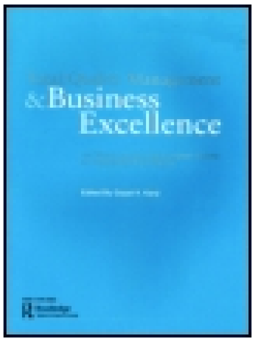

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Quality and Safety Management in Construction

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ABSTRACT *From a theoretical standpoint, quality management and safety management programs have similar characteristics. In construction work, a company's ability to deliver a quality product in a safe manner is the key to business success. In order to better understand what contributes to successful quality and safety programs in construction, a literature review was conducted using general, engineering, and business literature search engines. In all, 49 articles were found: 18 articles on safety, 26 articles on quality, and five articles on safety and quality. Overall, the literature supports the use of integrated safety and quality management in construction. However, according to the literature, there are three primary barriers to the success of quality management in construction projects: 'shoddy' implementation, the nature of construction work, and the industry itself.*

KEY WORDS: Occupational safety, quality management, construction industry

Introduction

Construction has long been considered dangerous work. In addition, the construction industry is under constant scrutiny for quality of work. Combining safety and quality management principles and methods capitalizes on the similarities between these two management concepts to create a single 'synergistic' management system for improving both safety and quality. In the interest of improving safety and quality performance in the construction industry, a literature review was performed on construction research articles to find out if this integrated management system concept has been investigated.

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Background

The US construction industry employs less than 7% of the workforce while accounting for over 22% of occupational fatalities (CPWR, 2002; BLS, 2003). In comparison, the US manufacturing industry employs 15–21% of the workforce and accounts for 11% of all occupational fatalities. Historically, the US construction industry's injury and illness incidence rates have been higher than all other industries. Only recently has the construction industry's incidence rate dipped below that of the manufacturing industry. However, that trend appears to be reversing (BLS, 2003; Hoonakker *et al*., 2005). From a business standpoint, occupational injuries and illnesses affect the bottom line or profitability of a construction project. Direct costs associated with occupational injuries and illnesses include medical costs, premiums for workers' compensation insurance, liability, and property losses (Smith & Roth, 1991).

Researchers have estimated that workers' compensation premiums cost contractors anywhere from 1.5% to 6.9% of total costs associated with a project (Agarwal & Everett, 1997). In considering losses from safety accidents, a construction company operating at a 3% profit margin would have to increase sales by $333,000 to pay for a $10,000 injury, such as amputation of a finger (CPWR, 1998). Injuries in construction affect project profitability in other ways as well. Indirect costs for medical-case, restricted activity, and lost-workday injuries were estimated at a 4.2 and 20.3 ratio to direct costs (Hinze & Applegate, 1991; Agarwal & Everett, 1997). Indirect costs associated with construction accidents include the cost of lost time for injured workers, loss of productivity, loss of supervisory time, decrease in labor morale, and cost of damage to equipment (Smith & Roth, 1991).

With regard to quality and productivity, the construction industry's track record is not impressive. Peter Love, Director of the Australian Agile Construction Initiative at Deakin University-Australia said,

> During the last fifty years the construction industry has been heavily criticized for its performance and productivity in relation to other industries. With the turn of the new millennium, it would appear that the construction industry is going through an intense period of introspection, which is exacerbated by increased technological and social change. These changes are altering the tempo of the environment within which construction operates. Moreover, such changes significantly affect the way business is conducted in not only domestic, but also international markets; which are now increasingly exposed to worldwide competition. No organization operation in the construction industry, whether large or small, private or public, can afford to ignore its changing environment if it is to survive. (Nesan & Holt, 1999: v)

From a quality/productivity standpoint, labor costs typically represent about 30% of the overall project cost (Picard, 1998, 2000). Jergeas *et al*. (2000) investigated manpower mismanagement and construction delays and determined that 40–60% of a typical construction worker's day is non-productive time. Love *et al*. (1999) found that costs associated with rework (having to redo a step or portion of construction due to poor craftsmanship or change in plan) were found to be as high as 12% of the total project costs and require as much as 11% of the total project working hours. The same authors commented that these costs do not take into account losses due to schedule delays, litigation costs and other intangible costs of poor quality. Clearly, poor work quality and unsafe work conditions have cost billions of dollars to construction companies, owners, and the general public, while causing undue suffering to construction workers and their families.

The Nature of Construction

The primary barrier to successful management system implementation seems to be the nature of the construction process itself. A common response to the cause of the decrease of quality and safety in construction is the ‘nature’ of the work environment. The ‘nature’ of construction is a cooperative effort of several participants, each with their own perspectives and interests at hand, brought together to complete a project plan that typically changes several times while being constructed, while trying to minimize the effects of weather/environment, occupation hazards, schedule delays, and building defects (to name just a few). The overall construction process, in itself, can potentially lead to errors or inefficiencies.

The construction industry has traditionally consisted of three primary participants: the owner (or customer), the designer/engineer, and the contractor. The basic construction process occurs like this: the owner hires an architect/engineering firm to design the project and places the project out for bid to contractors (competitive bidding process), and the contractors perform the actual construction work. Even though a common project goal is shared (i.e. completion of the plan), participants retain their own interests or what they hope to gain from the construction process. The typical owner would probably agree that they would like to spend as little as possible to get their desired project completed. Designers are in business to provide a service to the owners, however their relationship with the contractors is often unclear. The contractors attempt to provide the product as drawn by the designer as efficiently as possible in order to maximize their profit. These somewhat conflicting (and sometimes competing) interests are just one element of the nature of construction, and can lead to many of the issues discussed below (Carty, 1995).

The contractor ‘group’ can range from general contractor (construction management) to subcontractor (specialty trade) and is also sometimes characterized by industry (such as industrial, residential, highway, service/maintenance). Material and equipment companies (most often referred to as suppliers) also fall under this group, although their role may only be delivery to a project site. Contractors vary greatly in size. In the US, over 80% of all contractors have less than nine employees, albeit that accounts for 27% of the total construction workforce (CPWR, 2002). On the other side of the spectrum, contractors that employ over 500 employees make up only 0.05% of US construction firms, but they account for almost 5.5% of the total US construction workforce. A construction firm can also be distinguished by whether it has a union, non-union, or mixed (both union and non-union members) workforce. Although workforce distinction varies from state to state, about 19% of all US construction workers belong to a union. This issue is mentioned because unions (such as the AFL-CIO) provide professional resources (skill and safety training) and increased base pay and insurance benefits to their members. Gillen *et al.* (2002) found that union workers who were surveyed had a significantly greater appreciation for risks at work, and reported receiving more safety training than their non-union counterparts. Other ‘advantages’ may also be given to contractors who belong to a professional organization, such as the Associated General Contractors (AGC) or Associated Builders and Contractors (ABC). From a research standpoint, these factors are typically taken into account as they can contribute to the establishment of business or management programs.

The typical construction bidding process starts with the release of a project/job description for public review by contractors. The details of the project can vary, but typically specify enough detail so that experienced contractors can create a fairly accurate bid for the job. Some contract bidding is open only to general contractors, who are required to do the hiring of subcontractors after they are awarded the contract. There is concern among contractors, and researchers alike, over 'competitive bidding' for construction projects. For example, a contractor may try to reduce allotted resources towards safety or quality management in order to maintain a healthy profit margin for the job. As it was mentioned earlier, attempts to reduce involvement in safety and/or quality management could be very costly to a contractor, if they encounter accidents during the project. They may also experience schedule delays for many reasons: weather, labor shortage, late delivery of equipment or materials, and other events beyond the control of the contractor (Carty, 1995).

