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Total quality management in the construction process

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There is great potential for quality improvement in the construction process. A study of the literature and of surveys conducted in the USA indicated that management commitment to quality and to continuous quality improvement is very important; construction industry professionals are well aware of the importance of quality training; partnering agreements among the parties in the construction process constitute an important step in securing a high quality product; a feedback loop could upgrade the original quality standards used in the industry; the clarity of project scope and requirements as well as of drawings and specifications is a prerequisite for high process quality. © 1997 Elsevier Science Ltd and IPMA

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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 quality management procedures. The manufacturing industry has developed Total Quality Management (TQM) concepts, first applied in Japan and in recent years used in the United States, which have increased productivity, decreased product cost and improved product reliability. These concepts are also applicable to the construction industry. For example, Japanese construction companies, benefiting from the experiences of Japanese manufacturers, began implementing TQM during the 1970s. Even though construction is a creative, one-time process, the Japanese construction industry embraced the TQM concepts that some argued could only apply to mass production.

TQM is an effort that involves every organization in the industry in the effort to improve performance. It permeates every aspect of a company and makes quality a strategic objective. TQM is achieved through an integrated effort among personnel at all levels to increase customer satisfaction by continuously improving performance. TQM focuses on process improvement, customer and supplier involvement, teamwork, and training and education in an effort to achieve customer satisfaction, cost effectiveness, and defect-free work. TQM provides the culture and climate essential for innovation and for technology advancement.

In this paper, TQM concepts and their implications in the construction industry will be discussed. Reference will be made to industry surveys conducted in the USA and to the published literature.

Definition of quality

Quality can be defined as meeting the legal, aesthetic and functional requirements of a project. Requirements may be simple or complex, or they may be stated in terms of the end result required or as a detailed description of what is to be done. But, however expressed, quality is obtained if the stated requirements are adequate, and if the completed project conforms to the requirements.

Law defines quality in terms of professional liability, a legal concept that requires all professionals to know their trade and practice it responsibly. Every architect and engineer who offers his or her expertise to owners is subject to professional liability laws.

Some design professionals believe that quality is measured by the aesthetics of the facilities they design. According to Stasiowski and Burstein,[1] this traditional definition of quality is based on such issues as how well a building blends into its surroundings, a building's psychological impacts on its inhabitants, the ability of a landscaping design to match the theme of adjacent structures, and the use of bold new design concepts that capture people's imaginations. Because aesthetic definitions of quality are largely subjective, major disagreements arise as to whether quality has been achieved or not. Since objective definitions of aesthetic quality do not exist, design professionals generally take it upon themselves to define the aesthetic quality of their designs.

Quality can also be defined from the view point of function, by how closely the project conforms to its requirements. Using this definition, a high quality project can be described by such terms as ease in understanding drawings, level of conflict in drawings and specifications, economics of construction, ease of operation, ease of maintenance, and energy efficiency.

In the construction industry, quality can be defined as meeting the requirements of the designer, constructor and regulatory agencies as well as the owner. According to an ASCE study,[2] quality can be characterized as follows.

- Meeting the requirements of the owner as to functional adequacy; completion on time and within budget; lifecycle costs; and operation and maintenance.
- Meeting the requirements of the design professional as to provision of well-defined scope of work; budget to assemble and use a qualified, trained and experienced staff; budget to obtain adequate field information prior to design; provisions for timely decisions by owner and design professional; and contract to perform necessary work at a fair fee with adequate time allowance.
- Meeting the requirements of the constructor as to provision of contract plans, specifications, and other documents prepared in sufficient detail to permit the constructor to prepare priced proposal or competitive bid; timely decisions by the owner and design professional on authorization and processing of change orders; fair and timely interpretation of contract requirements from field design and inspection staff; and contract for performance of work on a reasonable schedule which permits a reasonable profit.
- Meeting the requirements of regulatory agencies (the public) as to public safety and health; environmental considerations; protection of public property including utilities; and conformance with applicable laws, regulations, codes and policies.

In addition, one should differentiate between 'quality in fact' and 'quality in perception'. The providers of services or goods that meet specifications achieve quality in fact. A service or product that meets the customer's expectations achieves quality in perception.[3] In other words, a product can be of high quality and yet it may not meet customer's needs and vice versa. An example of not meeting customer needs is the prefabricated high-rise apartment buildings that were built in the 1970s using cutting edge technology in low-cost building processes. The buildings had to be pulled down in the late 1980s because no one wanted to live in these apartments despite the low rents. The buildings failed to meet the tenants' expectations of comfort, aesthetics and function.

