QUALITY MANAGEMENT IN CONSTRUCTION INDUSTRY

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ABSTRACT: To address quality problems and their associated costs, the construction industry must pursue and implement innovative quality-management organizations and techniques. This paper presents the findings of a research project conducted to identify attributes of effective quality-management systems in the construction industry. The objectives were met through an extensive literature review and in-depth interviews with 142 engineering, construction, quality, and procurement personnel from 19 owner and contractor firms involved in heavy industrial, manufacturing, and commercial construction. The emergence of total quality management (TQM) applications in the construction industry was a significant finding of the interviews. The results indicate that substantial improvements in meeting quality requirements can be achieved by the use of TQM in the construction industry. Implementation techniques and attributes of effective quality-management systems were identified and categorized.

INTRODUCTION

The Construction Industry Institute (CII), Austin, Texas, Quality Management Task Force conducted research to identify quality management organizations and techniques that are being employed to improve quality performance in the engineering and construction industry (Matthews and Burati 1989). This paper presents a summary of the findings of the research and shows that the concepts of total quality management (TQM), which have for years been used successfully in the manufacturing industry and by Japanese contractors, are being adapted and implemented by U.S. owners, engineers, and contractors.

TQM is a company-wide effort that involves everyone in an organization in an effort to improve performance. It permeates every aspect of a company and makes quality a primary strategic objective. TQM is achieved through an integrated effort among personnel at all levels to increase customer satisfaction by continuously improving performance.

BACKGROUND OF TQM

The effective management of quality and productivity, defined within the Japanese concept of total quality control (TQC), is largely credited as the catalyst behind the Japanese industry's extraordinary improvements in quality and simultaneous reductions in costs since 1950 ("The leading" 1988). The Japanese concept of TQC has come to be known as TQM as it has been adopted and applied in the United States. The foundation of the modern Japanese TQC concept is rooted in the teachings of Drs. W. Edwards Dem-

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Note. Discussion open until November 1, 1991. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on December 19, 1989. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 117, No. 2, June, 1991. ©ASCE, ISSN 0733-9364/91/0002-0341/$1.00 + $.15 per page. Paper No. 25908.

ing and Joseph M. Juran. Deming's contributions are celebrated in the Deming Prize, the most prestigious industrial award in Japan. In appreciation for his efforts, Juran was awarded the Order of the Sacred Treasure, in 1981, by Emperor Hirohito (Teresko 1982).

During the 1950s, U.S. quality experts, most notably Deming and Juran, agreed to assist the Japanese in improving the quality of their products and boosting their exports. Deming made several trips to Japan, at the request of the Japanese Union of Scientists and Engineers (JUSE), to conduct seminars on statistical process control and building quality into the process. Deming stressed that 85% of the problems encountered in manufacturing are with the process and that statistics can be used to control that process. The focus of his philosophy is that quality cannot be inspected into the project, whether it is an automobile or a building, and that management must concentrate on improving the process. Management is not expected to solve all of the system problems, but it has the responsibility of providing the workers with the tools necessary for them to effectively address the problems of the system.

Striving for further improvements, in 1954 JUSE invited Juran to conduct a seminar on quality-control management. Juran's lectures outlined a managerial approach to quality control and focused on achieving customer satisfaction through a project-team approach, with project-by-project improvement. Juran stressed the importance of training and hands-on leadership by top management in order for quality improvements to be achieved. This concept greatly appealed to the Japanese, and for "the first time the term QC was positioned as a vital management tool" (Imai 1986).

The Japanese continued to adapt the teachings of the experts to meet the specific needs of their industries. The TQC concept in Japan has continued to evolve in such a way that now

> most new concepts, systems, and tools that are widely used in Japan today have subsequently been developed in Japan and represent qualitative improvements upon the statistical quality control and total quality control of the 1960's (Deming 1986).

TQC now serves a dual role in Japan as a powerful marketing mechanism ensuring the quality of their products and as a mechanism for improving management effectiveness (Smith and Smalley 1988).

In reaction to the new form of quality- and productivity-based competition, the last decade has seen a dramatic increase in the amount of attention given to quality management in the United States (Smith 1988). Quality management is now recognized as "a major strategic variable in the battle for market share" (Leonard and Sasser 1982). Since his publication of *Quality is Free* in 1979, Philip Crosby has joined Deming and Juran in increasing quality awareness in the United States (Crosby 1979).