Although competitive bidding is still a standard practice, some owners and general contractors have begun to realize the advantages of using either partnerships or pre-qualification criteria for the awarding of contracts. A partnership is basically what it sounds like, a general contractor works only with a select pool of subcontractors who they have worked with in the past and can rely on to meet their project needs. The use of pre-qualification criteria requires bidders to meet a minimum requirement of experience, performance, safety, or management programs implemented. Therefore, the owner or general contractor can reduce their risk of working with a poor performing subcontractor by requiring (for example) a maximum experience modification rating (better safety performance in the past) or evidence of an implemented quality management system (more reliable work product).

In summary, the nature of the construction clearly presents a barrier for successful safety and quality efforts. It begins with how well the designers solicit the expectations of the owners and integrate those 'needs' into the project design. Designers also have the opportunity to minimize the creation of worksite hazards through safety planning (Hecker & Gambatese, 2003). The competitive bidding process provides an opportunity for contractors to cut safety and quality budget items in order to win the job. The contract itself is a symbol of accountability, as it designates who is at most risk during the construction phase. The hiring of subcontractors and suppliers can also be tricky, if the general contractor had no prior work relationship with them, or does not use pre-qualification criteria as a hiring practice. And finally, unpredictable elements such as weather or 'hidden' ground or constructed problems can hinder a time schedule and increase construction costs. It would appear that a great deal of coordination, knowledge, and pre-planning is needed in order to complete a construction project on schedule and within the allotted budget. This is why the authors believe an integrated safety and quality management system could be an innovative way to improve the safety and quality performance in construction work.

Similarities between Safety and Quality Management

Safety research. Early concepts of safety management were developed by Heinrich in the 1930s, and espoused in his book 'Industrial Accident Prevention'. Heinrich realized that industrial accidents were more likely to be caused by unsafe acts 'by people' than caused by physical hazards. This concept ushered in an innovative management system approach, which addressed both physical hazards and the behavior of workers. Petersen (1988) elaborated on Heinrich's work, and published a text of safety management concepts that address the 'human element' of occupational safety. Research has shown a strong correlation between successful safety programs and management commitment in the safety program; more humanistic approach in dealing with employees; better employee selection procedures; more frequent use of lead workers performing training; greater degree of housekeeping; better plant environmental qualities; and a stable workforce (Smith *et al*., 1978).

Results of the Smith *et al*. (1978) study are similar to the recommended safety program elements from the occupational safety and health administration's 'safety and health program management guidelines' (OSHA, 1989). Those program elements include: management leadership and employee participation, workplace analysis, accident and record analysis, hazard prevention and control, emergency response, and safety and health training. This list of safety program elements is also used as headings for OSHA's voluntary protection program (VPP) assessment tool (OSHA, 1996).

It is also interesting to note that in addition to previously mentioned safety program characteristics, recent advances in safety and health management research has opened the door to a host of new perspectives in safety management. A short list of these new perspectives includes, but is not limited to: behavioral safety (Krause, 1994), safety culture (Petersen, 1988, 1997), safely climate (Zohar, 1980; Prussia *et al*., 2003), and human error theory (Reason, 1990; Dekker, 2002).

Quality research. Dean & Bowen (1994) reviewed theory relating to quality control and total quality management principles to provide insight on the relationship between successful management and total quality techniques. The background presented by Dean & Bowen (1994: 394) provides an excellent synopsis of the most influential academics in quality theory:

> Deming's (1986) framework emphasizes the systemic nature of organizations, the importance of leadership, and the need to reduce variation in organizational processes. Juran's (1981) framework involves three sets of activities – quality planning, control, and improvement – and emphasizes the use of statistical tools to eliminate defects. Crosby (1979) focused on reducing cost through quality improvement and stressed that both high- and low-end products can have high quality.

The authors defined the three basic principles of total quality: customer focus, continuous improvement, and teamwork. Applying these principles to management techniques, the authors concluded that business success could be measurable and controllable.

Hackman & Wageman (1995) built upon the concept of using total quality management (TQM) principles to improve management technique. The authors review the history of TQM, and compare research theory to practical use assertions. The concern in this paper is that too many people blindly accept the idea of TQM, but do not fully understand the depth of knowledge and level of commitment required to do it correctly. Partial blame is given to researchers, who typically have concentrated on the 'continuous improvement' principle of TQM, or only report the success of TQM in a given case study. Lack of comprehensive investigation has led to some serious problems (or dilemmas) associated with the use of TQM in business. Based on Hackman & Wageman (1995), three additional principles of quality management should be added to the original three proposed by Dean & Bowen: organization culture, employee empowerment, and training.

More recently, Forbes (2001) defined quality as 'conformity to established requirements', and linked quality to performance with regard to productivity, safety and timeliness. Other papers by quality gurus, such as Deming, have also acknowledged the similarities between quality and safety management.

Statement of Constructs

The goal of quality management is the identification and correction of variance (or unwanted outcomes) in a process. For safety management, variance is in the form of workplace hazards, unsafe behavior, and causes of human error. The similarities of safety and quality management are evident by the shared characteristics of each system's design (see Figure 1). For example, OSHA (1996) recommends that a successful safety management program be based on: management commitment; employee involvement; hazard identification and control, training, and accident investigation. Smith *et al.* (1978) made similar conclusions in a study that compared safety characteristics of high and low accident companies, whereas Dean & Bowen (1994) and Hackman & Wageman (1995) identified customer satisfaction, team work, continuous improvement, training and education,

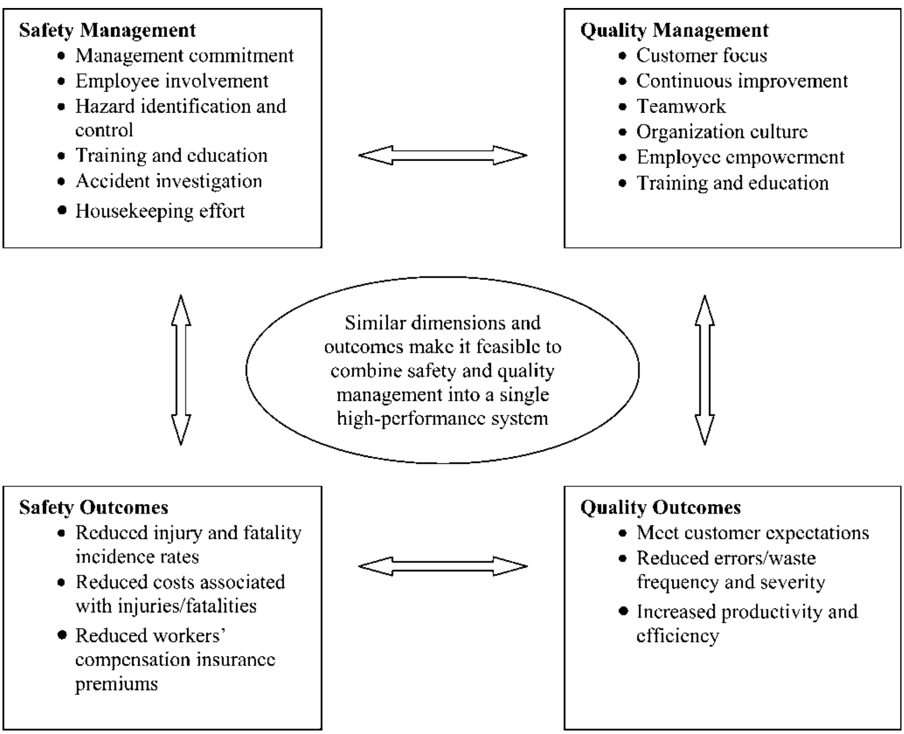

Figure 1. Conceptual framework: similarities between safety and quality management, and outcomes

employee empowerment, and organizational culture as keys to a successful quality management system.