One should also differentiate between 'product quality', i.e. the quality of elements directly related to the physical product itself, and 'process quality', i.e. the quality of the process that causes the product to be either acceptable or not.[4] For example, 'product quality' in the construction industry may refer to achieving quality in the materials, equipment and technology that go into the building of a structure, whereas 'process quality' may refer to achieving quality in the way the project is organized and managed in the three phases of planning and design, construction, and operation and maintenance.

Quality assurance/quality control

According to the *Manual of Professional Practice for Quality in the Constructed Project*,[2] "Quality Assurance (QA) is a program covering activities necessary to provide quality in the work to meet the project requirements. QA involves establishing project related policies, procedures, standards, training, guidelines, and system necessary to produce quality. The design professional and constructor are responsible for developing an appropriate program for each project. QA provides protection against quality problems through early warnings of trouble ahead. Such early warnings play an important role in the prevention of both internal and external problems". On the other hand Quality Control (QC) is the specific implementation of the QA program and related activities. Effective QC reduces the possiblity of changes, mistakes and omissions, which in turn result in fewer conflicts and disputes.[5]

As mentioned earlier, quality in construction is too important to be left to chance. A look at history gives some insight into the problem. Through the first half of this century, engineers and architects were in total control during the design phase. During the construction phase they carried out a role described as 'supervision', insuring that the owner received his money's worth in terms of quality. In the 1950s and 1960s, owners became increasingly concerned with cost and schedule, areas where design professionals were not providing good control.[6] The emphasis continued to be on quality and control of exposure to liability. At about the same time, the widespread use in the public sector and, to a large degree, in the private sector, of the sealed competitive bid gave the owner the advantage of competitive pricing, but also forced the general contractor to look for every advantage during construction to control cost and maintain a profitable stance. As mechanical and electrical systems became more complex, the general contractor turned responsibility for such work over to subcontractors, including quality control of their workmanship.[6] Through contract, subcontract and sub-subcontract, the general contractor ended up delegating responsibility for quality.

In the 1980s came the advent of the construction management project delivery system whereby construction management firms emerged as entities not responsible for design and/or construction, but performing only managerial functions on behalf of the owner from the inception phase to the completion of the construction phase. Inspection and quality control that had traditionally been performed by architects and engineers were now performed by construction management firms.

According to O'Brien,[6] one way in which more attention will be given to quality control is development of a project quality control plan. Presently, testing and inspection requirements are scattered throughout the contract specifications. To develop a firm plan, the testing and inspection requirements can be combined into a new division of the specifications. This would emphasize quality control and provide an organized location in which all quality control issues are identified to the bidders. As a part of a quality control plan, the manner in which the construction manager will apply quality control procedures should be described to the bidders. This will permit them to assign appropriate costs to the testing procedures.

The terms quality assurance (QA) and quality control (QC) are frequently used interchangeably. Since quality control is a part of quality assurance,[2] maintaining a clear distinction between then is difficult but important. Quality assurance is all planned and systematic actions necessary to provide adequate confidence that a structure, system or component will perform satisfactorily and conform with project requirements. On the other hand, quality control is a set of specific procedures involved in the quality-assurance process. These procedures include planning, coordinating, developing, checking, reviewing, and scheduling the work. The quality control function is closest to the product in that various techniques and activities are used to monitor the process and to pursue the elimination of sources that lead to unsatisfactory quality performance.[7] Most design-related quality assurance and quality control activities are covered by a design organization's standard office procedures. Developing and monitoring the activities within the quality assurance program in the construction phase are the responsibility of either the designer or the construction management firm depending on the project delivery system in use.

Factors that affect quality

Establishing the project requirements for quality begins at project inception. A careful balance between the owner's requirements of the project costs and schedule, desired operating characteristics, materials of construction, etc. and the design professional's need for adequate time and budget to meet those requirements during the design process is essential. Owners balance their requirements against economic considerations and, in some cases, against chance of failure. The design professional is obligated to protect public health and safety in the context of the final completed project. The constructor is responsible for the means, methods, techniques, sequences, and procedures of construction, as well as safety precautions and programs during the construction process.[2]

Project requirements are the key factors that define quality in the process of construction. The process of construction can be broken down into three main phases, namely, (1) the planning and design phase, (2) the construction phase, and (3) the maintenance and operation phase. *Figure 1* shows generally accepted elements of TQM and construction industry-specific factors that affect quality of the process of a building project. The factors that affect quality in each phase of the construction process have been identified through a literature review and are discussed in the following sections.

Management commitment and leadership

The Business Roundtable construction industry cost effectiveness study concluded that the primary causes for the decline of construction productivity directly or indirectly involved poor management practices.[8] Since quality is part of productivity, the first step for management is to recognize that there is a problem.