Crosby's philosophy is focused on transforming the management culture to being receptive to quality improvement. His approach begins with discrediting the assumption that there is a correlation between quality and cost. Crosby maintains that doing a job right the first time is more cost-effective than making mistakes, tracking them, and correcting them. Companies without this wisdom "probably spend more doing inferior work than if they adopted a clear, uncompromising, and high-quality standard of zero defects" (Dumas et al. 1987). With his 14-step quality improvement process Crosby (1979)

provides management with a structured methodology for implementing a cost-of-quality approach that involves everyone in the organization. By tracking the cost of quality (cost of prevention, appraisal, and rework), improvement opportunities can be identified with the ultimate goal of achieving zero defects.

Objectives

The objectives of the present research were: (1) To identify quality-management organizations and techniques that have been found to be effective in the construction industry; and (2) to identify the ways in which these organizations and techniques were developed and implemented.

Scope and Methodology

Interviews were conducted with construction, engineering, procurement, and quality personnel from 19 owner and contractor firms involved primarily in heavy industrial, manufacturing, and commercial construction (Matthews and Burati 1989). Table 1 is a summary description of the participating companies. A total of 142 people were interviewed. A categorical analysis was made of the processes that led to the various quality-management organizations and techniques to determine which attributes were perceived as most effective. Where available, cost-benefit data were used to verify this effectiveness. In addition, techniques from other industries were also analyzed in an effort to evaluate their potential for applying proven quality-management techniques to the construction industry.

Results

The emergence of TQM applications in the construction industry is a significant finding of the study. A clear majority of the companies that participated in the study have either implemented, or are in the process of im-

TABLE 1. Descriptions of Participating Companies and Their Quality Management Approaches

Company type (1)	Number of participants (2)	QA/QC (3)	Formal TQM (4)	Informal TQM (5)	Total (6)
Owner	8	2	6	0	8
Heavy industrial (7)					
Manufacturing/commercial (1)					
Large contractor[a]	8	2	6	0	8
Design-build (7)					
Construction only (1)					
Medium contractors[b]	3	0	0	3	3
Design-build (3)					
Total	19	4	12	3	19

[a]1987 work volume greater than $500 million.
[b]1987 work volume between $20 million and $100 million.

plementing, TQM in their companies. Table 1 summarizes the findings by company type and their approach to quality management.

The QA/QC category is characterized by the use of thoroughly developed, traditional quality assurance (QA) and quality control (QC) methods and the absence of the use of TQM. The QA/QC companies have strong and highly technical inspection and surveillance methods to control the quality of the work. The difference between the QA/QC companies and the firms with a formalized TQM approach is that technical inspection and surveillance procedures are just one component of the company-wide application of TQM. In the remaining discussions in this paper, companies without a TQM approach are referred to as "QA/QC companies" and companies with a formal or informal TQM approach as "TQM companies."

The informal TQM category relates to the three medium-sized firms in which a formalized TQM approach is not being used but where many of the concepts and methods characterized by TQM are. All three of the medium-sized firms have considerable experience (60–80% of their work) in working for Japanese clients. These companies are sensitive to the quality demands of the Japanese and, through years of experience, have incorporated many TQM concepts into their operations.

For presentation purposes, the interview results have been consolidated into two major areas: implementing TQM and quality-management attributes. Each of these areas is discussed in detail in the following sections.

Implementing TQM

Three-fourths of the owners and large contractors are in different stages of formally implementing TQM throughout their companies (Table 2). Based on the responses from these 12 companies, the implementation process consists of three distinct phases: motivation, investigation and development, and deployment. The process begins when the company is motivated by some source, either internal or external, to improve its quality. The available TQM approaches are then investigated. After the options are investigated, an approach is either selected from a quality consultant and adapted to the company, or one is developed by combining certain aspects from different sources. After an approach is developed, it is deployed either on a company-wide basis or through a series of pilot projects. Based on the results of the interviews, it was found that the implementation process requires about three years of dedicated effort before substantial benefits are realized throughout the company.

Motivation Phase

Table 2 summarizes the reasons the 12 companies decided to investigate TQM along with how long they have been involved in the process. Four of the six owners began to formally implement TQM in the early 1980s, when the manufacturing industry was faced with increasing competition from overseas. Five of the large contractors began implementing TQM within the last two years, and three of those five did so at the request of a major client.

