Strategies for Achieving Excellence in Construction Safety Performance

By Edward J. Jaselskis,[1] Associate Member, ASCE, Stuart D. Anderson,[2] Associate Member, ASCE, and Jeffrey S. Russell,[3] Member, ASCE

Abstract: This paper provides strategies for improving construction safety performance through the analysis of numerical profiles of companies and projects with varying levels of safety performance. This research perspective compliments much of the previous safety-related research, which tends to be more qualitative in nature, addressing "what" factors are important for success as opposed to "how much" is appropriate to achieve successful safety outcomes. Corporate safety coordinators completed questionnaires that solicited quantitative data (e.g., number of safety inspections, dollars spent on safety program, and percentage of time devoted to safety issues) at both the company and project levels. Several safety performance measures were investigated: Occupational Safety and Health Administration (OSHA) incidence rates, experience modification rating (EMR), and a subjective project performance rating. Forty eight company programs and 69 individual project safety programs are included in the analysis. Results from the statistical data analysis point to several company- and project-specific factors that are statistically significant in improving safety performance. This paper can benefit contractors, specialty contractors, and owners by providing them with objective strategies to consistently achieve better safety performance.

INTRODUCTION

There is interest in improving construction site safety for humanitarian reasons and because of the rising costs of worker compensation and Occupational Safety and Health Administration (OSHA) fines. According to the National Safety Council, construction accidents claimed 1,300 lives in 1993 (*1993 Accident* 1994). Further, the combined injury and illness rate for the construction industry is higher than for all other industries except for agriculture. Workers' compensation rates have increased dramatically in nearly two decades. From 1974 to 1994, for example, general carpentry rates increased an average of 3.8 times in the United States; structural steel erection manual rates increased nearly 3.5 times for the same time period ("3rd quarterly" 1974, 1994). OSHA has also increased its fines significantly in recent years.

In an attempt to reduce fines and the potential for accidents, construction companies are using full-time safety coordinators, increasing safety inspections, developing comprehensive safety programs, and implementing "back-to-work" programs for injured workers. Moreover, the National Institute for Occupational Safety and Health (NIOSH) created the Construction Safety Excellence Center at West Virginia University to provide a construction site safety resource to the industry. The Construction Industry Institute has also funded several research studies related to improving jobsite safety (Hinze and Figone 1988; Liska et al. 1993).

To date, much of the safety research performed has addressed critical safety success factors by identifying factors that are important for safety success. There is a need for research that provides quantitative safety factor inputs associated with improved safety performance. This study builds on other research work and identifies how much factor input is necessary to achieve successful safety performance; thus, providing the industry with objective strategies for improving construction safety performance. By quantifying these inputs, safety coordinators can allocate limited resources in a more cost-effective manner to attain improved safety performance and to replicate or improve the company or project safety record.

A diversity of safety performance measures were considered in this study because of the inherent strengths and weaknesses of each measure, as explained in detail in later sections of this paper. A combination of both quantitative and qualitative safety measures are used to evaluate the safety performance of a construction company. Quantitative measures include the OSHA recordable, lost time and severity rates, and the experience modification rating (EMR). A qualitative rating was also used consisting of outstanding, average, and below-average project performance. This rating compliments the more objective measures as it uses a subjective assessment by a knowledgeable company safety representative to evaluate safety performance at the project level.

METHODOLOGY

The research methodology involved the following steps: (1) Perform a literature review to identify significant factors related to improved safety performance and measures of safety performance; (2) develop a questionnaire related to both company and project safety programs; (3) collect data; (4) analyze the data; (5) summarize the results; and (6) provide recommendations for improving construction site safety performance.

PREVIOUS SAFETY RESEARCH

Researchers have investigated factors associated with company and project safety success for some time. Much of this research has been descriptive in nature, identifying attributes associated with enhanced construction safety performance. Table 1 provides a brief overview of key safety research. Significant factors associated with successful safety performance as determined by the research are summarized.

