 COMPUTERS IN QUALITY INFORMATION SYSTEM

In order to be sure of meeting client requirements it is necessary to create a quality information system. Computers may be used in such systems since the task of collecting, recording, and analyzing of data and information are easily automated.

Application of software packages are now available which have been purpose-designed for quality information systems. The basic requirement of any such package is for it to drive the preventive model of quality assurance (Fig. 8.4). It should include all the techniques necessary to implement the process control strategy and when problems occur operate a stepwise procedure to;

1. identify the problem
2. identify the cause of the problem
3. eliminate the cause of the problem
4. continuously monitor the process of recurrence of the problem

It should be borne in mind, however, that human managerial decisions must interface with the package in this procedure, particularly during elimination stage.

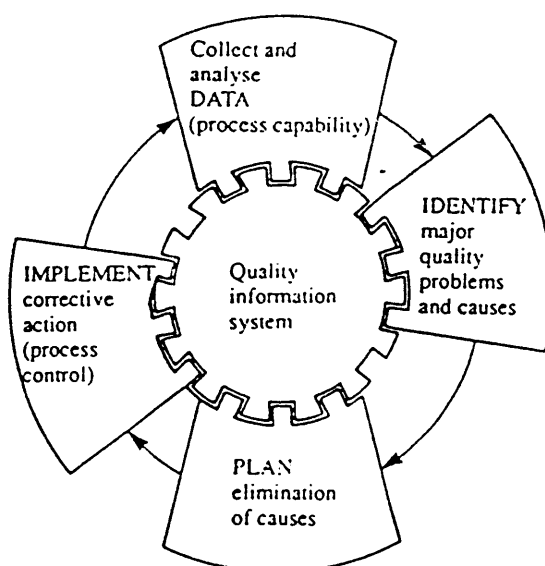


Figure 8.4 The Quality Information system 'drives' preventive quality management.

8.5.1 Construction Quality and Computers

The main role for computers in construction is their ability to allow all project team members convenient access to vital project information. As mentioned earlier, exchange of information among

project team members presents an important opportunity to assure quality in design and construction.

Computers allow construction personnel to accurately and rapidly monitor changes in contract commitments, costs, schedules, impact of change orders, subcontractor relationships, material deliveries, and many other aspects of the project. As the job progresses, profit and loss can be monitored, productivity can be improved and problems can be identified early.

Quality computer systems require contractors to select appropriate software and hardware and to develop specific objectives and responsibilities from the selected system.

Some of the computer applications in construction management are: change order; account payable; job cost reporting; cash flow reporting; action lists; network logic (CPM); bid evaluation; shop drawing control. In addition to these administrative functions, computer systems can assist contractors in other areas such as:

- . Telecommunications to connect remote sites by using dial-up telephone lines
- . Computer-aided design (CAD)
- . Income property analysis.

CHAPTER 9



CHAPTER 9: CONCLUSION AND RECOMMENDATIONS

9.1 GENERAL CONCLUSION

The study has highlighted many aspects of Quality Assurance. The points which the author considers to be especially significant are listed below.

. QA emphasizes that quality is a managerial function in which the quality of materials, process and product is controlled for the purpose of preventing defective products. To meet this responsibility, organisations must develop systems to prevent, detect and correct errors that occur in the steps of the construction process. This implies that to achieve the control of quality, the variables which may affect quality and which can result from the actions of men, the nature of materials and the performance of machines, must be controlled.

. Defining quality as conformance to requirements provides an objective basis for measuring quality and certain related costs, provided the requirements are clearly defined.

. Human factors are dominant in QA. These include motivation, self control, moral and ethical values, and education for all participants in the construction process. Individual commitments to quality are essential.

. QA system provides the opportunity to review, improve and co-ordinate the system in operation. This could help reduce costs and could identify areas that require concentration of effort to improve quality. Adoption of a formal quality system demonstrates a long term

commitment to quality, especially where third party certification is sought and maintained.