Non-construction research literature supports the similarities of quality and safety management programs (Krause, 1994; Curtis, 1995; Rantanen *et al*., 1999). In fact, some authors have demonstrated how quality and safety can be integrated and benefits result from a successful integrated quality and safety management system (Power & Fallon, 1999; Wilkinson & Dale, 1999; Wittman, 1999; Herrero *et al*., 2002). Most of the research investigating the integration of quality and safety management indicates that while quality improvement methods strive to minimize the variability inherent in product qualities, safety management minimizes the chance of occurrence, and the severity of those non-planned events or incidents that can cause harm to workers.

Methods

The literature search utilized exploration of the following databases available at the UW-Madison Library website: Applied Science and Technical Abstracts, Business ProQuest, EI Compendex, ABI Inform, Academic Search, CQ Researcher, Engineering Index/WebSPIRS, Lexis/Nexis, ProQuest Research Library, PsychINFO, and Web of Knowledge. Keywords used on each search included: quality, TQM (total quality management), quality management, safety, safety management, occupational safety, construction, and construction industry. A more diverse taxonomy for quality and safety was used on the Web of Knowledge and PsychINFO databases. Keyword search terms, such as 'construction worker', 'injury prevention', 'ISO 9000', 'trade union', and 'building site' were attempted, but did not provide any additional 'hits' that proved to be applicable to the search criteria.

Only construction-related studies and articles were selected for review. Abstracts were reviewed to ensure that safety or quality (or both) management was addressed. Effort was made to select studies that included some form of empirical investigation; however, some 'editorial' publications lent interesting viewpoints as well. The results of the literature review were broken down into three main topics: safety management, quality management, and integrated safety and quality management systems. Based on the background literature and the conceptual framework for this paper (see Figure 1), a list of characteristics was developed for each topic (see Table 1).

Table 1. List of characteristics observed in research literature

Safety in Construction	Quality in Construction	Combined Safety and Quality
Management commitment	Customer focus	Management commitment
Employee involvement	Team work	Employee involvement
Formal program (or policy)	Continuous improvement	Training
Training	Management commitment	Communication
Audits/observations	Employee involvement	Culture, climate
Culture, climate	Training	Audits/observations
Continuous improvement	Communication	Customer focus
Communication	Culture, climate	Team work
	ISO 9000 or Malcolm Baldrige Award criteria	ISO 9000 or Malcolm Baldrige Award criteria
		Continuous improvement

Results

Research on Construction Safety

Eighteen research papers on construction safety were reviewed (see Table 2). The following characteristics influenced safety performance in a positive way: management commitment (1, 6, 9, 10, 12, 13, 14, 15, 16,), communication (1, 10, 13, 16, 17, 18), audits/observations (2, 4, 6, 7, 8, 10, 11, 13, 14), strong safety culture/climate (1, 2, 5, 12, 13, 14, 15, 16), and employee involvement (1, 5, 14, 15, 18). Several new concepts were also found to have a positive effect on safety: continuous improvement effort (9, 11, 13, 18), attention to safety by designers (3, 8, 17), and partnerships (8). The experienced modification rate (EMR) and injury/accident rates were the most frequently used safety performance indicators (in eight papers). Training alone was not found to improve safety performance (2, 7).

Research on Construction Quality

Twenty-six research papers on construction quality management were reviewed (see Table 3). There were mixed results on the success of implementation and/or use of quality management in the construction process. The most commonly cited barriers to success in quality management were: the 'nature' of construction (19, 25, 26, 27, 28, 30, 32), poor understanding of customer expectations (19, 23, 25, 34, 37, 41), lack of management commitment and leadership (28, 35, 40), and lack of worker empowerment (sometimes referred to as 'motivation' and also 'incentives', 22, 34). The characteristics of a quality management program that yielded positive performance outcomes were: TQM in general (21, 28, 33, 39, 40, 43, 44), customer focus (29, 32, 33), team work (22, 34, 42), continuous improvement (22, 41), management commitment (28, 35, 42), employee involvement/empowerment (22, 29, 38, 42), and communication (34, 35). The use of a quality program self-assessment tool, such as ISO 9000, MBNQA, or BS 5750, was shown to be helpful for identifying missing quality management characteristics (20, 26, 36, 41, 44). The use of partnering (21, 24, 26, 32) and the inclusion of suppliers (23, 26, 43, 44) in the quality effort were shown to improve the overall quality management process. Cost (budget) and time (schedule) growth per project were the most commonly used quality performance indicators (22, 23, 24, 25, 26, 27, 30, 33, 36, 38, 42, 44). Quality management was also found to improve safety performance in a couple of studies (21, 22).

Research on Combined Safety and Quality Management in Construction

Only three empirical studies and two theoretical research papers were found (See Table 4). Although no definitive conclusions were reported, some interesting opinions and findings were:

- There is a call for an international standard to foster the use and success of an integrated safety and quality management system (ISQMS) (45).
- ISQMS criteria were used as pre-qualification to select successful contractors (46).
- Survey results indicated that unpopularity of ISQMS may be caused by the lack of highly skilled managers in both QM and SM techniques, and the lack of attention to the actual implementation of an ISQMS (47).

Table 2. Research papers on construction safety

Reference	Safety citation	Population (Response rates)	Management commitment	Employee involvement	Formal program	Training	Audits, observations	Culture, climate	Continuous improvement	Communication	Other	Outcome measure	Results
1	Dedobbeleer & Beland (1991)	272 survey responses out of 384 (71%), from construction workers from nine sites located in Baltimore, MA.	x	x				x		x	Safety climate: employee perception of management safety concerns and activities, and employee risk perception.	Subjective ratings by participants on survey questions.	Results found a good fit of responses to the safety climate model, and a better overall fit to two-factor model (perception of management commitment and work involvement). Results also indicated that management safety concerns and actions must be effectively communicated, and employees should be involved in all aspects of a safety program.
2	Dedobbeleer & German (1987)	Survey sample of 384 workers, 88 foremen, and 9 superintendents. Response from 272 workers (71%), 45 foremen (51%), and 8 superintendents(89%) at non-residential construction sites in Baltimore, MA.	x		x	x	x	x			Surveys were sent to workers and foremen, while in-person 15-min. interviews were held with superintendents.	Survey responses. Worker safety performance index (SPI) was calculated from responses.	Results indicated that low safety performance scores, low knowledge, and poor attitude for safety were predominant with younger workers. Attitude toward safety performance was the most powerful predictor of worker safety performance, and weak predictors included safety training and attendance to safety meetings. These results showed that more is needed than just safety interventions, and safety training alone may not affect worker attitude or lead to safer work behavior.

(*Table continued*)

Table 2. *(Continued)*

Reference	Safety citation	Population (Response rates)	Management commitment	Employee involvement	Formal program	Training	Audits, observations	Culture, climate	Continuous improvement	Communication	Other	Outcome measure	Results
3	Gambatese *et al*. (1997)	Based on a Construction Industry Institute (CII) study, comments and recommendations for safety practices by designers were collected. Over 400 were collected for this paper.								x	Development of a design 'tool', based on how designers could reduce safety hazards in the construction process	Suggestions and recommendations from construction workers and management.	The authors concluded that consideration of construction worker safety by design professionals can enhance project safety, mitigate common safety hazards, and reduce the number of worker injuries. The design tool (computer-based) can assist designers and engineers by providing information and indicating where safety concerns lie within the design/build process.
4	Gilkey *et al*. (2003)	Follow-up study of a cohort of residential construction workers/ firms who participated in a HomeSafe Pilot Program in Denver, CO.					x				Adherence to safety rules and policies, through observation of an investigator. Behavioral observation conducted.	A score was given based on worker behavior (PPE use, correction of hazards, housekeeping, and use of tools), and also injury rates.	Results indicated that audit scores had increased over time and use. The authors concluded that an audit tool (such as HomeSafe) can reduce unsafe behaviors and conditions from a jobsite, thereby decreasing injuries. The authors also cited a limitation that workers knew when they were being observed, and therefore may have controlled their behavior to get a better score.