Several safety performance measures can be used to evaluate a company's safety performance. Both EMR and OSHA reportable incidence rates are useful in evaluating company safety performance over a number of years (Levitt and Samelson 1987). A company's EMR is a significant indicator because it reflects the cost a contractor pays for workers' com-

[1]Assoc. Prof., Civ. and Constr. Engrg. Dept., Town Engrg. Build., Room 450, Iowa State Univ., Ames, IA 50011.

[2]Asst. Prof., Dept. of Civ. Engrg., CE Build., Room 222, Texas A&M Univ., College Station, TX 77843-3136.

[3]Assoc. Prof., Civ. and Envir. Engrg. Dept., 2258 Engrg. Hall, 1415 Johnson Dr., Madison, WI 53706.

Note. Discussion open until August 1, 1996. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on March 6, 1995. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 122, No. 1, March, 1996. ©ASCE, ISSN 0733-9364/96/0001-0061–0070/$4.00 + $.50 per page. Paper No. 10253.

J. Constr. Eng. Manage., 1996, 122(1): 61-70

pensation insurance. Worker's compensation is directly related to safety performance via claims paid due to accidents. EMR is calculated by taking the ratio between the dollar amount of adjusted actual claims filed to the dollar amount of adjusted expected claims for a particular type of construction, and is a three-year running average starting one year prior to the last full year ("The Workers" 1991). Thus, an EMR of 1.2 means that a contractor pays 20% more for workers' compensation insurance than a similar company with an EMR of 1.00. This additional cost can make a contractor less competitive. The actual EMR equation and a sample calculation can be found in Everett and Thompson (1995).

Both Levitt and Samelson (1987) and Everett and Thompson (1995) explain the limitations using EMR. Levitt and Samelson state that: (1) EMRs are not reflective of the present safety performance of a company since the latest EMR is

TABLE 1. Summary of Prior Safety Research

Year (1)	Author(s) (2)	Summary of research (3)	Key factors associated with safety success (4)
1976	Levitt and Parker	Related to top-management role in reducing construction accidents.	Company managers' awareness of safety problems. Evaluation of superintendents based on safety performance. Top managers pointedly talking about safety when they visited jobs had experience modification rates (EMR) lower than companies in which this was not mentioned during interviews. Companies that conducted formal safety orientation for all new hires had average EMR lower than companies that had no formal orientation for newly hired workers. Incentives based on lost-time accidents awarded to workers, foremen, and superintendents for accident-free work had no effect on safety, according to research findings. Crews were found to perform work quicker, better, and more safely when managers insisted on detailed work planning (including materials, equipment, man power, and safety requirements) prior to the start of the job.
1978	Hinze	Identified safety impact of new worker and turnover rates.	Superintendents whose crews had fewer injuries were those having larger percentages of workers transferring with them from one job to the next. Safety increases when companies retain their employees for more than one year, and there are additional safety benefits when employees are kept for even longer periods of time (five years in this study).
1978	Hinze and Pannullo	Found that increased job control led to better safety performance.	General trends suggested more top-management visits per week lowered the injury index. Injuries tended to be lower in those firms engaging in projects in close proximity to the home office. Safer companies employed the same workers for a longer duration. Safety performance improved when more workers visited the home office regularly.
1978	Hinze and Parker	Investigated superintendent characteristics associated with improved safety performance.	Increased job-related pressure on superintendents led to increased injuries. Superintendents in strong support of job competition between crews had more injuries than both those who opposed job competition and those who were only moderate supporters of competition. Superintendents who were under pressure to complete the job from the home office had higher injury frequencies.
1979	Hinze and Francine	Investigated supervisor-worker relationships and how they affect injury rates.	Supervisors who are more flexible in dealing with subordinate conflicts have better safety records compared to their more rigid counterparts. Safety performance is worse when foremen have full firing authority.
1981	Hinze and Harrison	Identified safety program practices in large companies associated with reduced injury frequency rates.	The corporate safety director hired the field safety representative. Field safety directors trained their subordinate workers. The safety director reported to the president or vice president of the company. New workers received formalized safety orientation. Safety awards were given to workers. Safety awards were given to foremen.
1982	Samelson and Levitt	Identified owner's guidelines for selecting safe contractors.	Owners who involve themselves actively in selecting and monitoring safety performance of contractors have significantly lower accident rates on their construction projects. Several owner strategies were found to have a significant impact on contractor safety: use of short-term work permits to regulate hazardous operations; stressing safety during the prebid site visit; incorporating detailed job-specific safety requirements in specifications and periodic inspections; maintenance of safety records; setting ambitious goals for contractor safety and rewarding successful achievement of those goals; considering safety as a criteria in preselecting contractors for bid lists; providing safety orientation and training materials for contractor's labor and supervision for hazardous operations unique to the particular project; and developing in-house owner construction safety personnel with the expertise to carry out their tasks. Actions such as requiring contractors to delegate safety to on-site personnel, examination of safety at jobsite meetings, and investigation of accidents were initiated by both safe and average owners. Placement of considerable emphasis on selection of safe contractors by the owner is necessary for fewer monitoring and control actions.
1988	Hinze and Raboud	Identified appropriate means of achieving or maintaining acceptable safety performance on large projects.	Employed a full-time company safety officer. Strong top-management support for safety. Safety meetings were conducted for supervisors. Supervisor safety performance was monitored. Specific jobsite safety tours were conducted. Safety issues were included in regularly held coordination meetings. Lower incident rates occurred on projects that employed sophisticated scheduling techniques. Better safety results occurred when the owner or owner's representative was included in coordination meetings. Job pressures (particularly those imposed by budgetary constraints) were found to adversely affect safety performance.