The pressure on contractors to adopt TQM will increase as the number of owners embracing TQM continues to grow. An individual from one of the contractors commented that clients have been implementing the TQM process in their companies and have come to expect their contractors to be

TABLE 2. Summary of 12 Companies with Formal TQM Programs

(1)	Number of owners[a] (2)	Number of contractors[b] (3)
Motivation[c]		
Increasing competition	3	3
Customer pressure	2	3
Poor quality	1	0
Better use of human resources	2	0
When Started		
0–2 years earlier	1	5
2–5 years earlier	1	0
5–10 years earlier	4	1
Responsibility		
Steering committee	5	6
Quality engineer	1	0
Method[c]		
Read, viewed, visited consultants	6	5
Visited other companies	3	3
Client recommendation	2	1
Approach selected		
Crosby	3	3
Deming	1	0
Juran	0	1
Combination	2	2

[a]Only includes the six owner companies with formal TQM.
[b]Only includes the six contractor companies with formal TQM.
[c]Total for owner column (column 2) is greater than six because of multiple responses.

knowledgeable and interested in quality improvement. Considering this current trend toward TQM, a majority of the individuals from TQM companies were convinced that companies failing to embrace TQM will no longer be competitive in five to 10 years.

Investigation and Development Phase

In five of the six cases involving owners, each division in the organization was responsible for investigating the available approaches, selecting or developing one that would best fit the company, and implementing it. At the time of the interviews, the various divisions in each company were at different stages in the development and implementation of their approaches. The engineering and construction divisions of three of the owners had fully developed their approaches and had substantially completed the implementation. Two were in the early stages of implementation and one was investigating how to readapt its corporate approach after a major restructuring. The remaining owner was developing a company-wide approach to be implemented in each division.

All of the large contractors chose to select and develop company-wide approaches rather than give the responsibility to each of the divisions within their companies. Five of the six large contractors had begun the investigation, selection, and development process within the previous two years. They

were in the early stages of implementation. The remaining contractor had begun the TQM process over five years earlier and had substantially completed its implementation phase.

In all but one of the companies a steering committee of leaders from the various departments within the division of the company was formed to investigate and select or develop an approach (Table 2). In the other case, the manager of the company's QA/QC organization was charged with the responsibility. In the cases in which a steering committee approach was used, a coordinator or group of coordinators was selected to assist the committee and to coordinate its efforts. Typically, the coordinators are either quality or industrial engineers with extensive knowledge of the TQM process.

Six of the 12 companies (Table 2) adopted the Crosby approach as their primary quality philosophy, one selected the Juran approach, and one decided on the Deming approach. The reasons given for selecting Crosby are that his approach is marketed better than the others, is tailored to attract management's attention, and is easier to implement and more suited to the construction industry than the others. The company that selected Deming did so because of his concepts of continual improvement and because his approach is more of a philosophy than a program.

With only one exception, the eight companies that retained a singular approach made extensive efforts to adapt the approach to their unique requirements. In the one case in which the company simply adopted an approach, the initial implementation failed and the company had to restart its efforts once it had developed an adaptation of the approach that was better suited to its specific needs.

The four remaining companies investigated all of the available approaches and determined that it was best to develop a tailored approach containing elements of different quality consultants. The companies concluded that all of the approaches are slanted toward manufacturing applications and that the most effective alternative was to pick and choose certain attributes of each that best fit the company's needs.

Implementation Phase

The guidance for the implementation efforts of all 12 of the firms was provided by a steering committee of company leaders, and the responsibility for the implementation was delegated in several different ways. Seven of the 12 firms used either a coordinator or group of coordinators to guide the implementation effort. The coordinators were full-time personnel with sole responsibility for the TQM process and its applications. For the remaining companies, either the steering committee or the quality engineer that selected the approach was responsible for the TQM implementation in addition to their normal job functions. Eight of the companies were at an early stage in the implementation process and were working to bring TQM down through the organization. The responsibility for this effort was given to the functional managers once they had been educated in the TQM process and methods. These companies have yet to fully establish their TQM structure and bring TQM throughout the organization.

The large contractor that was well into the implementation phase made an initial attempt in the early 1980s to implement TQM without achieving significant results. It began by training managers who were, in turn, responsible for training down through their respective organizations. They began track-

ing and measuring the cost of quality. But because supervisory, problem solving, and communication skills were not provided in the training, there was not much action on the problems identified by the tracking. This gave way to a decrease in cost of quality reporting. As the massive implementation effort filtered down through the organization, its effectiveness was diminished by the "ivory tower" effect. Three years after the initial implementation effort, the company restarted the program with a renewed emphasis on supervisor and management training. In retrospect, the coordinator for the present effort feels that originally the company should have researched different approaches and developed a pilot project before implementing on a company-wide basis.