. The steps in establishing and maintaining a quality system may be summarized as follows:

- Establish policy (where are we going?)
- Set objectives (what route shall we take?)
- Develop systems (how shall we travel, and who drives?)
- Implement system (start the journey)
- Audit (are we on the right track?)
- Review and improve (can we find a better way?)

. It is the management and the work force together who must produce the necessary procedures and to be responsible for producing quality. QA personnel can only monitor, audit and review the work. The main drive to make the system succeed must come from the management.

. There are several requirements for QA to be achieved in construction:

1. Clear definition of the responsibilities of the project team (owner, consultant, contractor).
2. The need for knowledgeable field representatives who should be familiar with the design who can really influence construction quality.
3. Construction quality must be 'built in', rather than 'inspected' in the final product.
4. Quality must be achieved within the constraints of the project.
5. Availability of realistic and accurate plans and specifications.

. Employees and workers at all levels should be convinced that concern for quality is a requirement of their jobs. Management must explain clearly why quality is important and express these concerns in

company communications, training and motivation programmes. Comprehensive training for all levels of management and workers should teach techniques such as "quality circles" and "Just-in-Time" to improve quality.

. Monitoring 'cause and effect' of decisions taken during the design and construction process is fundamental if the benefits, through planned corrective action, are to be correctly measured. Feedback therefore, is an essential component of a QA System.

. The cost of quality is defined as the sum of the costs associated with quality assurance efforts and with correcting errors.

QA is expensive to introduce, expensive to run initially and cost effectiveness is only gained slowly with time. There is also a relationship with company size and complexity. A well understood QA methodology is essential to contain development costs. There is an optimal point in cost effectiveness which should not be exceeded.

. The task of implementing QA needs effective leadership, teamwork, understanding and commitment by senior management together with explicit quality policies. Only then the success will be guaranteed throughout the entire organisation, which in turn generates a momentum for quality improvement of products and performance.

. Implementation time scale of a QA system should neither be too long nor too short. If it is too long then it risks enthusiasm being lost, whilst one that is too short risks false economies being made. A reasonable timescale of initial implementation is about one year.

9.2 THE BENEFITS OF QA

The benefits of introducing QA as a management technique in the construction process may be summarized as follows:

1. The client receives assurance that the structure he ordered has been constructed in accordance with established work procedures, using materials of specified quality.
2. The contractors procedures become more efficient, wasteful practices are reduced and communications within the company improves because the responsibilities of people involved in construction are better defined.
3. The contractor has a better chance of meeting his budget and completing the project on time. Any disputes which arise should be settled more easily by reference to the project quality records.
4. Communications between the parties to the construction work (owners, consultants, contractors, sub-contractors, etc.) improve through the use of more formal channels of communication.
5. More work is produced 'right first time', and cost savings are made because less remedial work is required.
6. Project information, drawings, specifications, etc. are supplied by the client's representatives more systematically. Specifications should also be clearer.
7. Young engineers gain experience with greater confidence, since the written procedures they are asked to apply have been prepared by engineers more experienced than themselves.
8. The contractor obtains assurance through audits and corrective action that his project management is operating correctly.
9. Improvement in the control over suppliers and subcontractors, especially those subject to third party certification.
10. Improved safety conditions by reducing the frequency of incidents caused by inadequate procedures.

11. Assurance that steps will be taken to make all the relevant information available before design or construction commences.
12. Better basis on which to select companies able to provide a specified level of quality.

9.3 RECOMMENDATION

The following recommendations are suggested to improve the level and quality of QA in construction.

1. Much more work needs to be done, both in terms of containing field trial and further quality-related studies.
2. Quality costs need further refinement optimization to make it effective, especially in the area of accurately tracking the true causes of deviation. Companies need to use the system on a number of projects to develop their particular cost of quality relationships and to reach the optimum point where these costs are minimized.
3. Preparation of a document interpreting or extending BS 5750 for the construction industry.
4. Development of QA awareness and training courses, or the assessment and approval of training activities run by others.
5. Research to be carried out on topics related to QA. Examples could be:
 - costs and benefits of QA for different forms of construction.
 - a study of how traditional contracts and relationships between contracting parties will be affected by the implementation of the QA system.

