Quality, Environmental, and Health and Safety Management Systems for Construction Engineering

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Abstract: The philosophy behind quality, environmental, and safety (QES) management systems is a concept that has been accepted by various contractors. Furthermore, a process has been developed insuring that the output produced conforms to customer satisfaction without violating any environmental, health, and safety rules and regulations. An effective QES program not only assures a quality product but also reduces costs, and enhances productivity. It is a top down process, i.e., top management together with line management and other employees develop the program and motivate all personnel to accept the process. Important functions to take under consideration are (1) explain and clarify the quality, environmental, and safety performance expected; (2) involve employees in decision-making and problem solving; (3) describe the consequences of poor quality and unsafe/unhealthy work conditions; (4) establish QES goals and provide feedback on performance; (5) provide a self-monitoring system; and (6) recognize and reinforce good performance and develop a reward system. This paper presents a discussion of the development of a portion of a QES management system which has been employed by a medium to large size construction company. In particular, Items 1–4, listed above, are described in detail.

DOI: 10.1061/(ASCE)0733-9364(2003)129:5(562)

CE Database subject headings: Construction engineering; Quality control; Safety; Construction management; Environmental issues; Contractors; Health hazards.

Introduction

Quality, environmental, and safety (QES) management systems are generally considered to be an integration of (International Standards Organization) ISO 9000, ISO 14000, and ISO 18000 regulations. They are an approach to doing business that attempts to maximize the competitiveness of an organization through the continual improvement of its product, services, people, and environment by emphasizing customer focus (internal as well as external), long-term commitment, and teamwork. A scientific approach to problem solving and decision making, continual process and product improvement, and intensive education and training are taken under consideration. Establishing a risk free work place, and reducing environmental pollution are important aspects of the system. Above all, unity of purpose of employees, and employee involvement and empowerment are vital for a successful program. Taking the aforementioned concepts under consideration, the principal objective of this paper is to evaluate the operations of a contractor in terms of the implementation of a QES management system.

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Note. Discussion open until March 1, 2004. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on September 5, 2001; approved on August 23, 2002. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 129, No. 5, October 1, 2003. ©ASCE, ISSN 0733-9364/2003/5-562–569/$18.00.

ISO 9000 in Construction

ISO 9000 is a generic name given to a group of standards developed to build a management system that will support continuous improvement in quality as well as integration with other business processes and regulatory requirements. It is driven by customer demand or the market place and is applicable to any industry including construction. Since first published in 1987, the ISO 9000 standards have been adopted by more than 158 countries throughout the world. The ISO 9000 family of standards embraces the use of Plan-Do-Check-Act principles and various project management procedures to enhance quality. Benefits associated with the adoption of ISO 9000 quality standards have been found to include the following:

- Increased profitability,
- Expanded market share,
- Increased customer satisfaction,
- Reduced operating costs,
- Heightened demand for products and services, and
- Better employee working conditions.

Since the introduction of the ISO 9000 standards, more than 350,000 organizations worldwide have adopted and implemented a quality management system (QMS) (Pheng and Wee 2001). Apart from the aim to operate from a common quality assurance platform, the development of ISO 9000 in construction is related to utilization of quality as a critical factor in determining project acceptance and success (Battikha and Russell 1988). Legislation has also directly and indirectly contributed to the propagation of the ISO standards. As an example, for Australian construction organizations wishing to export their services, the accreditation to ISO standards is a qualification for business operations (Jones et al. 1997; Love and Li 2000). In Singapore and Hong Kong, explicit reference is made to ISO 9000, and certification is a prerequisite for contractors who wish to bid on certain public sector projects.