The success of a TQM program first of all depends on management practices. TQM is a culture and philosophy that must permeate an organization as the method of management.[9] It can thrive only under a senior management that establishes TQM as a top priority. This commitment must be coupled with a thorough understanding of TQM. Only if supported by this commitment and understanding, can senior management lead the company toward the realization of higher quality in its undertakings.

The prominent method of management practiced in the United States today, including the construction industry, is management by control, not by participation. Forced by international competitive pressures and increasing demands for quality products and services, industries are reevaluating the effectiveness of management by control. According to Joiner and Scholtes,[10] in this style of management, the emphasis is on the organizational chart and the key control points within the structure. All managers, beginning at the top, are given certain goals for the next year. They, in turn, set goals and impose controls on each of their subordinates. In construction terms, cost, schedule, and possibly quality goals are established for each project. Project managers are rewarded on the basis of meeting these goals. This method has been somewhat successful. It is simple, logical, and consistent. But there are problems when the work gets displaced by the controls themselves.[9] Also, competition to meet short-term goals can lead to internal conflict, adversarial relationships, reduced communication, accusations

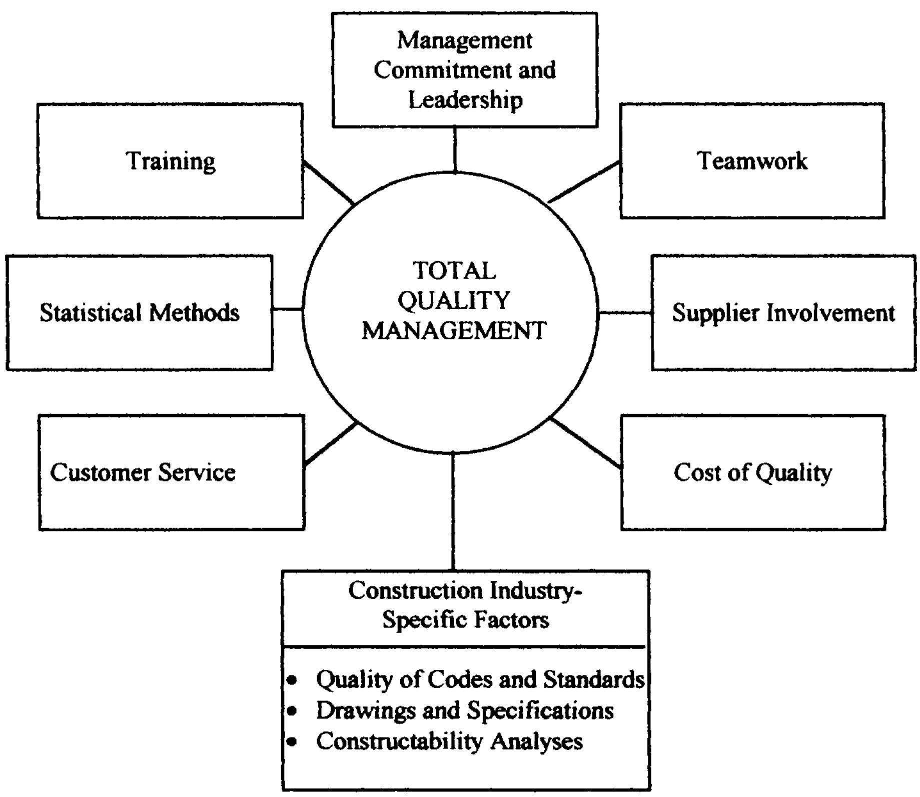

Figure 1 Elements of total quality management in the construction process

when goals are not achieved, and even fabricated reports of conformity. Management by control encourages an organization to look inward rather than outward to the customer and the customer's needs.[5]

Once it acknowledges that there is a problem, the second step for management is to develop a clear understanding of the underlying principles and elements of TQM. Management then demonstrates its commitment to quality through action. Without this understanding, management's action will most likely contradict TQM, confirming the doubts of the labor force and dooming the effort to failure.[11] The findings of a survey conducted by Gunaydin of a total of 143 construction managers, designers, contractors and facility managers to investigate TQM in the design, construction, and operation phases of projects undertaken in the USA, indicated that the level of management commitment to continuous quality improvement was rated as one of the most important factors that affect the quality of the constructed facility.[12]

Training

The importance is recognized by every quality expert. Under TQM, quality becomes everyone's responsibility and the training must be targeted for every level of the company.[13] There should be customized training plans for management, engineers, technicians, home and field office staff, support personnel and field labor.[14]

It can be argued that the transient construction work force is quite different from the relatively stable manufacturing work force. This transient nature may make it more difficult to train workers, particularly craft labor, for the construction industry[9]. However, there are many aspects, such as training and awareness, that are similar between the safety consciousness of construction firms and the implementation of TQM concepts. Many US construction companies that had safety forced upon them with the formation of the Occupational Safety and Health Administration have proven the cost effectiveness of their safety programs and now use their safety records as a marketing tool.[11] Some of the same techniques used to instill a safety awareness in craft labor may be adaptable to instill a similar quality awareness. It is easy to envision using a good quality performance record as a strong marketing tool.