9.4 THE FUTURE OF QA

The Companies which will follow the path of QA implementation will see many benefits. If we look ahead over the next ten years there will be an increasing number of companies moving to QA implementation. The cost benefits ratio is so favourable that the implementation of QA could be seen as perhaps inevitable in all construction companies. The real question is not whether a particular company will implement QA, but when.

For this to happen requires considerable changes in construction management approaches. Managers with sound experience of implementing QA will be in short supply and will be sought after. It is this shortage of expertise that will be a major constraint on the spread of QA and it will probably be a major responsibility of universities, colleges and professional societies to provide support services to allow QA to spread more quickly.

9.5 GENERAL COMMENTS

The study has been a very wide ranging overview of QA in construction. It has been written with the intention of introducing the newcomer to QA whilst critically exploring the whole concept of QA as a management tool.

It is the author's firm conviction that QA points the way forward into the 1990's for the construction industry. Many new constraints are already to be seen, the 'Green' Revolution and the protection of the environment, the radical political changes in the East, the force of the new European market, the likelihood of changes to existing energy sources hierarchy in the Middle East - all will greatly influence the construction industry in the coming decade and beyond.

In order to be competitive and efficient the industry must adapt and be capable of producing quality, safe, durable products to price and programme.

QA appears to have the potential to help management to react and compete in this rapidly changing world.

"There is gold in the mine - you just have to dig it out!" quality assurance can provide the shovel.

APPENDICES



EXAMPLE STATEMENT OF COMPANY QUALITY POLICY

The company carries out civil engineering construction*

The company places particular emphasis on obtaining client satisfaction by:

- meeting the specification set by the client,
- efficient construction, with value for money, and
- adherence to construction programmes and budgets.

To meet the specified requirements of the client, the company applies a quality system in conjunction with other management controls. The quality manual describes this system, and includes the allocation of responsibilities to company staff and the processes which substantiate the effectiveness of the system.

Assurance that the specified qualities are attained is provided by the application of a comprehensive range of formal and documented procedures meeting the requirements of BS 5750: 1987: Part 2.

Signed: _____ Date: _____

Designation: _____

Director responsible for quality assurance
(Managing Director or Chief Executive)

**Other activities such as building or mechanical services should be substituted or added as appropriate*

APPENDIX 2 CHECKLIST FOR MATERIALS QUALITY ASSURANCE/QUALITY CONTROL

	YES	NO	N/A
1. Quality Plans: Contents	_____	_____	_____
A. Responsibilities for quality	_____	_____	_____
B. Supplier performance evaluations	_____	_____	_____
C. Design and Specification reviews	_____	_____	_____
D. Supplier quality programs	_____	_____	_____
E. Coordination of inspections in plant	_____	_____	_____
F. On-site quality control	_____	_____	_____
2. Organizational	_____	_____	_____
A. Quality training programs: supervisors/ engineers	_____	_____	_____
B. Quality training programs: inspectors/craft	_____	_____	_____
C. Quality responsibilities defined and understood	_____	_____	_____
D. Quality manager designated	_____	_____	_____
E. Quality performance a factor in personnel evaluations	_____	_____	_____
3. Design and Specification	_____	_____	_____
A. Design review system	_____	_____	_____
B. Design complete before purchase	_____	_____	_____
C. Design change program includes effect on materials	_____	_____	_____
D. Specifications kept current	_____	_____	_____
E. Standards current, accurate, applicable	_____	_____	_____
F. Standards readily available to suppliers	_____	_____	_____
G. Specifications revised for errors, consistency	_____	_____	_____
H. Coordination with materials management	_____	_____	_____
I. Submittals clearly defined	_____	_____	_____
4. Supplier Relations	_____	_____	_____
A. Prequalifications include quality history	_____	_____	_____
B. Quality evaluations in selection of certain suppliers	_____	_____	_____
C. Supplier quality performance computerized	_____	_____	_____
D. Supplier contacts through buyers	_____	_____	_____
E. Formal supplier quality programs on certain critical items	_____	_____	_____
F. Suppliers aware of acceptance procedures	_____	_____	_____
G. Supplier aware of submittal requirements and implications	_____	_____	_____
5. Preshipment Quality Control	_____	_____	_____
A. In-plant inspection need evaluated	_____	_____	_____
B. Inspection coordinated with suppliers	_____	_____	_____
C. Inspection levels specified	_____	_____	_____