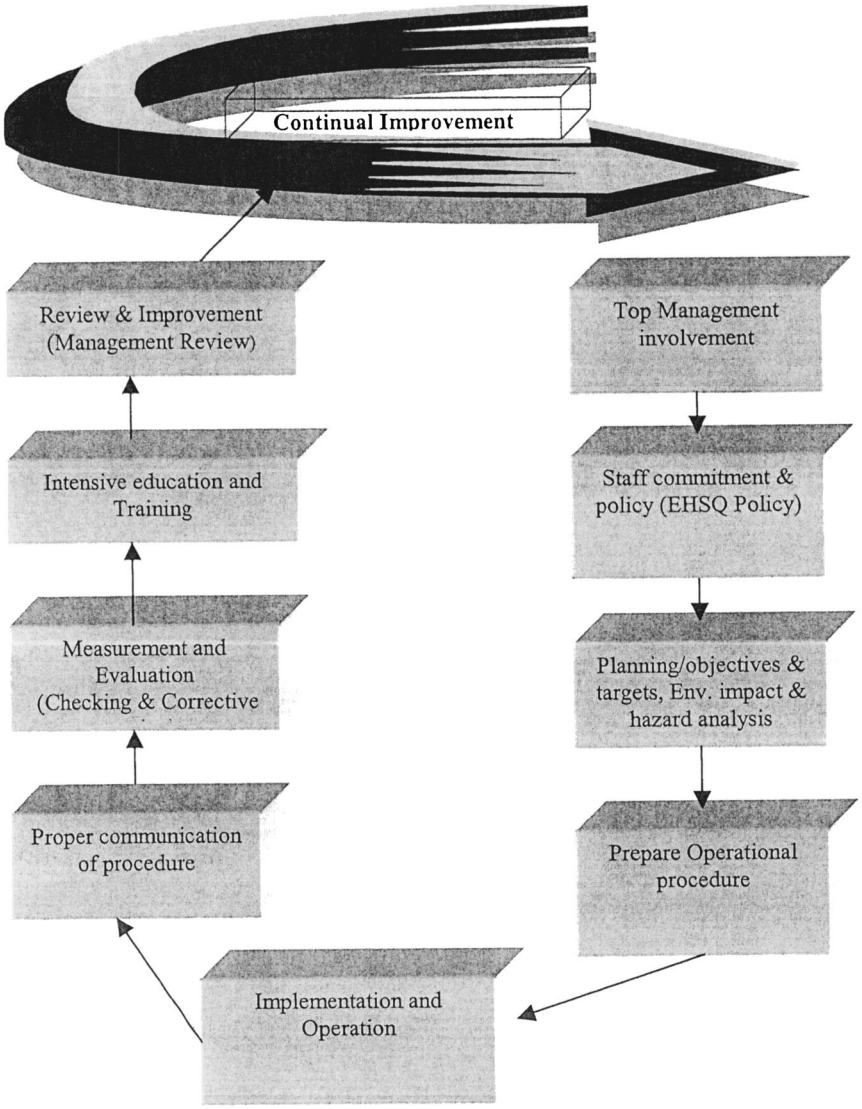

Fig. 1. QES: Continual improvement

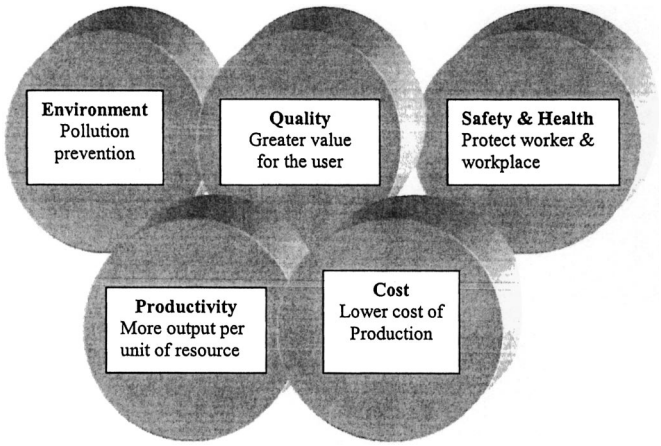

Fig. 2. QES and interaction of cost and productivity

ISO 14000 in Construction

The ISO 14000 family addresses various aspects of environmental management. Since its adoption in 1996, more that 430,000 organizations in 158 countries including 1,500 U.S. companies have achieved ISO 14001 registration, the majority of which are in the manufacturing industry. ISO 14001, an integral part of the ISO 14000 series of global environmental management standards, integrates business practices and environmental goals that enable an organization to manage its potential impact on the environment. From an operational perspective, utilizing the ISO 14000 criteria can lead to the following benefits:

- Reduced cost of waste management,
- Savings in consumption of energy and materials,
- Lower distribution costs,
- Improved corporate image among regulators, customers and the public, and
- Continuous improvement of environmental performance.