J. Constr. Eng. Manage., 1996, 122(1): 61-70

TABLE 1. (*Continued*)

(1)	(2)	(3)	(4)
1988a	Hinze and Figone	Investigated specialty contractor safety as influenced by general contractors on small- and medium-sized projects.	Superintendents who felt less project pressure had safer projects. Projects on or ahead of schedule were safer. Companies that emphasized other goals in addition to profits had safer projects than companies only seeking to maximize profits. Companies that negotiated a majority of their prime contracts had safer projects. Several variables related to job coordination affected safety positively: smaller projects; projects with fewer specialty contractors; companies that negotiated a majority of their subcontracts; and companies that use the same specialty contractors. Two variables related to company safety emphasis result in safer projects: companies whose home offices monitor project safety, and concern by top management. Two variables related to superintendents' concern for workers result in safer projects: superintendents who show concern for workers and superintendents who provide new worker orientation. Two variables related to job cleanliness result in safer projects: good housekeeping, and daily specialty contractor safety inspections.
1988b	Hinze and Figone	Investigated specialty contractor safety as influenced by general contractors on large projects.	Significant factors correlated with general contractor injury rates: conducting special safety meetings for field supervisors, and employing full-time safety professionals. Significant factors correlated with general contractor safety performance: specialty contractor was involved in project meetings with the owner; general contractor reported directly to the home office rather than the district office; general contractor reviewed specialty contractor safety programs or required them to follow project-wide safety programs; project schedules were prepared by superintendents or on-site scheduling departments; and general contractor required the specialty contractor to hold "toolbox" safety meetings. Factors that tended to show a relationship to improved general contractor safety performance: the general contractor was not experiencing excessive schedule pressure; general contractors were located farther from their home office; and the general contractor investigated all specialty contractor accidents.
1993	Liska et al.	Identified zero accident techniques	Safety preproject/pretask planning included safety goals, safety person/personnel, hiring employees, safety policies and procedures, fire protection program, accountability/responsibility, and safety budget concerns. Safety training and orientation required. Safety incentives provided. Alcohol- and substance-abuse program in place. Accident and near-miss investigation conducted. Record keeping and follow-up undertaken. Safety meetings held. Personal protective equipment employed.

based on an average of the company's performance four, three, and two years ago; (2) very small companies may not be eligible to receive an experience rating and, even when they are, their EMRs may not correctly reflect their own claims compared to larger companies; (3) new companies or new joint ventures are automatically rated at 1.0; and (5) the reserving practices of the contractor's insurance company and a contractor's practices on monitoring reserves can affect EMRs.