Quality Management Attributes

Five quality-management attributes were identified: Organizational structure; training; tools, methods, and techniques; contract party relations; and contracting methods. Each attribute category represents a prevailing quality-management activity or concern highlighted during the interviews. Each is discussed in detail in the following sections.

Organizational Structure

Full TQM organizations had been established by the four firms that were well into the implementation phase. Their TQM structures depend on the approach they selected. Although the particulars of each of the four TQM structures are different, they follow two basic forms.

Structure A (Fig. 1) is used by two owner firms that developed their own approaches based on concepts from Juran, Deming, and the Japanese. It is composed of levels of natural work group or functional teams from the executive steering committe through division teams, departmental teams, and craft teams. The teams are interlocked through managers and supervisors. The division managers are members of the executive steering committee and leaders of the division-level teams. Similarly, the departmental managers are members of the division-level teams and leaders of the departmental teams, and the supervisors are members of the department-level teams and leaders of the craft-level teams. This interlocking structure allows the efforts of the different teams to be coordinated with the overall corporate goals and objectives.

The executive steering committee establishes major improvement opportunities based on the mid- and short-term goals of the company. These opportunities are passed to the craft level through the different levels of teams. As they pass from one level to the next, the measures and action plans for each opportunity become more and more specific. Cross-functional teams and task teams are formed to address unique problems and matters that cross functional boundaries. The cross-functional teams can be established at any level to address problems that may involve different work groups, departments, or divisions. The task teams are established by management to address specific problems or opportunities.

The efforts of the various teams are supported by a group of facilitators or quality consultants comprised of individuals with expertise in TQM. They do not participate in the group functions, but act as coaches to the teams.

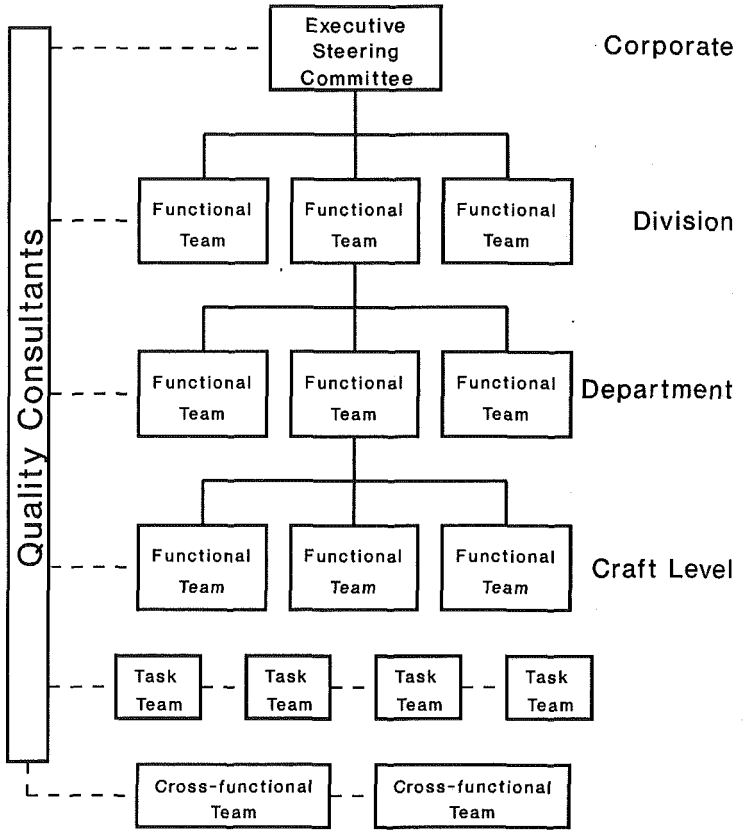

FIG. 1. TQM Structure A, Adapted from Deming, Juran, and Japanese Concepts (Crocker et al. 1984; Deming 1986; Juran 1988)

As the teams begin their work, the facilitators are heavily involved with the teams in terms of educating and guiding them in the TQM process. The involvement of the facilitator decreases as the team begins to function.