Today, the Environmental Protection Agency is encouraging the use of recognized environmental management frameworks, such as the ISO 14001 standard, as a basis for designing procedures and implementing outcomes aligned with the nation's environmental policy goals.

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Table 1. Previous Defects/Accidents/Environmental Impact as per Number of Occurrences

	Never happened before in this company	Previously happened but only once and now is in a controlled stage	More than one occurrence, presently controllable but needs supervision	Multiple occurrences causing negative image of the company, i.e., difficulties in bidding/getting jobs
Points	1	2	3	4

Table 2. Previous Defects/Accidents/Environmental Impact as per Severity of Damage/Injury

	Minor defect/impact/injury like bruises, scratches, minor cuts/no loss of man-hour	No financial loss but warning letter imposed by authorities because of quality, environmental, and safety issue, no impact/injury but near-miss	Reportable impact/accident, man-hour loss because of incident/ accident but no loss of life, significant amount loss during servicing because the poor quality	Death/multiple deaths, severe property damage/environmental pollution, severe defect during service period, retainage not returned by owner
Points	1	2	3	4

Table 3. Violation of Environmental, Quality, Health, and Safety Regulations

	Never violated quality, environmental, and safety laws and regulations	Previously violated the regulations but due to minor violation no fine or stop-work-order was imposed, presently controllable stage	More than one occurrence, fine imposed by authorities, is controllable but needs supervision	Multiple violations of quality, environmental, and safety regulations, as a result fine and stop-work-order was imposed by different authorities, clients, etc.
Points	1	2	3	4

Table 4. Quality, Environment, Safety (QES) Management System and Training

	Quality, environmental, and safety system exists in a documented form and proper implementation on site, auditing, corrective, and preventive action taken, satisfactory on-the-job training	Quality, environmental, and safety system exists in a documented form, some implementation on site was made but not systematical, no auditing, corrective, and preventive action taken	Quality, environmental, and safety system exists in a documented form but no implementation on-site, on-the-job training is negligible	No system in place only verbal instructions given during construction
Points	1	2	3	4

Table 5. Remedial Action

Table number	Quality, environmental, and safety score assigned	Occurrences
1	3	- More than one accident
2	2	-
3	3	- More than one violation
4	1	-
Total	9	

Table 6. Quality, Environmental, and Safety Score for Erection of Formwork

Table number	Quality, environmental, and safety score assigned
1	4
2	4
3	4
4	4
Total score	16

Table 7. Quality, Environmental, and Safety Score for Water Seepage

Table number	Quality, environmental, and safety score assigned
1	3
2	3
3	3
4	4
Total score	13

Table 8. Quality, Environmental, and Safety Score for Dengue Fever

Table number	Score assigned
1	4
2	4
3	3
4	3
Total score	14

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Table 9. Incidents and their Possible Solutions

	Causes of incidents (poor quality, environmental, and safety and health)	Possible solutions
1	Poor site supervision and practice	Implement work procedures, prepare inspection checklist, and use it effectively
2	Lack of motivation and care	Staff motivation and support
3	Lack of knowledge and training	Provide both job training as well as institutional training
4	Lack of quality, environmental, health, and safety budget	Provide adequate funds to improve poor quality, environmental, health, and safety conditions
5	Design too complicated to build	Take quality, environmental, and health and safety conditions under consideration during design stage
6	Overemphasis on speed of construction rather than quality, environmental and health, and safety conditions	Maintain uniform speed rather than rushing. Use critical path method, Microsoft Project, etc. for project duration calculations.
7	Defective materials	Reject defective materials on-site. Conduct material testing when required.
8	Overlooked site conditions	Visit site by qualified personnel before bidding a project
9	Defective documentation procedures	Proper documentation and document control
10	Lack of communication between contractor and design team including regulatory authorities such as Building Construction Authority, Occupational Safety and Health Administration, etc.	Establish proper communication channels. Check on any new rules and regulations, periodically.
11	Inadequate supply of personal protective equipment i.e., safety boots, helmets, ear plugs, etc.	Supply proper and adequate number of personal protective equipment and enforce workers to use them
12	Poor subcontractor with new unskilled workers	Select only those subcontractors who have a good record, and provide on-the-job training

Specifically, an environmental management system (EMS) may be an integral part of an organization's overall management system, which provides an order and consistency for the firm to address environmental concerns. This may be accomplished through the allocation of resources, assignment of responsibilities, and an ongoing evaluation of practices, procedures, and processes. In the past, some construction firms dismissed the application of EMS as too expensive. But a closer look may reveal the following benefits to a construction company through proper implementation of an EMS (ISO 1994b):

- Conservation of materials and energy,
- Improved cost control,
- Satisfaction of customer demand for a commitment to the environment,
- Maintenance of good public/community relations,
- Lower insurance rates,
- Enhanced image and market share, and
- Improved industry/government relations.