5	Gillen *et al*. (2002)	Survey of 255 construction workers who had sustained nonfatal falls (60% response rate).	x	x		x		x			Perception of job demands, decision latitude, and co-worker support. Union status.	Subjective responses to survey questions: perception of safety climate, job content, demands, and support based on injury.	Results indicated that injury severity was correlated with safety climate scores, and safety climate scores were correlated with union status. Union members were more likely to: perceive supervisors as safety oriented, aware of unsafe practices, receive safety training, have regular safety meetings, and not perceive risks as part of their job. Job satisfaction was similar for union and nonunion workers.
6	Glazner *et al*. (1999)	213 telephone interviews (83%) with contractors whose payrolls exceeded $250k, while working on the Denver International Airport.	x	x		x	x			x	Housekeeping or compliance with rules, job pressure, and incentives.	Workers' compensation claim payment. Non-lost time and lost time injury rates.	Three actions, or contract characteristics, results in lower non-lost work time injury rates: management establishing safety goals for supervisors, conducting drug testing at times other than after an accident, and completing the contract on budget rather and over-budget. Management established safety accountability of onsite supervision and when productivity was addressed (keeping within budget) a reduction of injuries was experienced.
7	Goldenhar *et al*. (2001)	45 Telephone surveys (52%) were conducted with non-union construction firms insured by St. Paul Fire and Marine.				x	x					Safety training elements and objectives, and subjective ratings of success/barriers.	Majority of non-union contractors in sample did not provide safety training to workers, and of those who did, they did not quantitatively evaluate their programs in terms of reduction of unsafe behaviors/exposure or productivity.

(*Table continued*)

Table 2. *(Continued)*

Reference	Safety citation	Population (Response rates)	Management commitment	Employee involvement	Formal program	Training	Audits, observations	Culture, climate	Continuous improvement	Communication	Other	Outcome measure	Results
8	Hinze & Wiegand (1992)	192 surveys were sent, 35 were returned (18.2%). 22 designers, one design-build firm, and 10 constructors (2 were D/B).					x			x	Designers role in construction safety.	Survey responses.	Less than one-third of the design firms and less than one-half of the constructability reviews address construction worker safety in the design process and approval process. The authors recommend partnering and education of designers to consider worker safety.
9	Hinze & Wilson (2000)	Surveys sent to 40 large, industrial construction firms, most were CII members. 18 responses (45%).	x			x			x		Pretask planning, safety incentives, drug testing, accident investigation.	Recordable injury rate, lost time injury rate, EMR.	Even highly successful safety programs can improve their safety management practices through continuous improvement and increased management commitment to a company safety goal.
10	Jaselskis *et al.* (1996)	450 surveys were sent to ENR's top 400 contractors and personal contacts of authors. 60 responses (13.3%). In all, 48 company programs and 69 individual project safety programs.	x		x	x	x			x	Safety coordinator, subcontractor safety, safety meetings, inspections, incentives.	Recordable incidence rate and EMR.	Upper-management support, time devoted to safety issues and number of informal safety inspections conducted by company safety coordinator, meetings with field safety reps and craft workers, length and detail of safety program, training for foremen, subcontractor safety management, and company safety expenditures, were identified as being more beneficial to safety program success.

11	Ketola *et al*. (2002)	Case study/Survey of four manufacturing companies and one subcontractor in Finland.	x	x	x	x	x		x	x	Development and testing of a safety self-assessment tool based on the Malcolm Baldrige criteria for performance excellence.	Score of self-assessment tool, as compared to MB performance excellence criteria.	Authors concluded that the self-assessment tool was a useful and fairly accurate method for finding strengths and weaknesses in safety management while providing a means to integrate safety and quality for continuous improvement. It was also discovered that this method of self-assessment is much easier if the company had used some other form of performance excellence assessment in the past.
12	Mattila *et al*. (1994a)	Case study of 16 construction sites, one construction firm in Finland. Safety climate survey of workers and foremen (77%).	x				x	x				Accident reports, safety checklist/audit, safety climate responses.	Results indicated that management support was essential to ensuring safety on the jobsite, and that poor site housekeeping was related to poor safety performance and climate.
13	Mattila *et al*. (1994b)	Case study of 16 construction sites, one construction firm in Finland. 15 site managers and 16 other first-line foremen cooperated.	x				x	x	x	x		Operant Supervisory Taxonomy Index (OSTI) used to analyze supervisor behavior.	Results indicated that effective supervision (in general) and successful safety supervision had similar characteristics. Foremen who paid more attention to monitoring worker performance also spent more time providing feedback to the workers, which led to improved safety attitudes of workers and reduced accidents.

(*Table continued*)

Table 2. *(Continued)*

Reference	Safety citation	Population (Response rates)	Management commitment	Employee involvement	Formal program	Training	Audits, observations	Culture, climate	Continuous improvement	Communication	Other	Outcome measure	Results
14	Molenaar *et al*. (2002)	Three construction companies participated via self-administered surveys to everyone in the firm. 212 responses (26.5% overall, ranging from 24-43%).	x	x		x	x	x			The culture survey incorporated: management commitment, employee involvement, safety policy, training, and audits.	Subjective responses from upper-management, middle-management, and front-line workers. 'Safety record' not defined.	Results indicated that the company with the least deviation of survey responses had the best safety record. Authors concluded that companies whose culture is similarly perceived by different levels would tend to out perform those who have differing conceptions of their organization culture.
15	Niskanen (1994)	Survey of 1890 workers and 562 supervisors in roadway construction and administration in Finland. Response rates were 81% among central repair shop, 72% among maintenance workers, and 52% among construction workers. Supervisors in repair shop 58%, maintenance 79%, and 75% for construction supervisors. (30% overall).	x	x				x		x	Job satisfaction, perceived job demands.	Climate responses, injury/accident rates.	Perceptions/opinions of supervisors differed significantly from those of workers on safety performance issues of the opposing group. This was related to attribution theory. Both workers and supervisors agreed that safety work habits improved productivity, safety was everyone's job, and safety is related to job skills. Safety climate for workers consisted of: attitude toward safety in their organization, changes in work demand, appreciation of work, and integrated safety and production. Safety climate for supervisors consisted of: changes in job demands, attitude toward safety within the organization,

											value of work, and safety as part of production work.
16	Riley & Clare-Brown (2001)	Survey and interviews with one construction company and two manufacturing companies located in the United Kingdom.				x		x	Internal communications, structure, customers, finance, suppliers, competitors, technology, and new products and processes.	Survey and interview responses from the different levels within each organization were compared.	The authors concluded that significant differences between several of cultural characteristics, and this inferred that transfer of management ideas and methods directly from manufacturing to construction needs consideration or modification. This study has limited applicability due to only comparing three firms.
17	Toole (2002)	105 Telephone surveys: 54 Design engineers (50%), 26 general contractors (30%) and 25 subcontractors (30%).	x						Site safety roles, accident root causes.	Subjective responses to structured interview.	Although the GC tends to be seen as responsible for safety, subcontractors actually have greatest ability to affect ‘root causes’ of injuries. Safety roles and expectations should be established in contracts.
18	Wilson & Koehn (2000)	Case study – one and one-half year project.	x	x	x		x	x	Safety plan implementation.	Lost time accidents.	Success of safety program and implementation was attributed primarily to the input and cooperation of workers. Importance for continuous improvement was also discussed.