Each team has its own mission statement and areas for measurement and improvement. The team is responsible for identifying, tracking, and controlling its work process. As problems are identified, solutions are determined and tested for effectiveness, and then the work standards are modified to reflect the improvement. To avoid having winners and losers in the solution process, decisions are made by the general consensus of the team and not by a majority vote.

Structure B (Fig. 2) is used by one owner firm and one contractor that have adapted Crosby's approach. It is based on the concepts of steering committees, quality improvement teams (QITs) and corrective action teams (CATs). The steering committees are at the top of each operating group or division, with horizontal communication lines. The steering committee is composed of cross-functional managers that are responsible for managing the TQM process in their own departments. Below each steering committee are the

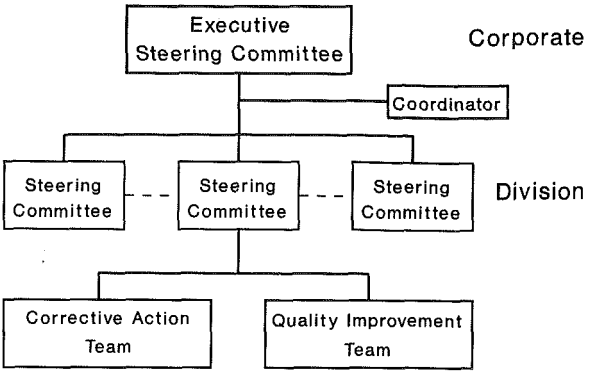

FIG. 2. TQM Structure B, Adapted from Crosby Concepts (Crosby 1979)

QITs and CATs, which are responsible for identifying and resolving improvement opportunities in specific areas determined by the steering committee. The CATs and QITs and their steering committees are interlocked by individual sponsors and the chairpersons of the teams. The chairperson is the facilitator for the team and serves as a liaison with the other teams. The sponsor provides a two-way communication link between the steering committee and the CAT or QIT.

For the four companies using either structure A or B, the development of the TQM structure from top to bottom took about three years to mature. The process begins at the top of the organization and with the commitment of the senior management. The process should move down through the organization by way of small pilot projects that management believes can document quick success. As successs stories from the various pilots become available, they are used to demonstrate the effectiveness of the effort to other areas of the company. The companies that were involved with the process for more than five years report that significant results were realized at about the three-year mark.

Training

The companies involved in formally implementing TQM had considerably more training efforts than the non-TQM companies. In cases in which companies adopted a primary TQM philosophy, the training closely followed the guidelines provided by the consultant. The training was considered to be more effective when efforts were made to integrate the consultant's training program with the job functions of the individuals being trained. The companies that developed their own corporate TQM approach had greater success in integrating the training into the job function than companies using a singular TQM approach from a consultant.

Table 3 lists the usual training topics used in implementing TQM and the training received at each level of the TQM structure. Team leaders are trained extensively in leadership, communication, motivational, and team development skills. Team members receive training in interpersonal and presentation skills.

The TQM team structure is used to carry out the training. The training

TABLE 3. TQM Training Topics

Topic (1)	Executives (2)	Team leaders (3)	Team members (4)
TQM philosophy	×	×	×
TQM implementation plan	×	—	—
Interpersonal relations	×	—	×
Team development	—	×	—
Leadership	—	×	—
Statistical methods	×	×	×
Problem solving	×	—	×
Organizational climate	—	×	—
Meeting rules and procedures	—	×	×
Presentation skills	—	—	×

begins with an introduction to the TQM concept for everyone in the organization. Meanwhile, the top management receives extensive training in TQM and, once completed, retains the responsibility for getting the training down through the organization with the assistance of quality coordinators. Team training topics are equally balanced between technical and humanistic issues, and the examples and problems used in the training relate to the job function of the team. As new tools are learned, a concerted effort is made to apply them as soon as possible to the job function of the team. This is done to illustrate the applicability of TQM and its effectiveness in solving problems. The sooner the team can solve its first problem the quicker it becomes committed to the TQM process.

Tools, Methods, and Techniques

All of the companies that participated in the study utilized various tools, methods and techniques in their quality-management efforts. The ones believed by the respondents to be the most effective are listed and briefly explained in the following sections.

Tracking

Several of the companies mentioned the difficulty of establishing meaningful measures in engineering and construction. Others had developed several measures and were using them to control their work processes and reduce problems that were affecting work performance. These companies said that the data they were using were not new, but they were just using them more effectively. Some of the measures established by the companies interviewed include the following.