ISO 18000 in Construction

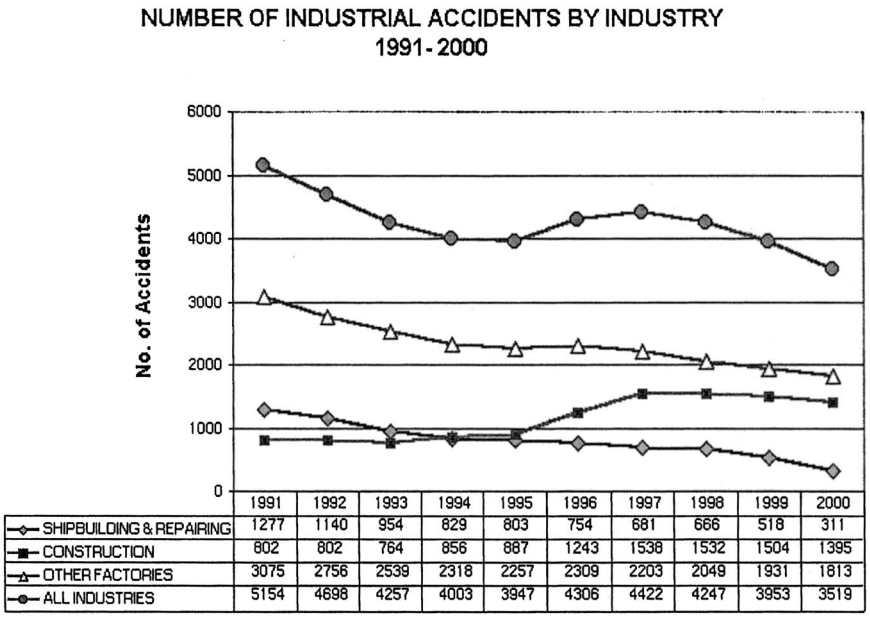
The ISO 18000 criteria has been proposed for the development of an occupational health and safety management system. The requirements are similar to the ISO 14001 environmental management systems (EMS) standards and the section numbering is nearly the same. The primary difference is the ''risk assessment'' section, which replaces the environmental aspects section of ISO 14001, and the substitution of the words ''health and safety'' for ''environmental.'' It also requires a management system that identifies, controls, and seeks continuous improvement in occupational health and safety. Many contractors do not comply with the international, national, and regional legal safety requirements. This may result in major problems when employees become injured on the job site. ISO 18000 recommends the development of a holistic risk management process to ensure compliance with international, national, and regional safety requirements. In most instances, the risk management process should also be integrated with environmental management and quality systems. In addition, the risk management process should ensure that an adequate number of personnel are legally appointed to manage health and safety and that employees are trained and understand the importance of job site safety.

Unfortunately, the international organization for standardization has not yet released ISO 18000, but it is being utilized on a national level in the United Kingdom, Australia, and Singapore. It may be considered an improved version of a safety management system (SMS) which itself is a relatively new approach of controlling safety policies, procedures, and practices within a company. This philosophy is currently being implemented by many construction companies to limit their liabilities and costs, thereby making them more competitive in the construction market place (Wilson and Koehn 2000).

In some countries and regions such as Singapore and Hong Kong, submission of a SMS is mandatory before starting a construction project above a particular monetary volume. In the United States, the Occupational Safety and Health Administration (OSHA) mandates that employers such as contractors are responsible for providing a safe and hazard free workplace for all employees. Proper implementation of ISO 18000 (SMS) could serve the requirements of a governmental regulatory body, such as OSHA, as well as provide a firm base line towards a safer working environment (Occupational 2001).