According to Everett and Thompson (1995), several additional limitations exist: (1) The formula is complex and incentives are difficult to recognize; (2) different versions of the EMR calculation are used (although most of them use methods similar or identical to the National Council on Compensation Insurance); (3) EMR gives greater weight to loss frequency than to loss severity; (4) for large employers, the importance of severe losses is higher than for small employers; (5) employers end up paying higher insurance premiums as a result of accidents that occur today; and (6) everything being equal (work classification, person hours of work, actual losses) differing wages rates will affect the calculated EMR. One can clearly see that there are limitations in using EMR as a sole measure of a contractor's safety measure.

Despite the limitations associated with EMR, it is still an industry-wide accepted measure. Levitt and Samelson (1987) state that EMRs provide a useful method for comparing a company's safety performance with that of similar companies. According to an insurance industry professional, EMR can and is still used as an indication of a company's overall safety record. If the EMR is greater than 1.0, it means the contractor is experiencing losses greater than the other companies in that state and has the opportunity to improve. If the EMR is less than one, the contractor is experiencing fewer losses than other comparable companies.

OSHA has identified other measures of safety performance that can be used in conjunction with EMR. Incidence rates provide an indication of how a contractor compares to others and adjusts for the size of a project. The incidents can involve the number of lost time cases (lost time incident rate), the number of days lost for all lost time cases (severity rate or lost workday rate), and the number of fatalities, injuries, and illnesses with and without lost workdays (recordable incidence rate). The basic equations are as follows:

$$\text{Lost time incidence rate} = \text{number of lost time incidents} \times 200{,}000/\text{employee hours worked} \quad (1)$$

$$\text{Severity rate} = \text{number of days lost} \times 200{,}000/\text{employee hours worked} \quad (2)$$

$$\text{Recordable incident rate} = \text{number of fatalities and injuries and illnesses with and without lost workdays} \times 200{,}000/\text{employee hours worked} \quad (3)$$

[In (1), the 200,000 employee hours worked reflects a 100-person crew working 40 hours per week for 50 weeks.]

Incident rates can be calculated from information found in the OSHA 200 Form and can be determined at both the company and project level. Levitt and Samelson (1987) state that these rates have the advantage of being more recent and of being applicable to small companies as well as medium-sized and large ones. Also, they can be compared to incidence rates published by the Bureau of Labor Statistics, and provide a valuable supplement to the EMR for comparing safety records with other firms' records and for selecting contractors and specialty contractors (Levitt and Samelson 1987). Levitt

J. Constr. Eng. Manage., 1996, 122(1): 61-70

and Samelson (1987) agree that the recordable incidence rate is a better reflection of project safety performance than just injuries and illnesses with lost workdays. The primary disadvantage of the incidence rates is they can be less objective because companies may not use exactly the same definitions outlined by OSHA (Levitt and Samelson 1987). Hinze et al. (1995) discuss the issues related to EMR versus lost-time rate and the measure that is better for predicting company safety performance. He states that a combination of the injury frequency, injury severity, lost ratio, and other variables that are used to compute the EMR should be used to measure a contractor's safety performance.

It appears from this literature review that there are inherent limitations associated with each safety performance measure and that a combination of measures might give the best overall indication of company safety performance. This knowledge was helpful in formulating the questionnaire since it provided the basis from which to ask questions related to key factors associated with safety success and the different measures of safety performance.

QUESTIONNAIRE

Each questionnaire requested information pertaining to the individual respondent and his or her company safety and project safety programs. The company portion of the survey contained three parts: (1) Company characteristics (e.g., primary organization type, billings, peak number of craft personnel, and number of years in construction); (2) information about the company safety program (e.g., number of formal and informal safety inspections per week, percentage of time devoted to safety by field safety coordinators, and the number of activities in the written program); and (3) safety performance measures, which included EMR and the OSHA recordable rate, lost workday rate, and lost-time rate. Data were also collected on the number of restricted workday cases (column 2—OSHA 200), number of cases involving lost workdays (column 3—OSHA 200), number of days away from work (column 4—OSHA 200), number of days of restricted work (column 5—OSHA 200), the number of cases defined as recordable without lost workdays (column 6—OSHA 200), and the number of fatalities. In addition, the total amount of fines charged and paid out were collected.