If TQM concepts become widely accepted throughout the construction industry, workers switching from one company to another should require less TQM training since all workers would have received basic quality awareness in their previous employment.[9]

The training effort may include instruction in the basics of TQM, cause-and-effect analysis, team problem solving, interpersonal communication and interaction, rudimentary statistical methods and cost of quality measurement. A study of TQM in more than 200 companies found that skills in human interaction, leadership, and initiative are instrumental to the success of any quality improvement effort.[15] The demands on these interpersonal skills increase as the complexity and sophistication of the technical systems increase. The training effort follows a specific plan, and its implementation and effectiveness are carefully tracked. It is initiated in a limited number of pilot teams. The success stories of the pilot teams are then used to fuel the remaining training effort. Follow-up training is essential, and is part of the overall training plan and a job requirement for each individual.[16]

The training of employees in the design phase was found to be not very important, in the construction phase moderately important, and in the operation phase very important by the respondents in Gunaydin's study of TQM in US construction projects.[12] It follows that operation and maintenance crews working in constructed facilities should be the main recipient of training efforts. Findings are parallel to ISO 9001 which emphasizes the importance of training and underlines that activities demanding acquired skills should be identified and the necessary training provided.[17]

Teamwork

Quality teams provide companies with the structured environment necessary for successfully implementing and continuously applying the TQM process. Quality training is conducted and the continuous improvement process executed through a well-planned team structure. The ultimate goal of the team approach is to get everyone, including contractors, designers, vendors, subcontractors, and owners involved with the TQM process.

At the industry level, extending the TQM concept to the parties mentioned above in the form of joint teams achieves higher customer satisfaction. These joint teams are responsible for establishing joint goals, plans, and controls. The teams provide a mechanism for listening to and communicating with the owner and for measuring the level of customer satisfaction. Two obstacles to establishing joint teams are the state of legal independence between companies and their traditional methods of working individually.[5] These obstacles can be overcome in the construction industry however, if the owner is dedicated to doing so. There are several case studies of successful partnering arrangements. For example, on a large refinery project, TQM was applied on a project team basis; representatives of the owner and the two major contractors on the project served on the project quality steering committee. While this is a new concept, early progress is encouraging.[9]

At the company level, teams composed of department representatives are necessary to implement TQM throughout the organization. The same team approach can be used at the project level.

"Extent of teamwork of parties participating in the design phase" was found to be the most important factor that affects quality in Gunaydin's study of TQM in US construction projects.[12] In the same study, construction managers and designers ranked this factor as the most important factor. This result shows that teamwork among parties such as structural, electrical, environmental, civil engineers, architects, and owners is essential to reach the quality goals for design. In the construction phase, "extent of teamwork of parties participating in the construction process" was found to be very important and ranked 2nd by constructors and 4th by construction managers.[12] It appears that the importance of teamwork in the design phase was relatively more pronounced than in the construction phase.

Statistical methods

Statistical methods provide problem-solving tools to the TQM process. According to Perisco,[18] they provide teams with the tools to identify the causes of quality problems, to communicate in a precise language that can be understood by all team members, to verify, repeat, and reproduce measurements based on data, to determine the past, present, and to a lesser degree, the future status of a work process, and to make decisions on facts that are based on data rather than the opinions and preferences of individuals or groups. The most commonly used statistical methods in the TQM process include histograms, cause and effect diagrams, check sheets, Pareto diagrams, graphs, control charts, and scatter diagrams.[19]

Statistical methods are very important for manufacturing industries in order to improve quality.[20] Oberlender underlines the importance of statistical methods in order to provide essential problem-solving tools to the TQM process. The importance of statistical techniques is also underlined by ISO 9001.[21] However, contrary to TQM philosophy, the use of statistical methods was found to be in Gunaydin's survey the least important factor that affects quality in the construction process and ranked at the very bottom of the importance lists in the design and construction phases by designers, constructors, and construction managers. It can be concluded that all the professionals involved in this study agree that the use of statistical methods has relatively very little effect on the quality of the construction project.[12] This finding supports Hellard's[21] contention that individual construction activities are typically unique and eliminate the potential for any kind of statistical process control.