Quality, Environmental, and Safety Management Systems

A QES Management System is involved with continual improvement and subscribes to the principles illustrated in Fig. 1. As shown, management and staff commitment, education and training, and measurement/evaluation are associated with the QES



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
SHIPBUILDING & REPAIRING	1277	1140	954	829	803	754	681	666	518	311
CONSTRUCTION	802	802	764	856	887	1243	1538	1532	1504	1395
OTHER FACTORIES	3075	2756	2539	2318	2257	2309	2203	2049	1931	1813
ALL INDUSTRIES	5154	4698	4257	4003	3947	4306	4422	4247	3953	3519

Fig. 3. Accidents in Singapore

process. However, for a small construction company implementation of a QES management system may be, at times, a slight burden. But for medium to large organizations, application of QES should bring about an improvement in cost and productivity factors along with improved quality and a safer working environment. As materials, processing, and operations are brought under single control, the production rate should also increase (Lester et al. 1985). In addition, consideration of specifications and tolerances should reduce the waste of basic materials such as steel and concrete. Due to a safer working environment, personnel may increase their sense of belonging, which may also increase productivity and quality as shown in Fig. 2. Lower cost of production and decreased pollution are also important attributes of a QES system.

It is generally known that accidents, if they happen, can incur high direct and indirect costs. Management can control these expenses through proper implementation of a QES management system. Direct expenses may include medical costs, increased workers' compensation insurance charges, as well as liability and property-damage premiums.

Indirect or hidden costs may be a much larger part of the economic burden imposed on a firm with a poor accident record. Reduced productivity, job schedule delays, added administrative time, damage to equipment and facilities, and costs of administering and handling workers' compensation insurance are some of the indirect costs associated with accidents (Koehn and Regmi 1990; Koehn et al. 1995). For construction companies with very poor safety records, insurance premiums for worker's compensation can be costly enough to render a company noncompetitive compared to safer firms, especially in industrial construction (Harper and Koehn 1998).

Quality, Environmental, and Safety in Construction

The second writer was employed by a construction contractor in Singapore, and was a member of a team which successfully implemented a QES management system for the company. The firm had a good track record in achieving certification for ISO 9000, ISO 14000, and SMS (ISO 18000) accreditation from the Building Construction Authority in Singapore (Building 2001). It has won numerous quality as well as construction excellence awards from the government. The firm was also one of the first building contractors in Singapore to be certified with a QES management system. Due to their systematic approach of quality control, timeliness, environmental care, and hazard/risk free work sites, it is recognized as one of the market leaders in Singapore. Today, the company is structured to include nine principal departments associated with construction; administration, design/planning, contracts and purchasing, accounting/finance, project, QES, human resources, MIS (management information system), and quantity surveying. The QES department, previously managed separately under different sections involving quality, environmental concerns, and safety, is now collectively grouped into one department responsible for implementation and maintenance of ISO 9000, ISO 14000, and ISO 18000 rules and regulations. Merging of the functions into a one-body stem helps the company to synergize their closely related activities so as to improve productivity and quality.

In Singapore, certification of ISO 9002 for a construction company is a prerequisite for a G8 contractor (a firm with a bidding capacity above Singapore S$ 50 millions). For the above reason, the firm gained certification of the ISO 9002 QA Standards in 1994, which reinforced the firm's long-standing and uncompromising commitment to quality. Five years after implementing ISO 9002, the Ministry of Manpower (MOM) issued a directive that every project site (exceeding a specific dollar value) should implement and submit a safety management system (SMS) and a safety budget for approval to MOM. Additional inspectors were also hired in order to frequently visit construction sites. Adoption of the QES management system satisfied the MOM regulations and allowed the company to avoid extra paper work, and auditing frequency (three versus nine times a year), which made the firm more environmentally friendly and competitive.

Quality, Environmental, and Safety Scoring System

Construction is a unique industry unlike a stationary or fixed work place such as a factory (Reese and Edison 1999). Contrac-