- | | | | |
|--|-------|-------|-------|
| D. In-house versus contract inspection services evaluated for cost, qualifications, specialization | _____ | _____ | _____ |
| E. Specifications reviewed with suppliers | _____ | _____ | _____ |
| F. Test notification procedure set | _____ | _____ | _____ |
| G. Witness and hold points defined | _____ | _____ | _____ |
| H. Release for shipment procedure understood | _____ | _____ | _____ |
| I. Nonconformances noted in writing | _____ | _____ | _____ |
| J. Materials management informed of progress of inspection releases and nonconformances | _____ | _____ | _____ |
| K. Deficiencies follow-up | _____ | _____ | _____ |
| L. Certifications correct and properly signed | _____ | _____ | _____ |
| 6. On-Site Quality Control | | | |
| A. Responsibilities for verification, handling, storage, acceptance established | _____ | _____ | _____ |
| B. Incoming shipments checked properly | _____ | _____ | _____ |
| C. Overages, shortages, and damages reported to carrier and supplier | _____ | _____ | _____ |
| D. Items checked for packing and marking | _____ | _____ | _____ |
| E. Defects noted on shipping documents (Do not reject shipments) | _____ | _____ | _____ |
| F. Damaged items segregated | _____ | _____ | _____ |
| G. Material receiving reports show deficiencies | _____ | _____ | _____ |
| H. Supplier notified to repair or replace damaged or short items | _____ | _____ | _____ |
| I. Manufacturer's instructions available | _____ | _____ | _____ |
| J. Adequate lift capability and equipment available (spreaders, dunnage, etc.) | _____ | _____ | _____ |
| K. Storage areas predesignated | _____ | _____ | _____ |
| L. Storage areas for critical items clean, humidity controlled, well ventilated | _____ | _____ | _____ |
| M. Equipment properly maintained in storage (rotation, mechanical functioning, lubrication, etc.) | _____ | _____ | _____ |

APPENDIX 3 ENGINEERING FIRM QUESTIONNAIRE TO BE INCLUDED WITH
LETTER INVITING CONSULTANTS TO SUBMIT PROPOSAL

1. Firm name
2. Business address
3. Telephone
4. Year established
5. Type of service(s) particularly qualified to perform
6. Names of principals of firm and their experience
7. Names of key personnel, with experience of each, years of membership in firm, and type of specialization
8. Number on staff at this time
9. Present Activities:
 - Number of Projects:
 - Estimated Construction Cost:
10. List of completed work similar in nature to this project
11. References

APPENDIX 3 . SAMPLE CONSULTANT SELECTION RATING FORM

(PROJECT NAME)

Name of Consultant

Criteria	Maximum Point Assignment	Point Rating
1. Technical experience	25	—
2. Past performance/reputation (references from clients, number of years in business)	25	—
3. Staffing (number of personnel available for this project—project manager)	20	—
4. Project approach and objectives (concept of project, innovations, familiarity with project site, time schedule)	25	—
5. Proximity (time distance from consultant's office and project)	5	—
TOTAL	100	