Cost of quality

The cost of quality is considered by both Crosby[22] and Juran[5] to be the primary tool for measuring quality. In their approach, it is used to track the effectiveness of the TQM process, select quality improvement projects, and provide cost justification to doubters. By bringing together these easily assembled costs of review, inspection, testing, scrap, and rework, one can convince management and others of the need for quality improvement.[11] Cost of quality has received increasing attention in recent years. It is effective in its intended purpose of raising awareness about quality and communicating to management the benefits of TQM in terms of dollars.

Quality costs consist of the cost of prevention, the cost of appraisal, and the cost of deviation. Prevention costs are those resulting from activities used to avoid deviations or errors, while appraisal costs consist of costs incurred from activities used to determine whether a product, process, or service conforms to established requirements.[23] The cost of design or constructability reviews, as well as the cost of modifying work procedures to adhere to quality standards might be considered prevention costs, while inspection is an example of an appraisal cost. A survey of US firms indicates that the major obstacle to using the ISO 9000 standards is the additional cost of modifying work procedures and the additional cost of revising standards.[24] Deviation costs are those resulting from not meeting the requirements. Some deviation costs are incurred on the project site due to scrap, rework, failure analysis, re-inspection, supplier error, or price reduction due to non-conformity. Other deviation costs are incurred once the owner takes possession of the constructed facility. These include costs for adjustment of complaints, repair costs, costs for handling and replacing rejected material, workmanship or equipment costs for correcting errors, and litigation costs.[25]

In the construction industry, contractors are selected by owners on a competitive basis. Even though the bid is considered to be the major criterion of selection, especially private owners also consider the contractors' safety record, technical support, equipment capabilities, and especially reputation regarding the quality of the work performed. Contractors with a reputation for poor quality are not likely to be awarded many projects in the existing competitive marketplace. It therefore pays for contractors to invest in measures to achieve high work quality in order to increase chances of winning contracts.

Supplier involvement

The ability to produce a quality product largely depends on the relationship among the parties involved in the process; the supplier, the processor, and the customer. The quality of any stage in a process is contingent upon the quality of the previous stages. The quality of the project built by the constructor is directly related to the quality of the plans and the specifications prepared by the designer, the quality of the equipment and materials supplied by the vendors, and the quality of work performed by the subcontractors. Close and long-term relationships with these suppliers to the construction process are required if the constructor is to achieve the best economy and quality.[11]

Traditionally, in the construction industry, contractors, subcontractors, and vendors are all pitted against one another to compete on the basis of low-bid contracts. Yet, the fourth of Deming's[26] 14 recommendations for reaching a high level of quality stresses that companies must end the practice of awarding business on the basis of price tag alone. According to Peters,[27] successful projects in the future are likely to be decided based on quality, life-cycle costs (not initial cost), and supplier responsiveness, which can only be achieved through partnership relationships; these relationships will involve fewer suppliers, and they are expected to be based on mutual trust. This is already being proven true in certain areas of the industrial construction market. Long-term partnering agreements have been formed between a number of owners and contractors. Some owners are requiring their contractors to have formal TQM programs, and both owners and contractors are requiring their vendors to implement TQM if they wish to be considered for future work.[9]

Customer service

TQM is a process that requires universal involvement to be successful. This includes customer involvement. As more and more companies become involved in the TQM process and demands for improved quality increase, this concept becomes increasingly important.

Customers may be either internal or external. Satisfying the needs of these customers is an essential part of the process of supplying the final external customer with a quality product. Juran[5] claims that the parties in a process (supplier, processor, and customer) have a "triple role". *Figure 2* shows Juran's "triple role" concept applied to construction.[28] The designer is the customer of the owner because the designer has to receive the project requirements from the owner in order to provide a feasible design. The designer supplies plans and specifications to the constructor; in this case the constructor is the designer's customer because the constructor uses the designer's plans and specifications, then conducts the construction process, and finally supplies the completed building to the owner. The owner is now the constructor's customer. Quality in each phase is affected by the quality in the preceding phases. Therefore customer service in each phase is important for the overall quality performance of the process.