1. Weld reject rates, by welder.
2. Cost of quality.
3. Customer survey results.
4. Productivity.
5. Equipment availability.
6. Safety.
7. Schedule adherence.

8. Cost adherence.
9. Procurement cycles.
10. Interdiscipline communication ratings.
11. TQM implementation.
12. Resource utilization.
13. Change-order rates.
14. Rework.
15. Cost savings.

Several of the firms indicated that the accuracy of the measures was not important in absolue terms. What is important is the accuracy of the measures in relative terms. The tracking of the measures is intended to demonstrate general trends in performance that can then be acted upon. The absolute value of the measurement is not as critical as accurately illustrating trends in performance.

Data Bases

Data bases were established in many of the companies to provide an easy method for accessing various types of information to assist in the avoidance of and resolution of problems. Several of the respondents commented that these were helpful in keeping them from having to "reinvent the wheel" on every project. One of the more common comments by both owners and contractors was that they were not very good at learning from their mistakes. By maintaining certain data files, some of the companies are addressing this problem. The most common types of data bases identified during the interviews were the following.

1. Problems and solutions identified during post-project review.
2. Problem-history files.
3. Contractor/subcontractor/vendor evaluations.
4. Quality-team problems and solutions.
5. Punchlist items.
6. Checklist items.

Preplanning

The ability to affect the quality of the project decreases rapidly after the conceptual phase is completed and is minimal once construction has begun. To capitalize on the leverage to affect the outcome of the project that is provided during the early stages of design, all of the interviewed companies exert an extensive up-front effort in scope definition and preplanning. A project team (task team) is formed as early in the project as possible with members from all phases of the project. The teams are cross functional and effective at identifying and minimizing potential problems. In general, the team consists of a project manager, representatives of the major design engineering disciplines, a construction representative, a quality engineer, a procurement manager, and an operations representative. Depending on the contract arrangement, members from the other contract parties are added to the project team.

Contract Party Relations

In addition to the normal evaluation criteria, the TQM owners review the contractor's quality program as part of the bid-evaluation process. In some

cases, the owner includes minimum quality-program requirements in the bid documents. Based on the interviews, the trend among owners is away from the traditional inspection approach in controlling the contractor's quality to an audit function. The owners realize that two parties cannot be responsible for quality, and are placing that responsibility on the party that is actually doing the work.

In some cases, owners are requiring the contractors to have TQM implemented on projects. Where a contractor has not yet established TQM, the owners are willing to assist the contractor in getting started. However, the owners do not feel that it is their responsibility to directly pay for the contractor's effort in implementing TQM.

Owners and contractors are making a concerted effort to improve relationships with their vendors by establishing standard specification formats and formal feedback mechanisms for the vendors. They meet as early as possible with vendors to ensure that all of the requirements are clear. In some cases, the owners meet with the people who are actually performing the work and not simply the business or marketing managers.

Several of the owners and contractors are no longer awarding contracts to vendors based on low bid, but are looking at life-cycle costs. The quality program plays an important role in the evaluation process, and where the vendor does not have TQM, the owners are willing to help them get started. After the contract is awarded, the owners have objective evaluation criteria for the vendor's performance. By identifying and eliminating poor performers, objective measures of performance provide a means for maintaining a smaller group of highly qualified vendors.

The contractors are working on reducing the numbers of vendors on their vendor lists, but most do not feel that sole-sourcing is possible. One procurement manager pointed out that manufacturing is able to use sole-source contracts because they use the same materials day-in, day-out. Construction requires about 50,000 different materials, in different quantities, and at different times. Another problem can be convincing a client to accept the vendor with which the contractor has an agreement.

Contracting Methods

Several topics from the interviews addressed preferences of contract types and variations to the traditional contracting methods. However, it was generally indicated that the quality of a project ultimately depended on the capabilities of the project management team.

Design-Build

With only a few exceptions, the respondents believed that the design-build method of contracting provided the best project. On design-build projects, communications are more effective and the project team can quickly adapt to changes. There is more of a "team" atmosphere with both design and construction striving for the same goals.

Partnering

Long-term "partnering" contracts are a natural outgrowth of the TQM process, and several of the interviewed owners and contractors are parties to long-term arrangements. Partnering provides the owner with readily accessible design and construction capabilities without having to maintain the ac-

companying overhead burden. As the relationship matures, the partners become more comfortable with the other's business methods and the efficiency of their work improves. The contractors benefit from the relationship by being able to stabilize fluctuations in work load. Because of the continuous work load, the project team remains together and the communications among the project team improve.