Table 3 Research Papers on construction quality

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Cultutre	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
19	Atkinson (1998)	Mail survey to a sample of 420 construction industry participants, located in SE United Kingdom. 107 responses (25.5%).				x	x		x	x		Human error, from primary factors (individual performance), management factors, and global factors (external influences).	Building defects, survey responses.	The top five rated factors that contributed to construction error were: communications, time pressures, defined (or lack of) responsibilities, avoiding competition, and education and training. These results were fairly uniform across construction areas. The author concluded that error prevention is a team effort and has socio-technical or systemic characteristics.
20	Bubshait & Al-Atiq (1999)	15 construction contractors in Saudi Arabia.									x	Conformance with ISO 9000 Quality Management criteria.	Number of ISO 9000 criteria met by current quality management program.	Contractors' quality systems varied quite significantly, from informal inspections to comprehensive analysis systems. The four ISO 9000 criteria most often complied with were: inspection and test status, inspection and testing, control of nonconformance product, and handling, storage, and

											preservation. The four ISO 9000 criteria least often complied with were: design control, internal auditing, training, and statistical techniques. The authors indicated that actual documentation of a quality program was scarce among their survey sample.
21	Chase (1998)	Case study: composite of 20 companies that used TQM and partnering techniques.	x	x	x	x		x	Partnering, safety.	Lost work day incidence rate (LWDIR), customer satisfaction, employee satisfaction, profit per contract, direct and indirect costs per contract, subcontractor incidence rate (IR), and litigation expenses.	Author concluded: ‘Jobsite partnering leads to improved jobsite performance. Owners, designers, contractors, and subcontractors should welcome the opportunity to participate in partnered projects. The use of TQM as a corporate management strategy leads to improved corporate performance. Contractors and subcontractors should adopt TQM as a management strategy, using trained and motivated teams of employees to help improve both company-wide and jobsite processes.

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Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
22	Courtice & Herrero (1991)	Case study at a Shell Canada/Fluor Daniel construction site in Hamburg, Alberta.	x	x	x			x	x			Critical success factors: module fab, field construction, and procurement of critical equipment.	Quality defined as 'conformance to defined requirements'. Meeting critical success factor objectives. Cost and schedule growth and safety.	This project focused on defining critical success factors, strategies/tactics to meet criteria, measurement and monitoring, and rewards and recognition. All goals were met. Zero lost time accidents, two-month early completion, and 18% below targeted budget. Key steps in the QM program: kick-off and team building sessions, establish critical success factors, agreement of performance criteria and measurement, development of a strategy to meet criteria, monitor and feedback, and rewards and recognition (motivation).
23	Formoso & Revelo (1999)	Three construction companies in the Brazilian building industry.	x	x	x	x		x				Material supply management.	Cycle time, processing time, on-time delivery, costs.	Difficulties were realized in the use of quality teams, due to lack of clear objectives/goals and lack of training. Working with data proved useful for the

														improvement project. Techniques found to be useful: problem identification, analysis and solving, flowchart, brainstorming, checklist, and Pareto diagrams.
24	Gransberg *et al*. (1999)	408 Texas Department of Transportation (DOT) construction projects, overall worth nearly $2.1 billion. 204 partnered, and 204 non-partnered.		x								'Partnering' as a technique to employ TQM.	Cost growth and time growth.	Data analysis revealed that: partnered projects outperformed non-partnered projects in virtually every category (if award was >$5M), the average partnered project finished 4.7% earlier than originally planned, and for the $5-$40M ranged projects, there were no costs associated with disputes and claims on partnered projects.
25	Jaafari (1996)	Based on two studies/ surveys conducted in Australian construction companies.	x	x	x		x	x	x		x	Worker's perceptions of quality assurance and success of quality management initiatives.	Cost growth. Cost of quality program. Subjective responses to survey.	Author concluded that communication within construction remains poor. Quality push is more to get 'certified' than to actually improve processes and management systems. Most effort is 'client focused' only, and therefore has not been shown to be cost effective. TQM should be project-based, with project-specific training and

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Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
														programs. Construction is too different from manufacturing to carry over programs, also too dynamic to use the same process and management systems from project to project.
26	Kanji & Wong (1998)	Case study of a construction firm in Hong Kong.	x	x	x					x	x	Project partnering, Supply Chain Management.	Meeting performance criteria (or customer satisfaction), cost, safety, and schedule.	Authors concluded that, 'The construction industry has numerous problems in getting quality performance as a result of the complicated nature of the industry. Project partnering, managing supply chain as a whole and adopting total quality systems and procedures cannot yield best results without the creation of a quality culture for the parties to operate in.'
27	Kiwus & Williams (2001)	40 environmental construction projects for the U.S. Navy. TQM techniques were	x	x	x							Stem and leaf plots used to analyze data.	Cost growth, time growth, and supervisory effort.	The authors chose to use 'stem and leaf plots' to analyze and compare their data. They concluded that

		used for 21 of the sample projects.											TQM techniques may provide a benefit by reducing the frequency and severity of schedule over-runs, however the overall application of TQM did not significantly lower project costs. No difference was found in the required supervisory effort between the two types of management. The primary reason for cost and schedule growth was the need for subsurface remediation work (unpredictable issue in environmental work).
28	Kuprenas & Kenney (1998)	Follow-up survey of 6 engineering and construction companies who had implemented TQM three years prior.	x	x	x	x					Motivating factors, barriers, and perceived overall effectiveness.	Subjective responses to survey questions.	Results indicated that the overall motivating reason for using TQM remained the same, and most firms still felt that TQM was a good idea. Methods and effectiveness of TQM efforts did vary within this sample. Only firms with strong management commitment experienced success with their TQM program. Analysis of correlation indicated that firms who chose to implement TQM for quality reasons were more successful than those who chose TQM to increase profit.

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Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
29	Lahndt (1999)	Survey sample consisted of the entire membership of the Dallas Chapter of AGC, numbering over 650 general and specialty contractors. The 16% response rate slightly exceeds the reported 15% statistical average for construction.	x	x	x			x				Use of software or statistical process control.	The survey questions were open-ended. Intent of survey was not to gain statistical significance, but rather qualitative information about TQM use.	Over 80% of respondents indicated that training, and very capable personnel were critical to their firm's overall success. Over 80% of responses indicated that quality plans and specifications (and conformance) were critical determinants of project quality. All responses indicated a high level of use of basic computing equipment and software, but only 5% used specialty contractor software. 80% indicated that customer and/or owner perception of quality (customer expectations) of quality was a critical determinant of project quality.
30	Love *et al*. (1999)	Investigated the cause and effects of rework from previous research.	x	x	x			x				Factors in construction that cause rework. Empowerment, incentives, motivation.	Cost and time growth, amount of rework/errors.	'The incidence of rework increases the likelihood of project time and cost over-runs, and ultimately leads to customer

													dissatisfaction.’ Based on their review of previous research, the authors concluded that, ‘the construction industry (in general) did not fully understand TQM nor is it effectively implemented, and therefore it cannot achieve the full potential of its use.’
31	Maloney (2002)	Survey of public, to gain insight as to what they look for when selecting an electrical contractor. Size and demographics of sample not provided.	x		x						Evaluation of construction as either a product or a service.	Subjective responses from survey sample.	Based on survey results, the following criteria were indicated as being important factors in dealing with electrical contractors: 87% said ‘quality/competence’, 78% said ‘safety procedures’, 76% said ‘on time’, and 72% said ‘works within budget’. The author concluded that the determinants for ‘quality’ were based on perceptions and expectations by the customer, and therefore it is vital for contractors to achieve this understanding prior to the start of a project.
32	McIntyre & Kirschenman (2000)	Survey mailed to 1500 construction firms in the Midwestern states of the U.S. 208 responses were received (14%).	x	x	x	x	x				Partnerships, establishing performance measures.	Perceived concerns and benefits of implementing TQM.	73% of respondents indicated they currently use TQM in their business and 90% of that group reported that by