NAME OF RATER _____ TOTAL RATING _____

Appendix 4: Case Study

MANAGING QUALITY INTO THE WORKPLACE

HOWARD A. PEEK AND DONALD J. BROWN*

Introduction

In February, 1983, our organization began a process designed to enhance attitudes about quality in every individual member of the organization. The process requires educating each individual, from Chief Executive Officer to Mail Room Clerk to Laborer, in the principles of Quality Improvement as we now define them. To date, one thousand officers and managers have attended either a 2½ day, or a 4 day training course to learn the principles of managing the Quality Improvement Process. Additionally, almost nine thousand supervisors and employees have attended quality training programs to learn the individual's role in quality improvement. The education effort was predicated on management's conviction that quality, as defined here, must be first among equals with schedule and cost; that is, we must deliver our product or service on time, at the agreed upon price and in conformance to the contract, right, the first time. In order for that to happen, each individual must understand and be committed to quality and to Brown & Root's Quality Improvement Process. We instituted a system of "Quality Management" — a systematic way of guaranteeing that organized activities happen the way they were planned. We formed Quality Improvement Teams at each functional level of the organization to devise methods to improve communications, solicit suggestions for improving our work methods, and investigate and correct situations and conditions that hinder individual employee's ability to do their jobs right the first time. We stress teamwork, recognizing that no one can cause quality improvement alone. We have formed Corrective Action Teams, down to the field crew level, to identify and correct problems as they arise, and to plan preventive measures to keep problems from arising. Traditionally, each individual or operating unit has adopted some abstract definition of quality. We now have only one definition which everyone can understand. The system of quality control has been to detect the defect and fix it. Our system is, ultimately, to prevent the defect from occurring. Formerly the performance standard was a comparison to past performance — "We reworked 10% of the fabricated pipe on the last job, and our rework is only running 8% on this job so we are doing well." Now our performance standard is zero defects — do it right the first time every time. Measurement, too, was a comparison to historical ratios — "Historically, on a project of this type, surplus runs about 9%. Our surplus is running 8½% so we are OK." Now we are calculating the cost of all nonconformances for the purpose of improvement, and applying the standard, Zero Defects.¹ The traditional management approach to quality as opposed to our approach may be seen as follows:

*Howard A. Peek, Construction Manager
Donald J. Brown, Ed.D., Senior Manager, Performance Improvement
Brown & Root, Inc., P. O. Box Three, Houston, Texas 77001

TRADITIONAL MANAGEMENT APPROACH

Expensive, solid, pretty, shiny, big, bright, etc. (Opinion)

Defect detection and correction. (Fix it)

That's close enough

Comparison to historical defect ratios. (Acceptable Quality Levels)

Definition

System

Performance Standard

Measurement

BROWN & ROOTS APPROACH

Conformance to agreed requirements the first time every time.

Improvement through defect prevention.

Zero defects.

Cost of nonconformance in dollars

Zero Defects Concept

The concept of Zero Defects, traditionally maligned and misunderstood, does not mean that no one is ever allowed to make a mistake. Rather, it is a sub-system within the quality improvement process. The concept, Zero Defects, is an attitude and a process. The attitude, adopted by each employee is one of commitment. It says, in effect, "I will do my very best to do my job right, in conformance to requirements, the first time, every time." To implement the process, when one does make a mistake, the employee:

- 1) Defines the situation — What is wrong with this piece of work?
- 2) Fixes it — make the nonconforming product conform to requirements. This step is designed to keep a defective product from reaching the client.
- 3) Investigate the defined situation to identify the root cause of the defect. This can be done by oneself, or as a team effort with co-workers, supervisors, vendors, etc.
- 4) Once the root cause is identified, take action to remove the cause so that that defect never occurs again. It is through the systematic elimination of individual defect causes that we approach the goal of Zero Defects.

No one can cause quality improvement alone. It takes a coordinated effort by all parties to the project; client, contractor, sub-contractors and vendors. Requirements, stated in such a way that they cannot be misunderstood, are solicited from clients, provided to employees and negotiated with vendors.

Supplier Quality

A significant element of the quality improvement process is contractor-vendor relationships. These relationships are developed and maintained by a Supplier Quality management team. Working in concert with key suppliers, teams are established to enhance communication, establish requirements and plan for the

elimination of defects in vendor supplied items. The contractor's team is comprised of representatives from procurement, QA/QC, engineering and operations. Regularly scheduled meetings between the contractor and vendor teams identify potential problem areas and plan for problems not to occur. Through these teams we have gained valuable insight in each other's operations and identified problems and constraints we tend to impose on one another. Specific successes to date have resulted from the improved communication systems which are a natural by-product of the quality improvement process.