The portion related to project safety contained three parts: (1) Project characteristics (e.g., project type, cost, and year construction was completed); (2) project safety inputs (e.g., number of formal meetings, amount of time devoted to safety issues, and money expended on the project safety program); and (3) safety performance measures were collected, which included the OSHA recordable rate, lost workday rate, and lost-time rate. Data were also collected on the number of restricted workday cases (column 2—OSHA 200), number of cases involving lost workdays (column 3—OSHA 200), number of days away from work (column 4—OSHA 200), number of days of restricted work (column 5—OSHA 200), the number of cases defined as recordable without lost workdays (column 6—OSHA 200), and the number of fatalities. Further, each company was asked to provide project safety data on one outstanding, average, and below-average project. Company safety coordinators were asked to use their own judgment in categorizing the performance of their projects. For a copy of the questionnaire, please contact the first writer.

DATA COLLECTION PROCESS

Different types and sizes of construction companies were asked to complete this survey. The list of companies was developed from the *Engineering News Record* top 400 contractors, former participants from Texas A&M University's continuing education programs, and personal contacts of the writers. Approximately 450 surveys were mailed to potential respondents. Sixty company surveys were completed, representing a response rate of 13.3%. Twelve of the returned surveys could not be used in the analysis because of missing company safety performance measures. Additionally, 69 project surveys were collected from the 60 responding companies, representing an average of approximately 1.2 projects per company.

DATA ANALYSIS APPROACH

The data analysis approach involved statistical comparisons between safety inputs for companies and projects with differ-

TABLE 2. Company Characteristics

Company characteristics (1)	Experience Modification Rating (EMR) >1 $N = 11$ (2)	1 − 0.75 $N = 22$ (3)	<0.75 $N = 15$ (4)
Billings ($ 1993)	10,911,360	89,343,180	1,458,850,000
Billings range ($)	600,000–28,000,000	650,000–600,000,000	1,000,000–9,500,000,000
Company type (%)			
General contractor	36	82	87
Specialty contractor	64	4	6.5
Other (e.g., construction manager (CM) and GC/CM)	0	12	6.5
Years in construction	37	43	62
Years safety program in existence	10	11	19
Subcontracted work (%)	65	60	51
Peak craft size (1993)	58	465	4,679
EMR range	1.0–1.5	0.74–0.95	0.74–0.48
Average EMR value	1.2	0.85	0.66

Note: CM stands for construction manager and GC/CM stands for general contractor with construction management responsibilities.

TABLE 3. Safety Inputs Showing Statistical Significance for Improved Recordable Incidence Rates at Company Level

Safety input (1)	Recordable Incident Rate <12.5 $N = 26$ (2)	≥12.5 $N = 4$ (3)	Significance level (α) (4)	Difference (%) (5)
(*a*) Program characteristics				
Number of pages in written safety program	143	99	0.076	44.4
Percent safety expenditures (safety $/billings)	0.0021	0.00089	0.0046	136.0
(*b*) Field safety representatives				
Safety training for part-time safety coordinator (hrs per year)	23.5	7.8	0.00025	201.3
(*c*) Safety meetings				
Meetings to discuss safety performance with field supervisors (number per month)	2.9	1.3	0.014	123.1
(*d*) Safety inspections				
Informal safety inspections on each project (number per month)	2.9	1.7	0.0013	70.6
(*e*) Training and orientation				
Duration of safety training for new foreman (number of hours)	6.2	3.6	0.014	72.2

J. Constr. Eng. Manage., 1996, 122(1): 61-70

ing levels of safety performance. At the company level, the recordable incidence rate and EMR were used as measures of safety performance. Safety inputs of companies with a recordable incidence rate of less than or equal to 12.5 were compared to those with incidence rates greater than 12.5. This cutoff value was chosen since it is, approximately, the industry average (Levitt and Samelson 1987). Insufficient data were collected on the lost time and severity rates, which made it difficult to obtain meaningful results using these measures. An incremental approach was used to analyze the effects of safety inputs based on EMR. Companies were divided into three categories: (1) EMR > 1.00; (2) EMR between 1.00 and 0.75 (inclusive); and (3) EMR < 0.75. The researchers felt this categorization would provide even more meaningful information compared to simply having two categories (i.e., EMR > 1 and EMR ≤ 1).