(*Table continued*)

Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
														dedicating more than 2% of their total annual expenses toward TQM, they experienced a significant increase in overall product quality and customer satisfaction. The highest rated concern of implementing TQM was ‘low bid contracts’, and the highest rated benefit was ‘higher customer satisfaction’
33	McKim & Kiani (1995)	Survey of one (rough framing) contractor located in North America, who split 15 test projects into two groups, 8 using traditional construction management, other 7 using TQM.	x	x	x	x						Customer/supplier relationship. Selecting quantifiable performance measurement.	Profitability, customer satisfaction, schedule growth, and number of defects (quality).	Analysis showed a strong correlation between profitability and customer satisfaction, and between schedule containment and quality (fewer defects). The authors concluded that by using TQM principles, projects generally finished closer to schedule and with fewer defects, which in turn yielded a greater profit for their work.

34	Oakland & Aldridge (1995)	In-depth interviews with consulting engineers and different level staff from six engineering firms.	x	x		x	x	x	x	BS 5750 (British Quality Standard).	Interview responses, BS 5750 audit.	Recommendations made to the sample, based on their responses and compared to what is required of quality management to be effective: Communication of objectives to all staff, better understanding of ‘quality’, improve communication, teamwork, address policy and culture, empower and encourage staff to participate, define roles and responsibilities, provide training, and introduce measurement techniques used to improve processes.
35	Ortega & Bisgaard (2000)	Review of previous studies, using empirical data in Pareto analysis. Case study of construction accident.				x		x		Human error as a cause of poor quality. Use of macro-, micro-, and methodology analysis.	Construction project data, accident data, mostly ‘latent’ indicators analyzed for future projects or process improvements.	Citing Schneider (1976), approximately 75% of construction failure cases result from human error. Remaining 25% caused by intentionally accepted risk. In addition, 85% of the human error failures could have been avoided through management strategies. Management must lead quality efforts, and communicate objectives and implement processes to reduce error and failure.

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Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
36	Pheng & Wee (2001)	In-depth case study of a construction firm located in Singapore.									x	Impact of ISO 9000 on quality management system.	Building defects, cost growth.	The model (or framework) developed and tested by the authors for building defects reduction consisted of three subsystems: technical, human resource, and management. Based on their case study, the authors concluded that contractors certified by ISO 9000 can affect the amount of defects occurring in their building projects.
37	Pheng & Yeap (2001)	Interviews with 15 contractors in Singapore who were currently involved in a Design/Build (D/B) project.	x						x			Quality function deployment (customer satisfaction).	Awareness and perception of QFD.	Results indicated that one of the constraints to QFD was the inability of the owner to communicate their expectations resulting in a poor understanding of actual needs. Most respondents agreed that QFD was a good idea for larger contractors and D/B firms.

38	Ripley (1996)	Case study of a Fluor Daniel's project.	x	x	x		x	x	x		Cost and schedule growth, customer satisfaction, input by workforce.	Over 500 suggestions/input were given at the site, which resulted in cost reduction of $1,750,000 over the entire project (employee involvement).
39	Russell *et al.* (1994)	Based on review of case studies involving petrochemical, general building, and manufacturing construction.	x	x	x	x	x	x		'Constructability' as a subset of TQM.	Cost/benefit ratio of constructability.	The authors reviewed characteristics of a successful quality management program, and models were designed to quantitatively measure the cost/benefit ratio of constructability processes. Based on the case studies, the cost/benefit ratios exceeded 1:10. The authors also described qualitative benefits to constructability, but no hard data was provided.
40	Sommerville (1994)	Case study of a construction firm located in the United Kingdom that successfully implemented a TQM program.	x	x	x	x				Barriers to TQM cased by nature of construction.	Repeat/new customers, cost of waste, increased job security.	Actual data was not presented, however the author did perform a theoretical analysis of barriers to TQM. These were: product differentiation, organizational stability, change, contractual relationships, and teamwork and management behavior. The case study reported achieving these benefits

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Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
														after TQM was implemented: a quality product/service (that would increase both repeat and new customers), reduction in the cost of waste, and increased job security (through increased competitiveness and job satisfaction).
41	Sun (1999)	Survey of 900 Norwegian QA members, 363 replies (40% resp rate).									x	Comparison of ISO 9000, European Foundation for Quality Management (EFQM) criteria and MB criteria.	Responses from surveys and self-assessment tool of company's quality program.	Quality programs must be 'total and complete' otherwise they either fail or cost benefits are not seen. The use of self-assessment tools provides adequate evaluation of quality program status. Only 9% of the sample was able to fully implement TQM.
42	Sypsomos (1997)	Reported on data from a CII survey, conducted in 1992 and involving 34 leading construction companies	x	x	x	x						Delivery, and employee empowerment.	Benefits of project control systems: repeat business, schedule conformance,	Based on data received from a CII survey, project success at 'leading companies' was mainly attributed to 'hard'

		implementing TQM/ process improvement.				budget conformance, % rework, profit/ loss, meeting project objectives.	measurements such as cost, schedule, and safety, in addition to ‘soft’ factors such as leadership, employee satisfaction, and teamwork. The surveys also estimated that 80% of the problems on a construction site can be corrected through three tools: check sheets, Pareto analysis, and cause-and-effect analysis. The author concluded that collection and analysis of data on these factors provided companies an opportunity to make immediate improvements instead of using ‘lessons learned’ for future projects.
43	Torbica & Stroh (1999)	Telephone interview and survey of home builders in Florida, customer satisfaction surveys to previous home building customers (54% resp rate).	x	x	x	Self-assessment survey of existing TQM practices and customer perception survey (on satisfaction).	Results found a significant relationship between TQM practices and home-buyer satisfaction in the population of medium to large Florida home builders. Results indicate that focusing on customer satisfaction can increase business potential. Authors caution contractors to include suppliers in their TQM program to ensure overall business results.

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Table 3 *(Continued)*

Reference	Quality citation	Population	Customer focus	Team work	Continuous improvement	Management commitment	Employee involvement	Training	Communication	Culture	ISO 9000/14000 or Malcolm Baldrige	Other	Outcome measures	Results
44	Wong & Fung (1999)	Case study of a construction company in Hong Kong.	x	x	x	x	x				x	Supply chain management.	Costs and schedule.	Managers indicated that 82% of the total construction cost comes from suppliers and subcontractors, therefore cooperation and quality are essential to their business. Authors concluded that suppliers and subcontractors must be part of a contractor's TQM or ISO 9000 program in order for that company to be successful.

Table 4. Research papers on integrated safety and quality programs

Reference	Combined safety and quality citation	Population	Management commitment	Employee involvement	Training	Communication	Culture, climate	Audits/observations	Customer focus	Team work	Continuous improvement	ISO 9000/14000 Malcolm Baldrige	Other	Outcome measure	Results
45	Curado & Dias (1996)	No survey or case study, only theoretical discussion and review of concepts.	x						x				Partnering, designer inclusion.	Customer demands, site safety (injuries).	The authors' purpose of the paper is to provide the basic frame work that supports the integration of safety and quality, and calls for the development of an international standard for safety and quality management.
46	Hatush & Skitmore (1997)	Delphi study consisting of 8 experienced construction personnel, and two validators.	x		x		x	x	x				Financial standing, subcontractor work experience.	Time, cost, and quality (project success factors).	Investigated perceived relationship between 20 contractor selection criteria and project success factors. Results of analysis show that past failures, financial status, financial stability, credit ratings, experience, ability, management personnel and management knowledge were perceived to be the dominant CSCs affecting all three PSFs, with safety criteria (safety, EMR, IR, and management safety accountability) and length of time in business being perceived to have the least overall effect.