The partnering arrangements are perceived as greatly improving the interfaces between the contractor and owner, and the execution of projects. Several of the owners and contractors had recently entered into partnerships. In each case, the effectiveness of the relationship is subject to periodic review and, based on the review, can be renewed or terminated at the discretion of the owner. The medium-sized contractors had not established partnereships with owners, but maintain long-term relationships with them whenever possible.

Incentive Contracts

Several companies have included quality performance along with productivity, schedule, field management, and safety performance in incentive contracts. Incentive contracts are perceived as creating the best working atmosphere for both owners and contractors. The incentive awards are generally made by an evaluation team composed of an equal number of representatives from the owner and contractor.

Effectiveness of Quality-Management Effort

Cost-Effectiveness

Both TQM and QA/QC companies had documented cost benefits resulting from their quality-management efforts. The savings documented by the TQM companies tended to be credited to the overall quality effort; the QA/QC companies tended to credit the savings to specific applications of tools, techniques, or methods. Table 4 presents quality-management applications and documented savings that were identified during the interviews.

The companies that had been involved in TQM for over five years emphasized that the figures they provided were only from savings they could document. They are firmly convinced that there are many other "unknown and unknowable" benefits that cannot be documented.

Perceptions

An important aspect of the interview process was to determine the perceptions of the individuals about topics relating to quality. The following four topics were addressed: (1) Definition of quality; (2) top management commitment to quality; (3) ranking of cost, schedule, quality, and safety; and (4) sources of quality problems.

The first three topics were intended to develop a relationship between the quality-management approach used by their company and how the individuals in a company perceived the three topics. For each company, an overall company opinion was developed based on the majority opinion of the responses. With only a few exceptions, the responses within each company were quite consistent.

The fourth topic, sources of quality problems, was intended to determine the relationship between the type of company (owner or contractor) and its

TABLE 4. Quality-Management Applications and Cost Benefits

Application (1)	Benefits (2)
Partnership relations with vendors	Price decreases of 12–14%.
	By promising to purchase a certain volume of common equipment as pumps, 35% savings realized.
Weld reject tracking per welder.	Brought down reject rates from 49% to 1%.
Cost of quality, closer attention to job planning, and execution of plan.	40% reduction in the cost of quality in three years.
	3% reduction in work orders affected by nonconformance in one year.
Independent QA/QC program for a power plant. Approved and mandated by executive management.	$1+ billion, four year project completed six weeks ahead of schedule and $70 million under budget.
Employee suggestions for quality improvement.	$300,000 savings in labor and completed the project two weeks ahead of schedule.
Total quality management implemented on projects	Virtually nonexistent rework and zero punchlists. The project was completed below cost and 15% ahead of schedule and received 100% of incentive award.
	Project completed $10 million under budget.
	Project completed $3.9 million under budget.
	Documented 4% savings of total installed project cost.
Total quality management in engineering.	Documented $50+ million annual savings.
	$12+ million in total cost savings on two $50 million projects.
Total quality management in construction.	Documented $4.7 million annual savings. Cost for the TQM process was $250,000.
	Reduced overall rework from 30% to 15%.

TABLE 5. Perceptions Regarding Quality

Perception (1)	Quality Management Approach	
	QA/QC (2)	TQM (3)
Definition of quality		
Conformance to requirements	4	7
Customer satisfaction	0	8
Top management commitment to quality		
Yes	2	14
No	2	1

perception of the primary sources of quality problems. For each company, an overall list was developed based on the responses of the individuals in the company.

Definition of Quality

The company opinions for the definition of quality are shown in Table 5. The exact definitions of quality differed slightly from person to person, but they remained in two basic categories: conformance to requirements; and customer satisfaction. The two definitions are interdependent and are related to the TQM approach employed by the company. The one conclusion that can be drawn regarding the definitions of quality is that all the companies with the QA/QC approach defined quality in terms of conformance to requirements.

Top Management Commitment

The perception of top management commitment by the QA/QC companies was divided equally between yes and no (Table 5). However, one of the companies that had the perception that top management was committed to quality clarified the statement by stating that top management did not understand quality. The top management commitment to quality of the companies with TQM was generally perceived as positive. Many of the people interviewed responded to the question by stating that their company could not have TQM unless top management was committed. The one case in which top management was perceived as not committed relates to the management of just one department of an owner firm. This perception was expressed both by individuals from outside and within the department.