One vendor had long experienced problems in matching mill test reports (MTR's) with shipments, causing our company extensive record keeping difficulties. Through team negotiations, the vendor initiated a system whereby their internal records do not indicate an order to be complete until mill test reports are received by our project. The MTR's provided traceability of the materials for the owner in the event of defects.

Receipt of MTR's was a client requirement. We were unable to meet this requirement when the supplier did not provide the reports. Consequently, Brown & Root was expending excessive manhours expediting the reports, invoices from the supplier were delayed, and, we were often obliged to request the client to issue waivers and/or change orders.

As a result of the supplier quality team efforts, the supplier began listing all MTR requirements on its order to the producing mill as a line item. The order was not considered complete and payable until the MTR's were received.

When all parties to the process understood and complied with the requirements, the problem ceased, and all parties benefited. Expediting time and cost were reduced, work proceeded on schedule without the need for waivers and change orders, and the vendor was paid in a timely manner.

Another vendor was experiencing difficulties in the timely delivery of critical components to our project. Traditional contractor-vendor interface methods would have eventually solved the problem, but only after considerable delay and increased cost. The supplier quality management teams were able to quickly identify and remove the source of the problem before it severely affected cost and schedule.

Planning

The system, prevention, involves the design of a structured planning methodology to identify potential areas of concern and planning them out of the work process.

On our construction projects, structured planning begins at the project manager level, then cascades downward through the crafts to the crew level. Each level of the project hierarchy understands which functions they have responsibility for planning and each planned activity is coordinated up, down and laterally as appropriate. Nothing is left to chance. Requirements (who, what, where, when and how) are communicated in such a way that they cannot be misunderstood. Potential problem areas are identified and discussed, preventive measures taken and alternate plans devised to deal with problems should they occur. When practical, the crews assigned to do the work walk the area with the foreman or superintendent to familiarize themselves with the work and ask questions or

make suggestions. Through planning, support functions such as equipment, tools, scaffolding, etc., are provided with sufficient lead time to enable them to schedule themselves to be where they are needed, when they are needed. A specimen of the planning forms used is included as Attachment "A".

Quality improvement teams, comprised of senior site supervisors, are established for the purpose of managing the on-site quality improvement process. It is common practice for a client representative to attend these team meetings. Recognizing the prevention of problems is preferable to fixing them, these teams assist in developing planning systems to prevent defects and improve productivity. The results have been encouraging.

On one project, drawings for a shut-down were received four working days prior to the shut-down. The client estimated the work would take fourteen, 10-hour days to complete. Through application of the structural planning concept, the work was completed in ten, 10-hour, and three, 8-hour days. More significantly, in testing the work, client inspectors found no defects and did not prepare a punch list.

Another shut-down was estimated to require twenty-two people working fourteen, 10-hour days to complete, and require a 140-ton crane for 1½ days. By applying the structured planning concept, the shutdown was accomplished by seventeen people working seven, 8-hour days and use of the crane for 8 hours. Again, testing was successful and no punch list was required.

These successful shut-downs occurred because of accurate planning, quality workmanship and full client and vendor cooperation.

The impact of the quality improvement process on the quality professional has been significant. Most importantly, it has validated his concept of quality; i.e., that quality is attained when the requirements of the specifications, procedures and codes are met. It has also removed him from the position of arbitrator. No longer must he negotiate from that unenviable position because the concept of "that's close enough" is simply unacceptable. The work in question either conforms to requirements or it does not.

The quality improvement process is a major, permanent, and critical element of our company's long range goals. It began with a firm commitment and dedication to quality by our corporate executives. A corporate quality policy, which reads as follows, has been established and communicated throughout the organization:

It is the policy of Brown & Root and associated companies that we perform our jobs and deliver services and products in conformance to agreed requirements. Quality shall be first among equals with schedule and cost. Every individual and operational unit shall adopt a standard of performance that demands conformance to requirements and doing things right the first time.

It has been implemented world-wide and involves every aspect of our business.

We are realizing tangible benefits from the process now, but when it fully becomes a way of doing business throughout the organization, we will have created an environment in which the quality professional can truly do his job.

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