(*Table continued*)

Table 4. *(Continued)*

Reference	Combined safety and quality citation	Population	Management commitment	Employee involvement	Training	Communication	Culture, climate	Audits/observations	Customer focus	Team work	Continuous improvement	ISO 9000/14000 Malcolm Baldrige	Other	Outcome measure	Results
47	Pheng & Pong (2003)	Mail survey of 96 construction firms out of 215 (44.6%) in Singapore.	x			x			x	x		x	OHSAS 18001:1999 criteria for safety management.	OHSAS criteria implemented, possibility and difficulty in integrating OHSAS 18001 with ISO 9000, benefits of integrated system, and costs of integrated system.	Results of the survey indicate that it is feasible to integrate quality and safety into one management system. Benefits of integration include: optimized management system, increased competitiveness, and better utilization of resources. The authors concluded that in a practical sense, the management of two or more different systems under one single umbrella might be a cause for concern in some organizations. It may be difficult to find someone who is proficient and possesses the necessary knowledge in all the different areas of quality and safety to handle such an integrated system. A final, and very difficult hurdle is implementation.

48	Pheng & Shiua (2000)	Mail survey of 90 local/foreign contractors (one to each the safety and quality manager) in Singapore. 26 QM replied (29%), 17 SM replied (19%).	x		x	x	x	x	x	ISO 9000, BOWEC safety requirements (building operations and works of engineering construction regulations).	Responses to surveys regarding the use and integration of quality and safety management programs.	Quality managers were more positive towards the integration than safety managers. However, safety managers reported perceiving better possible improvements to their own system through integration. The authors concluded that this study confirms the similarities between safety and quality managements systems, however it is necessary for companies to determine their operational capacities before attempting this integration.
49	Sommerkamp (1994)	Theoretical perspective of using Deming's principles on safety to change worker behavior.	x	x	x	x				Deming's management theories.	N/A	The author concludes that implementing a safety initiative within a company is no different than executing a quality initiative, both attempt to change human behavior. Understanding variation within a workplace is key to program management.

- Quality managers were more positive towards the integration of safety compared with safety managers. Also, companies should determine their operational capacities before attempting an ISQMS or chances for failure increase (48).
- The use of Deming's philosophy for quality and safety are similar: both attempt to change human behavior via system changes (49).

Discussion

Safety

Overall, the studies reviewed support the basic characteristics of successful safety management programs. Management commitment and communication were the most frequently studied safety program characteristics and tended to be related to successful construction safety programs. The use of audits and observations (identification of hazards or unsafe behaviors), measures of safety culture/climate, and employee involvement were also frequently studied and found to contribute to improved construction safety performance. With regard to safety culture and climate, when the workforce perceived safety as important and felt empowered or committed to the project, they kept the site clean and orderly (Mattila *et al.*, 1994a; Glazner *et al.*, 1999; Gilkey *et al.*, 2003). Worksite accident investigation was found to improve safety, but it was disguised as 'drug testing after an accident' (Glazner *et al.*, 1999; Hinze & Wilson, 2000).

The most commonly used measure for safety performance was the subjective responses collected during surveys and interviews. However, some studies confirmed that the use of survey responses from management and workers are representative of reported incidence rates or other rates associated with injuries or accidents (Mattila *et al.*, 1994a; Niskanen, 1994; Jaselskis *et al.*, 1996; Glazner *et al.*, 1999). This provides support for the notion that workforce safety perception seems to influence safety behavior.

Several studies alluded to quality management as either a means to address safety or as an outcome measure. Glazner *et al.* (1999) found that contractors who reported lower non-lost work time injury rates also tended to complete their contract on budget rather than over-budget. The quality management characteristic of continuous improvement was found to improve safety performance through increased communication and/or feedback from management to workers, resulting in a higher level of safety commitment by both parties (Hinze & Wilson, 2000; Ketola *et al.*, 2002; Mattila *et al.*, 1994b; Wilson & Koehn, 2000).

Interestingly, Ketola *et al.* (2002) reported that construction companies that used previous process improvement or quality management initiatives had a much easier time evaluating and improving their safety program. In addition, Riley & Clare-Brown (2001) concluded that management-based initiatives or programs need special consideration or modification before being transferred from manufacturing to construction. These two issues both support and refute the integration of safety and quality management. However, both reports were based on case studies of only a few companies.

Quality

The research papers on construction quality reviewed in this paper supported the six characteristics of a successful quality management system listed in the conceptual framework. Although total quality management (TQM) was by far the most frequently studied topic on construction quality (seven studies), other researchers focused on individual characteristics and how they contributed to quality performance. Customer focus, teamwork, continuous improvement, management commitment, employee involvement/empowerment, and communication were all identified as contributors to successful construction quality management systems. The use of quality standard (ISO 9000) or quality award (MBNQA) criteria for the evaluation of a contractor's quality management system prove to be effective in identifying discrepancies and improving quality performance. Researchers also focused on the use of partnerships, or inclusion of subcontractors and suppliers, to the construction quality management system. Increased involvement of these parties improved their understanding of quality and their overall contribution to a project while increasing their perception of involvement. The use of quality management was found to improve project safety in two studies (Courtice & Herrero, 1991; Chase, 1998). The most frequently used quality performance outcome measure was project cost and schedule growth (12 studies). Other outcome measures included in studies were: customer satisfaction rating, amount of rework, number of defects, survey responses, and evaluation against quality criteria (ISO 9000 or MBNQA). Sypsomos (1997) investigated high-performance construction companies and reported that successful quality systems were attributed to using both 'hard measures' (such as cost, schedule, and safety) and 'soft measures' (such as leadership, employee satisfaction, and teamwork).

The notable difference between quality and safety papers was that studies on quality tended to focus on what did not seem to work versus what worked. For example, a third of the papers (8 out of 26) on construction quality either focused on, or reported specifically on, barriers associated with implementing and sustaining quality management in construction. The most commonly cited barrier to successful quality management in construction was the 'nature of construction'. Characteristics of the nature of construction include: multiple parties (owners, designers, general contractors, suppliers, subcontractors) with different interests and poor communication (work system complexity), lack of understanding of the expectations of the customer, inability of owners to communicate construction 'needs' upfront, unpredictable site conditions, lack of clear quality performance objectives, low-bid contract competition, and dependence on suppliers for timely delivery and product quality. Lack of management commitment/leadership in quality programs and lack of worker empowerment were also cited as barriers to quality performance in construction.

Interestingly, Love *et al.* (1999) reviewed past literature on construction quality and concluded that, 'the construction industry (in general) did not fully understand TQM nor is it effectively implemented, and therefore it cannot achieve the full potential of its use.' Relating to Love *et al.*'s conclusion, Sun (1999) reported that quality programs in construction must be 'total and complete' for cost benefits to be realized. And finally, similar to a finding in the construction safety literature, Jaafari (1996) stated that, 'construction is too different from manufacturing to carry over programs.' These statements, taken from the literature on construction quality, lead us to believe that the nature of construction may be the largest barrier to the success of quality management in construction. If true, it would be very difficult for a single contributor (or company) within a construction project to improve quality. Perhaps there are construction contractors out there who are satisfied with the level of quality they achieve, as long as they continue to make a profit. Or maybe the proposal to alter or change the traditional methods or processes of construction is too daunting for them. Regardless, the complexity of the construction process requires that all parties make a consorted individual and combined effort to improve quality through a common understanding. The common understanding of quality work and quality management requires teamwork and strong communication between all parties of the construction project. With strong teamwork and communication, a measure for quality performance can be developed, along with a system to continuously measure, analyze and report performance. In fact, this 'recipe for success' is simply the three primary elements of TQM: teamwork, continuous improvement, and customer satisfaction.