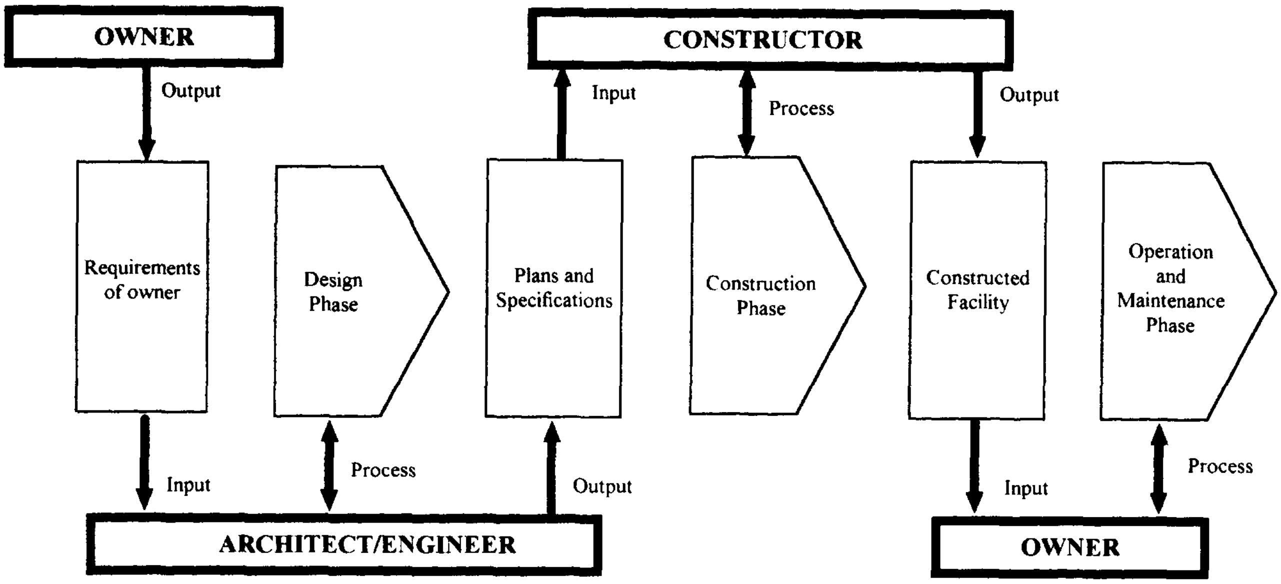

Figure 2 Construction process

Construction industry-specific factors

While the evolution of quality control in the construction industry is parallel to that of the manufacturing industry, many dissimilar characteristics distinguish the two industries. The following differences, some of them significant, must be considered when applying a quality program to construction.[29]

- Almost all construction projects are unique. They are single-order, single-production products.
- Unlike other industries, which usually have a fixed site with similar conditions for production, each construction production site always displays different conditions.
- The life-cycle of a construction project is much longer than the life-cycle of most manufactured products.
- There is no clear and uniform standard in evaluating overall construction quality as there is in manufactured items and materials; thus, construction projects usually are evaluated subjectively.
- Since construction projects are a single-order design project, the owner usually directly influences the production.
- The participants in the construction project—owner, designer, general contractor, subcontractor, material supplier, etc.—differ for each project.

Because of these distinguishing characteristics, the construction industry has generally been considered to be quite different from manufacturing industries. That is why, quality control procedures that work effectively in a mass production industry have not been considered suitable for the construction industry. Consequently, quality control throughout the construction industry has not evolved to the level attained in manufacturing industries.

According to Asakaoru,[30] project design and construction planning are carried out based upon a standard derived from relevant codes, owner requirements, and design company standard practice. Construction is then managed to conform to this composite standard as interpreted by the constructor. Quality assurance via owner, designer, or building authority, or a combination, occurs after completion, and in some cases, after partial compensation. This process results in the following trends.

- Quality is designed into and evaluated for each individual project each time. Except for some specialized areas of construction such as nuclear power plants and interstate road construction, there is no comprehensive quality policy employed to establish quality assurance for the entire industry or large segments of the industry.
- No feedback system exists for reexamining quality control work. Correction only occurs when the owner, designer, or building authority points out defects in the project. This makes quality evaluation difficult.
- It is difficult to establish a data collection system to build an information base that could lead to early identification of defects. Since post-completion correction of unacceptable work is damaging to a company's or an individual's reputation, or both, the defect that occurs during construction is usually corrected or concealed before top level management or the owner discovers it. Thus, lack of information means no change in procedures, and allows the defect to reoccur during the next project.
- No mechanism exists for practical implementation of standards. This is not only because too many standards exist, but also because there are no efficient means for inputting new information and, thus, maintaining relevant standards.
- No system exists to manage quality throughout the design/construction process. While a 'construction management' block appears in *Figure 3*, it is only the execution of the construction plan, and does not contain a quality management component.