Projects were classified using the recordable incidence rate (12.5 was again used as the cutoff) and a subjective rating

Safety Input (1)	Experience Modification Rating (EMR) > 1, N = 11 (2)	Note 1	1 - 0.75, N = 22 (3)	Note 2	< 0.75, N = 15 (4)	Significance Level (α) (5)	% Difference (6)
(a) Upper Management Support							
Number of safety meetings between upper management and field safety representatives (# per year)	4.5	5.9	6.6		13.4	0.0850	127
Total time spent by upper management in meetings with field safety representatives (hrs per year)	3.0	4.0	4.5		15.0	0.0141	275
(b) Company Safety Coordinator							
Time devoted to safety issues (% total time)	14.0		39.0	48.0	59.0	0.0593	242
Handles workers compensation and general liability claims (% yes responses)	79.0	80.0	81.0		53.0	0.0332	-34
Informal safety inspections on each project (# per month)	1.7	3.3	4.0		7.6	0.0888	130
Meetings to discuss safety performance with field supervisors (# per month)	1.5	1.8	2.0		2.7	0.0645	50
Meetings to discuss safety performance with craftworkers (# per month)	2.0	2.6	3.0		3.9	0.0341	50
(c) Field Safety Representatives							
Projects staffed with full-time safety representatives (% yes)	10.0	24.0	32.0		53.0	0.0530	121
(d) Safety Program							
Number pages in written safety program (#)	44.0	64.0	74.0		146.0	0.0291	128
Total number of activities in safety plan (#)	21.0		28.0	29.0	30.0	0.0364	38
Number of pages per activity (#)	1.8	2.2	2.3		4.5	0.0339	105
Activities in Plan							
Perimeter guarding (% yes)	9.0		64.0	70.0	80.0	0.0075	678
Signs, barricading, and flagging (% yes)	27.0		68.0	75.0	87.0	0.0164	178
Site safety monitoring (% yes)	18.0		86.0	78.0	67.0	0.0036	333
Toxic substances (% yes)	45.0		91.0	86.0	80.0	0.0304	91
Work hazard reporting (% yes)	45.0		86.0	81.0	73.0	0.0138	80
(e) Training and Orientation							
Safety training program for new foremen (% yes)	30.0	31.0	32.0		73.0	0.0098	136
Duration of safety training for new foremen (# hrs)	0.33	1.4	1.8		3.9	0.0610	179
(f) Specialty Contractor Safety Managment							
GC safety coordinator meetings with subcontractors (# per month)	1.7	1.8	1.9		3.5	0.0084	94
Specialty contractor employees participate in alcohol and substance testing program (% yes)	18.0	15.2	14.0		40.0	0.0660	163

Note 1: Represents the average between EMR > 1 and EMR between 1 and 0.75

Note 2: Represents the average between EMR between 1 and 0.75 and EMR < 0.75

FIG. 1. Safety Inputs Showing Statistical Significance for Improved EMR

approach involving three distinct project outcome categories: below-averge, average, and outstanding projects. Company safety coordinators were asked to use their own judgment to categorize their projects according to each outcome. The high response rate showed that safety representative had very little difficulty in evaluating a project using this subjective rating approach. Due to a substantial amount of missing data related to lost time and severity rates, it was not possible to evaluate safety inputs using these additional incidence measures.