Ranking Safety, Schedule, Cost, and Quality

The general perception of the ranking of safety, schedule, cost, and quality, in terms of what drives a project, was that the items could not really be ranked; they were viewed as all being equally important and interdependent. If the project is a safe, quality job, then it will more than likely be on budget and schedule. For the cases in which they were ranked, safety was always first, quality was primarily second, and schedule and cost alternated between third and fourth. However, in the three cases in which the perception of management's commitment to quality was negative, quality was not ranked second, it was ranked last.

TABLE 6. Perceptions of Sources of Quality Problems

Areas of quality problems (1)	Number of owners (2)
Misunderstanding quality	4
Vendors/subcontractors	4
Engineering	3
Management	3
Coordination	2
Communication	2
Heavy work load	1
Craftsmen	1
Time constraints	1
Materials management	0
Lack of experience	0

TABLE 7. Perceptions of Sources of Quality Problems

Areas of quality problems (1)	Number of contractors (2)
Engineering	8
Time constraints	6
Vendors/subcontractors	5
Coordination	5
Communication	4
Misunderstanding quality	3
Craftsmen	3
Lack of experience	3
Management	2
Materials management	2
Heavy work load	0

Sources of Quality Problems

Eleven problem areas were identified from the responses of the 19 interviewed companies (Tables 6 and 7). Each company has only one response per area, but the totals for the responses are greater than the total number of owners and contractors because most companies identified problems in more than one area. There are three areas of primary concern to both owners and contractors (identified when the responses in Tables 6 and 7 were three or more for both contractors and owners). The first of these involves the lack of a universal understanding of quality both within the company and throughout the industry. This lack of understanding was common to both TQM and QA/QC companies and is perceived as a barrier to the successful implementation of TQM.

The second area of common concern to owners and contractors is the performance of suppliers and subcontractors. Part of the problem is caused by unreasonable demands being placed on the subcontractor or vendor, but the majority of the responses referred to poor management and workmanship in the vendor and subcontractor companies. One individual made the comment that the vendors maintain a philosophy of "you can have it done right or

you can have it on time." However, one procurement manager noted that 75% of vendor problems are caused by poor planning on the part of the owner and contractor, by not providing sufficient time for the vendor to properly prepare a bid, and by giving the vendor unclear specifications.

The last area of common concern relates to engineering and problems of constructibility, clarity of specifications, insufficient specification reviews, tolerances being too strict, and mistakes being made early in the project. The majority of these problems were attributed to time restrictions on fast-track jobs, which are viewed as a primary source of quality problems second only to engineering problems.

Conclusions

The following conclusions can be drawn regarding TQM in the construction industry.

Early indications reveal substantial improvements in achieving quality requirements among organizations that have implemented TQM.

Construction companies have adapted the methods and concepts of TQM that are being used in U.S. manufacturing and applied them to construction operations with minor modifications.

The development and deployment of a TQM approach should be tailored to the specific needs of an organization. A program should not simply be adopted from a consultant and deployed.

Management participation in the implementation process is an essential ingredient of successful TQM programs.

The use of pilot projects is the most effective method for gaining acceptance of TQM among the employees and management of a company.

The TQM process takes about three years before it is accepted throughout a company and significant results are achieved.

Training for TQM will not succeed unless both the technical and humanistic aspects are addressed. The more technical the processes, the more the emphasis in training should be placed on interpersonal and communication skills.

The topics and examples used in the training effort should be integrated with the work processes of the individuals being trained. The employees should apply newly learned skills to their jobs as quickly as possible.

Owners and contractors seek improved relationships with each other and with vendors and subcontractors. Partnership agreements are being formed between owners and contractors. Both owners and contractors seek to reduce the numbers of qualified vendors, but the majority feel that formal partnerships with vendors are not possible at this time.

Acknowledgments

The writers gratefully acknowledge the Construction Industry Institute (CII) for providing funding to support this research effort, and the National Science Foundation, which provided matching funds through the Presidential Young Investigator program. The writers also extend their gratitude to the members of the CII Quality Management Task Force for their guidance, support, and contributions. Additionally, thanks are offered to the companies and individuals who contributed their records, time, and experience.

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