According to Kubal,[31] the concept of quality control should be changed from "controlling quality" to "controlling management for quality". This would result in using an integrated quality standard, based upon current industry-wide experience, to define policies and organization to manage quality. Policies are defined for the quality, for the control of quality, and for management of the quality control system.

The organization created to implement quality control policies must have well-defined responsibilities and authority. In construction, failure can result from malfunction on the part of constructor, designer, or even owner. In most cases however, it is the result of a combination of actions by several or all of these parties. The quality management

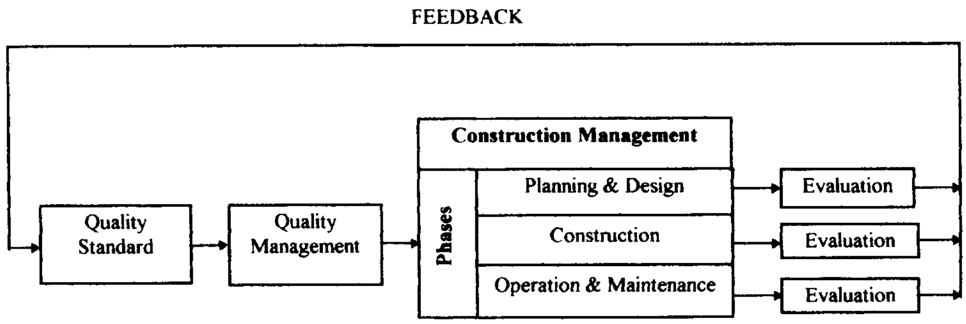

Figure 3 Total quality control flow chart

organization must, therefore, have the ability to deal effectively with all parties involved. A quality flow chart (*Figure 3*) demonstrates the following characteristics for a properly organized quality control program in the construction industry.

- The quality standard is derived from a current database created through feedback from previous projects, providing a more uniform and comprehensive standard.
- Quality management in the planning and design, construction, and operation and maintenance phases is integrated through the construction management project delivery system.
- Defects are identified and corrected early.
- Feedback expands the quality data base to eliminate repetition of the identified defects.

Quality of codes and standards

According to the ASCE manual,[2] the primary purpose of codes and standards is to protect the public's health and safety. Compliance with codes and standards should be an issue addressed early in the design phase. Without early identification of the appropriate codes and standards, reworking plans and specifications can result in considerable cost and delay. The design professional must be knowledgeable about the provisions of codes and standards before starting the design process because the building codes directly control the minimum standards of many components of a building project, and are responsible for much of the finished product quality. Kubal[31] claims that regulations controlling the construction process are much more restrictive than in most manufacturing and service industries.

Stasiowski and Burstein[1] underline that quality design begins with sound engineering and scientific principles, must satisfy the criteria of applicable codes and standards, but also the owner's project requirements. Codes and standards refer to the minimum criteria. Owners, however, may have particular requirements. Gunaydin's survey of US designers and construction managers indicates that the effect of codes and standards on the quality of the operation is perceived as minimal.[12]

Quality of drawings and specifications

Drawings and specifications are the two sets of documents given to the constructor that provide technical information on materials, performance of the constructed facility, and quality requirements. Drawings are the only documents given to the constructor that show the design concept, size and scope of the job, number and size of materials or items, and how they are assembled into a final project. Oberlender[11] also underlines that the final product of design work is a set of contract documents (drawings and specifications) to guide the physical construction of the project. There are often inconsistencies between the drawings and specifications.[1] That is why it is critical that drawings be clear, concise, and uniform.[2] Indeed Gunaydin's findings indicate that the quality of the drawings and specifications received from the designer affect the quality in the design and construction phases, and consequently the quality of the constructed facility.[12]

Constructability of design

Constructability is one of the major factors that affect the quality of design. According to the ASCE manual,[2] the design professional must consider the requirements of the constructor. The project must be constructible by those retained to build the project. Like codes, constructability and construction techniques vary in different geographical areas. Kubal[31] indicates for example that in addition to general reviews of constructability, designs must also be reviewed for effectiveness and compatibility with local requirements, including both the initial construction and postconstruction operations. Both the initial design constructability and the completed operational design should be reviewed in the quality construction programs instituted by the design team members. In addition, design professionals must clearly and adequately communicate the design intent to the constructor. This is done initially with the contract documents, both plans and specifications. Quality design extends throughout the construction phase of the project.[2]

Oberlender[11] indicates that traditionally, engineering and construction have been separated early in the project. The adoption of new technology such as three-dimensional computer-aided drafting and design, robotics, and automation in construction has generated increased interest in the constructability of the project. With these new innovations, designs can be configured to enable efficient construction, which places more emphasis on merging engineering and construction to include constructability's input in the design effort. The desired result is to facilitate the exchange of ideas between construction and design before and during design, rather than after design.