Hypothesis testing was used to identify statistically significant variables between all possible combinations of data (e.g., projects with average versus outstanding project performance and companies with EMR greater than or equal to 0.75 versus EMR < 0.75). Both the student's t-distribution and the chi-square test were used to handle both continuous and discrete data, respectively. A significance level (α) of 0.10 was selected by the writers to determine the statistical significance.

RESULTS

Company

Table 2 presents the company characteristic data. On average, larger companies, measured in terms of annual billings, have better EMRs and have been in existence longer than the smaller companies. There was an inverse relationship between EMR and a firm's years of construction experience [i.e., the longer a firm has been in business, the lower the EMR (p = 0.091)]. Also, there was a direct relationship between billings and the firm's years of experience ($p = 0.05$). There was not, however, a significant relationship between EMR and company size on the basis of revenues ($p = 0.31$). Based on this data, this may mean that experience rather than simply size is more directly related to improved EMR. The average EMR value decreases as the company's years in construction increases (based on an average of data in each classification). Companies with EMR less than or equal to 1 are primarily general contractors while 64% of the firms with EMR > 1 are classified as specialty contractors. The peak craft size ranged from 58 (EMR > 1.00) to 4,679 (EMR < 0.75). In addition, the average EMR values for each category are 1.20, 0.85, and 0.66 for companies with EMR ratings > 1.00, between 1.00 and 0.75, and <0.75, respectively.

TABLE 4. Safety Program Inputs Not Statistically Significant

Safety input (1)	Mean (2)	Range (3)	Standard deviation (4)
(*a*) Upper-management support			
Upper-management support (1 = none, 5 = moderate, 10 = very strong)	8.7	2–10	1.84
Formal safety program implemented (includes written safety plan, safety organization chart, accident reporting procedure, safety inspection protocol, training programs for craft and management personnel) (% yes)	89.6	NA	31
Average meeting duration between upper management and field representatives (number of hours)	1.4	0–17	2.5
(*b*) Company safety coordinator			
In-house and out-of-house safety training (hours per year)	156	0–1,000	246
Number of formal inspections per project on force account labor (per month)	2.0	0–20	3.4
Number of formal inspections per project on specialty contractors (per month)	1.8	0–20	3.3
Number of informal inspections per project on specialty contractors (per month)	2.3	0–20	3.7
Trains managers to fulfill their safety responsibilities (% yes)	74	NA	44
Implements safety programs that hold safety representatives accountable (% yes)	81	NA	NA
Keeps organization updated of safety matters through newsletters, seminars, etc. (% yes)	85	NA	NA
Authority to shut down jobs in situations of imminent danger (% yes)	89	NA	NA
Randomly performs safety site inspections (% yes)	92	NA	NA
(*c*) Field safety representatives			
Projects staffed with part-time field safety representatives (% yes)	63	NA	NA
Time devoted to safety program for part-time safety representatives (%)	15	0–100	12
Projects not staffed with field safety representatives (% yes)	15	NA	NA
(*d*) Safety program			
Written safety program (% yes)	100	NA	NA
Activities in plan			
Company safety policy (% yes)	100	NA	NA
Driving safety (% yes)	54	NA	NA
Safety coordinator duties (% yes)	81	NA	NA
Electrical safety (% yes)	71	NA	NA
Emergency procedures (% yes)	85	NA	NA
Equipment safety (% yes)	88	NA	NA
Eye protection (% yes)	96	NA	NA
Fire protection (% yes)	77	NA	NA
First aid facilities (% yes)	92	NA	NA
Foot protection (% yes)	77	NA	NA
Hand protection (% yes)	75	NA	NA
Head protection (% yes)	94	NA	NA
Hearing protection (% yes)	83	NA	NA
Housekeeping (% yes)	88	NA	NA
Incorporating client's safety rules and regulations (% yes)	54	NA	NA
Injury reporting (% yes)	94	NA	NA
New-worker indoctrination (% yes)	77	NA	NA
Respiratory protection (% yes)	70	NA	NA
Rigging and crane safety (% yes)	69	NA	NA
Safety awards (% yes)	65	NA	NA
Safety belts and lifelines (% yes)	72	NA	NA
Safety inspections (% yes)	88	NA	NA
Safety meeting attendance (% yes)	79	NA	NA
Safety organization (% yes)	60	NA	NA
Scaffolding (% yes)	81	NA	NA
Specialty contractor safety policy (% yes)	71	NA	NA
Substance-abuse program (% yes)	73	NA	NA
Training (% yes)	75	NA	NA
Zero accident policy (% yes)	40	NA	NA
(*e*) Training and orientation			
Field safety representatives			
Training duration for full-time safety representatives per year (number of hours)	30.3	0–200	44
Training duration for part-time safety representatives per year (number of hours)	15.3	0–100	19.5
Total training for full- and part-time safety representatives per year (number of hours)	21.6	0–200	34.5
Craftworkers			
Craftworker training as part of orientation program (number of hours)	2.5	0–16	3.3