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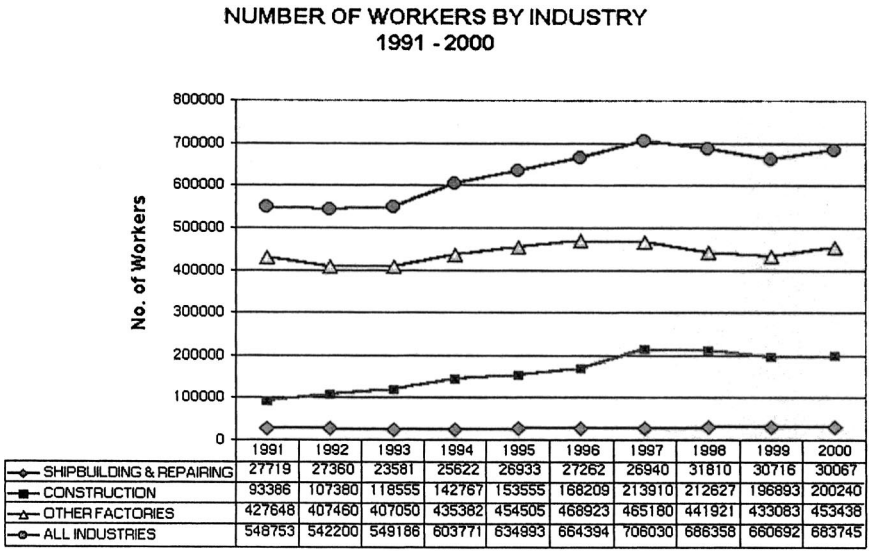

Fig. 4. Number of workers in Singapore

tors are faced with a situation where different types of hazards are encountered at various stages of a project. Environmental concerns and impacts including hazard identification are therefore a big challenge. To investigate this problem, the firm selected three different projects at various stages of construction.

The QES team, which included the second writer, together with external consultants, inspected every project repeatedly so that all possible environmental aspects and impacts including hazards were noted. Concerns were then sorted in order to determine the most significant problems. Tables 1–4 illustrate the sorting and scoring procedure developed and utilized by the firm. Additional QES scoring systems may be developed to satisfy future specific requirements.

The scoring system illustrated in this paper is not unique. Different firms have developed similar but not identical systems for their organizations. Nevertheless, the system presented provides a template which may be utilized by firms as a guide to design a procedure to satisfy specific organizational requirements. In fact, some constructors may perceive that information of this type may be, in particular situations, proprietary in nature.

In order to solve a specific problem, the company QES team, line management, together with external consultants, list all the possible activities such as earthwork, erection of scaffolding, erection, and dismantling of formwork, placement of concrete, etc., involved with a project. Each activity is then selected for individual scoring. For any activity, with a score exceeding 10, remedial action is taken. This may include enforcing nonstandard work procedures, more frequent inspections, and/or modification of existing procedures. In some cases, actions should be taken even if the QES score is under 10. For example, as shown in Table 5, scores from Tables 1 and 3 indicate that more than one accident/violation may occur. Here, the QES score is 9 and action should be taken so as to minimize the number of accidents and violations in the future.

Implementation of Quality, Environmental, and Safety Systems

An example of the implementation of a QES system is as follows: A firm experienced a number of incidents involved with the erection of external formwork for a facility. This included the death of two construction personnel. The sorting and the scoring procedure for this activity utilizing Tables 1–4 is shown in Table 6. The overall total-score of 16 means that immediate action is necessary to eradicate the problem. In response, the QES team members together with line management implemented a revised standard work procedure for erection of external formwork. Special training was provided to formwork crews and a permit-to-work procedure was introduced. Under this approach, construction engineers must seek a permit-to-work form from the project manager before starting erection of external formwork activities. After receiving an application for permit-to-work, the Project Manager or Project Engineer and the site safety supervisor must inspect the site. If they are satisfied with site conditions and the training of the crews, they may issue a start-work order unless there are other problems.

Another problem involved water seepage from toilets and kitchens. This incident occurred a number of times during a one-year servicing period. The total QES score as shown in Table 7 was calculated to be thirteen. Here, additional water retardant materials during casting were specified. This and the next problem are presented as illustrative examples. Other approaches may, of course, be utilized to solve the problems.

In the third case, an outbreak of dengue fever was traced to a construction site. The firm received a fine and a partial stop-work order for the presence of stagnant water (favorable condition for breeding mosquitoes). The scoring for this situation is shown in Table 8. Here, the total QES score is 14, which indicates a problem area, which was solved by draining the water.

As shown, the problematic areas above have been defined by QES team members, line management, and external consultants. The causes of some incidents, including various remedial measures, are also described in Table 9 (Goetsch and Davis 1985; Hinze 1988; ISO 1994a; Randall 1995). The data in Table 9 reveal that many of the possible solutions may be related to ISO 9000/ISO 14000/and ISO 18000 (SMS) recommendations. Therefore, implementation of a QES management system can be considered to be, in some cases, strongly related to the ISO rules and regulations.