The potential benefits of quality management hinge on the ability to control the construction process by identifying and correcting sources of variance (error, defect, undesired outcome) before the process extends beyond tolerance limits (customer expectations or design plans). In this context, one must consider 'what' is being measured, and 'how' to measure it. Unlike the use of the EMR or incidence rate for safety, quality performance measures need to be defined and validated as a means to identify potential issues and to control a process before things go bad. The varying definitions of quality and the characteristics of quality management need to be captured before attempting to understand how it applies to construction.

Based on previous publications, researchers in construction quality gave the following definitions for quality performance: 'meeting expectations of the customer' (McKim & Kiani, 1995; Chase, 1998; Kanji & Wong, 1998; Torbica & Stroh, 1999), 'reduced rework or defects' (McKim & Kiani, 1995; Sypsomos, 1997; Atkinson, 1998; Love *et al.*, 1999; Pheng & Wee, 2001), 'repeat business' (Sommerville, 1994; Sypsomos, 1997), 'conformance to ISO 9000 criteria' (Bubshait & Al-Atiq, 1999; Sun, 1999), and 'completion on-time and within budget' (Courtice & Herrero, 1991; McKim & Kiani, 1995; Jaafari, 1996; Ripley, 1996; Sypsomos, 1997; Gransberg *et al.*, 1999; Love *et al.*, 1999; Wong & Fung, 1999; Kiwus & Williams, 2001). Referring back to the use of lagging indicators in safety (EMR or incidence rate), the use of rework, defects, or repeat business as measures of quality will only provide information on quality of previous projects. Quality management effort should focus on proactively identifying quality problems, and the data collected should be applicable to improving processes currently in use on a construction project.

Throughout these studies, it appears that quality management is not as simple as just 'controlling the construction process'. Apparently, in construction, quality should be defined as the project/service expectations of the owner/customer. The number of studies that focus on customer satisfaction or customer-focused initiatives supports this. Basically, if the owner/customer is delivered with the constructed product or service as they desired, then the contractor can avoid expensive litigation, expect future business opportunities with the client, and possibly gain new clients through referral from a satisfied customer.

However, the ability to control the construction process begins with adequately soliciting the precise expectations of the owner/customer. This is not as straightforward as it may sound. First, it may be difficult to identify the customer in order to request their expectations. Second, the customer may not have a clear picture of what they desire in the finished product by the contractor. Only if the customer expectations are clearly defined can they be designed or marked by milestones as a means to monitor progress. But this is just one way to implement quality management. Regardless, most construction projects will be defined by two primary attributes: length of time to complete and cost of the job. In consideration of time and cost, a contractor can attempt to identify and reduce situations or circumstances that can delay or increase the cost of a project. Some of the more common causes of 'project delay' or 'cost increase' include: changes to the plan or design, rework caused by poor craftsmanship, building or material defects, late delivery of materials and equipment, labor shortage, accidents and/or injuries, and weather conditions that prevent (or slow) outside work due to safety/quality reasons.

Many of these issues were mentioned earlier in the section describing the nature of construction. It is essential for contractors to realize the existence of these issues, and attempt to minimize the risk of encountering them through a quality management system. In addition to customer focus, continuous improvement and teamwork are equally important. Continuous improvement requires continuous monitoring of work or collection of data (sometimes called 'benchmarking'), analysis, and changes in the work process to ensure that work is progressing toward the predetermined goal(s). One needs to keep in mind that sometimes goals change. The teamwork aspect essentially combines the concepts of management commitment, employee involvement, and communication.

Management provides the means and goals based on project goals, and communicates them to the workers who utilize their trade skills to perform a job as instructed by management. Supervisors are required to handle the data collection and analysis portion of the system, and report progress to management while providing feedback to workers. This process should be integrated as a work cycle, by which progress can be quantified and documented. Based on the changing needs of management, or unpredicted encounters at the job site, the system allows for evolution of work practices to maximize efforts or minimize losses, which benefit the construction organization.

Safety and Quality

Each of the five papers reviewed on the topic of integrating safety and quality management in construction were in agreement: the two management systems are similar and therefore can be integrated. In fact, Sommerkamp (1994) indicated that, 'implementing a safety initiative within a company is no different than executing a quality initiative.' However, some authors did conclude that integration of these two management systems might be difficult. Pheng & Shiua (2000) felt that, 'it is necessary for companies to determine their operational capacities before attempting this (safety and quality) integration.' Pheng & Pong (2003) concluded that, 'it may be difficult to find someone who is proficient and possesses the necessary knowledge in all the different areas of quality and safety to handle such an integration system. A final, and very difficult hurdle is implementation.'

These comments made by the aforementioned researchers agree with the findings in the quality management literature, that the construction industry seems to underestimate the time and resources required for the development and implementation of a successful quality management system. The primary barrier continues to be the nature of construction.

Study Limitations

The literature search was conducted in 2003–2004, and limited to databases available on the UW-Madison Library website. Articles collected were limited by the search keywords.

The authors attempted to be comprehensive in their search and review of papers on construction-related safety and quality management.

Recommendations for Future Research

The ‘nature’ of construction is a very real barrier to safety and quality management success. Love & Li (1998) stated that, ‘Numerous studies have examined the [construction] industry’s performance and most concluded that its fragmented nature, lack of coordination and communication between parties, adversarial contractual relationships, and lack of customer focus inhibit the industry’s performance.’ Based on the availability of research pertaining to safety or quality management in manufacturing, construction has been given very little attention by the academic community. The next step for academic researchers is to take a more holistic (macro-) approach to studies in the construction industry. Involving owners, designers, general contractors, suppliers, and subcontractors in data collection (surveys, interviews) would enrich the data and provide more insight to analysis (Ribeiro-Ferreira & Rogerson, 1999). One common error noted in available studies is that most performance indicators are latent representations, or ‘lagging’ indicators, of safety or quality (Everett & Thompson, 1995; De la Garza *et al*., 1998; Warrack & Sinha, 1999). These include the EMR and incidence rates for safety and project cost and time growth for quality (Hinze *et al*., 1995). Some studies successfully correlated safety performance with climate, and quality management success with self-assessment tools (such as ISO 9000). A combination of hard and soft performance measures is probably the best way to establish ‘usable’ performance criteria (Sypsomos, 1997).

Finally, as noted by the response rates of the studies cited as well as our own personal experience, the ‘nature’ of construction also makes it difficult to perform research (Loushine *et al*., 2004). Perhaps, through continued support by trade unions, professional construction organizations, and entities such as the Center to Protect Workers’ Rights (CPWR), the academic community can continue to make progress to assist the construction industry in its quest to improve quality and safety performance.

Conclusion

The similarities between safety and the quality management process were supported by findings of the research literature. Similarities were also established for the outcome measures of safety and quality. However, as several researchers indicated, the construction industry is too different and complex simply to take a successful management system from manufacturing and transplant it into construction. The nature of construction is a dominant force in keeping construction ‘the way it is’. As evident by the papers on construction quality, the success of quality management is increased through the combined effort by all parties involved with a project. The integration of safety and quality management is a possibility, but it requires much more research before it can truly become a reality. It may take an effort by academia to educate the construction industry to realize that a policy-level change is needed before construction safety and quality can improve.

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