According to the ASCE manual,[2] the project design team should include engineers with field experience. Many organizations have these engineers on staff. However, it may be necessary in some cases to retain engineers with the necessary expertise, or form a joint venture with an appropriate concern.

ISO standards

The Geneva-based International Organization for Standardization first published a series of standards in 1987.[32]

The term ISO describes the series of international standards dealing with product design, production, delivery, service and testing. The ISO 9000 series comprises two basic types of standard: those addressing quality assurance and those addressing quality management. The quality assurance standards are designed for contractual and assessment purposes and are ISO 9001, ISO 9002, and ISO 9003. The quality management standard is ISO 9004 and is designed to provide guidance for companies developing and implementing quality systems.[17] A company registered as complying with ISO standards has demonstrated to an accredited third party (an approved outside auditor) that its processes have been documented and that the company is systematically auditing and being audited that they are following the policies and procedures necessary to produce high quality products.

ISO standards are directed towards improving a firm's production processes. A TQM system is the big picture and is concerned with customer satisfaction and all activities conducted by a firm. A good way of viewing ISO is that the emphasis in the ISO registration is on the management of process quality. This is not meant to minimize the role of ISO in a TQM system. The ISO standards provide an excellent beginning point for a firm starting a TQM program.

Conclusions

There is great potential for quality improvement in the construction industry. In today's competitive world, the term 'quality' and its concepts are vital for the construction industry. There is not much time nor resources to waste. Reworks and delays are not acceptable. As in the manufacturing industries, the construction industry should focus on process quality. It is clear that TQM and its principles do apply to the construction industry. TQM philosophy of teamwork and co-operation not confrontation and conflict, is long overdue for the construction industry.

This study indicates that future strategies and potential developments should based on the following findings. Project managers and company administrators should consider the following points in developing their quality systems.

- Management commitment to quality and to continuous quality improvement is very important in each phase of the building process. Management must participate in the implementation process and be fully committed to it if TQM is to succeed.
- Construction industry professionals are aware of the importance of quality training. Engineering, architecture and construction management students who eventually become the industry's future leaders must be instructed in the basics of quality management. Education and training in TQM theory and practice at all levels (management as well as operative levels) and in all phases (design, construction, and operation phases) are essential to enhance competitiveness.
- Teamwork is necessary to allow each person to get the assistance required to be successful individually, and collectively as a team. The whole construction industry is project oriented; so improved quality performance must be project-related and must include the whole project team. Manufacturer, subcontractors, main contractor, vendors, professional designers, project managers and above all, the owner must be involved in the process. Partnering arrangements between these parties will enhance total quality.
- Statistical methods are essential problem solving tools and are very important in monitoring quality in manufacturing industries. But they are not perceived as very useful by construction professionals; yet, there appears to be potential for a feedback system in the construction process. As the project is being completed, feedback loops originating at the end of each phase could be used to upgrade the original quality standards adopted at the beginning of the project.
- Taking measures to achieve high quality cost money. This cost should not be considered an expense but an investment. Construction organizations that achieve reputation for high quality can maximize their competitiveness and increase their business opportunities.
- The construction project should be considered as a process where all customers must be satisfied. These customers include internal customers (employees, units, departments within an organization) and external customers (owner, designer, contractor, etc.).
- The requirements of the owner must be clearly defined at the beginning of the project and be agreed to by both the owner and design firm. The more time and effort are spent at the beginning in defining requirements, the more smoothly the project will progress. Objective setting is important because it provides a focus for scope definition, guides the design process, controls the construction process, and influences the motivation of the project team.
- Drawings and specifications received from the designer affect the quality of the construction. Drawings are the only documents given to the constructor that show the design concept, size and scope of the job. It is critical that drawings and specifications be clear, concise, and uniform. The project must be constructible by those retained to build the project. Design professionals must be familiar with construction materials and techniques that constructors will be using in the project.

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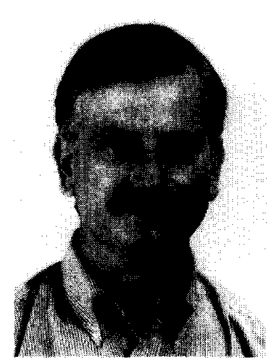

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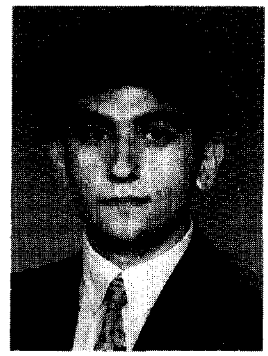

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