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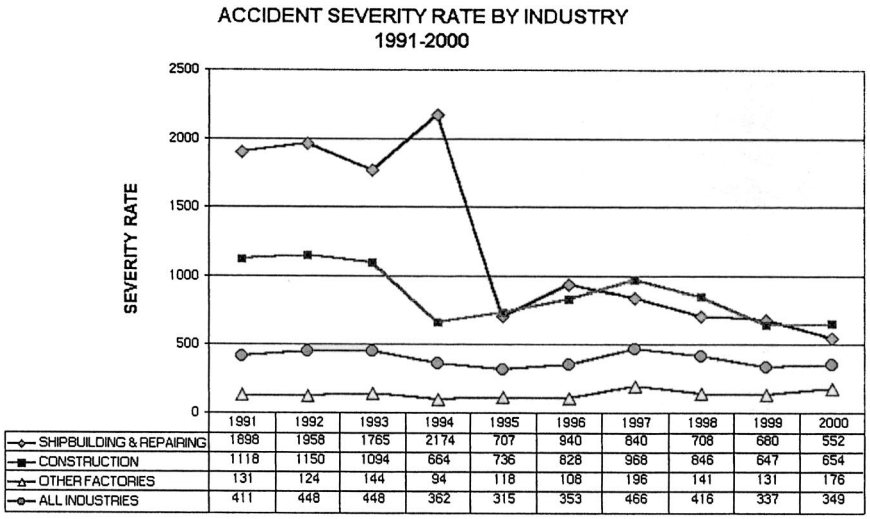

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
SHIPBUILDING & REPAIRING	1898	1958	1765	2174	707	940	840	708	680	552
CONSTRUCTION	1118	1150	1094	664	736	828	968	846	647	654
OTHER FACTORIES	131	124	144	94	118	108	196	141	131	176
ALL INDUSTRIES	411	448	448	362	315	353	466	416	337	349

Fig. 5. Accident severity rate in Singapore

Occupational Accidents and Illnesses

The occupational illnesses affecting construction workers are difficult to measure. However, it may be assumed that construction workers suffer both acute (short-term) and chronic (long-term) illnesses from their exposure to chemicals, dusts, fibers, noise, radiation, vibration, and temperature extremes. For some particular trades, specific occupational illnesses have been documented such as asbestosis and cancer for asbestos workers. Nevertheless, few comprehensive investigations as to the prevalence of occupational illnesses among construction workers have been undertaken. Precautions need to be taken to limit exposures, which have the potential to cause detrimental health effects to construction workers. This is especially important since accurate exposures often cannot be determined due to the transient nature of construction work.

Realistic data involving occupational illnesses of construction workers in Singapore is difficult to find. However, accident data is readily available. For example, Fig. 3 (Ministry 2001) illustrates the number of accidents in Singapore for a variety of industries. As shown, the number of construction accidents has increased by 74% between 1991 and 2000. However, Fig. 4 (Ministry 2001) indicates the construction work force has increased by 114% during the same time period. Therefore, an increase in the number of accidents is to be expected. The change in the accident severity rate for various industries in Singapore is illustrated in Fig. 5 (Ministry 2001). As shown, the accident severity rate in construction has decreased 42% between 1991 and 2000. It can be assumed, therefore, that it may be possible that the influence of the authorities in Singapore forcing contractors to develop QES management systems has been, to some degree, effective.

Summary and Conclusions

A QES management system is concerned with actions that can create an organizational setting in which workers can be trained and motivated to perform safe, healthy, and productive construction work which satisfies customer needs. It is a plan-do-check-action process. To be successful, management must continually remind employees to engage in comprehensive planning, checking, and review to ensure that quality, safety, and concern for the environment are achieved. Specifically, the findings suggest that it is possible for a construction company to develop a system that is effective in ensuring quality, environmental protection, health, and safety. Similar measures could also be taken by other organizations to eradicate poor quality, unsafe and unhealthy working conditions, and lack of environmental control.

Acknowledgment

The writers wish to recognize Ms. Linda Dousay for her assistance with the production activities involved with the preparation of this paper.

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