Note: NA stands for not applicable.

Recordable Incidence Rate

Table 3 summarizes the findings related to statistically significant variables for companies with recordable rates less than 12.5 and greater than or equal to 12.5. This value was selected because it reflects the average industry recordable incident rate. Not surprisingly, companies with better recordable incidence rates had more detailed safety programs measured in

J. Constr. Eng. Manage., 1996, 122(1): 61-70

TABLE 5. Project Characteristics

Project characteristics (1)	Project Safety Outcome: Below average $N = 18$ (2)	Average $N = 22$ (3)	Outstanding $N = 29$ (4)
Project cost ($)	23,230,770	50,969,150	27,161,280
Duration (months)	13.4	15.7	12.8
Project type (%)			
Building	50	59	59
Heavy/highway	28	9	21
Process plant	6	5	14
Power plant	0	27	3
Other	16	0	3
OSHA recordable rate	8.00	2.60	0.94
OSHA lost-time rate	5.60	2.90	0.14
OSHA lost workday rate	125.00	88.00	12.70

terms of total number of pages (143 versus 99 pages). Additionally, a larger percentage of revenues was expended on safety programs for companies with better safety performance (0.0021% compared to 0.00089%). Training time was greater for foremen (6.2 versus 3.6 hours) and part-time safety coordinators (23.5 versus 7.8 hours per year) on projects experiencing better recordable incidents rates. Finally, there were more informal inspections per month (2.9 versus 1.7 per month) and more meetings to discuss safety performance with field representatives (2.9 versus 1.3 per month) for companies with lower recordable rates. Many of these findings are reinforced in the analysis related to EMR.

EMR

Fig. 1 summarizes findings related to statistically significant differences in safety inputs for companies with lower EMRs (<0.75) versus those with higher EMRs (≥0.75). Key findings are highlighted in this section. Fig. 1 clearly demonstrates the impact of upper management's role in supporting safety through increased communication. Upper management had on average 13.4 meetings with field safety representatives per year for companies with outstanding safety performance (EMR < 0.75), compared to 5.9 meetings per year for companies with less-than-successful safety outcomes (EMR ≥ 0.75; significance level = 0.0850). [There was not a statistical difference between the first two categories (EMR > 1 and EMR between 1 and 0.75); as a result, data from both categories were combined and compared to that of the third category (EMR < 0.75).] This translates into an average of 15 annual contact hours versus four between upper management and the field safety representatives for companies with EMR < 0.75 compared to those with EMR ≥ 0.75.

Safety coordinator involvement is greater for companies with a lower EMR. Safety coordinators devote, on average, 14% of their time to safety issues for companies with EMR > 1.00 versus 48% for companies with an EMR ≤ 1.00. Results show that the number of informal safety inspections performed by the company safety coordinator are 7.6 per month for companies with EMR < 0.75 compared to 3.3 for EMR ≥ 0.75 companies. Further, there are approximately four meetings per month with craft workers for companies with EMR < 0.75, compared to 2.6 for companies with EMR ≥ 0.75.

Companies with a better safety performance have more detailed safety programs. For example, companies with EMR < 0.75 have, on average, 146 pages (including 29 activities) versus 64 pages (including 22 activities) for those with EMR ≥ 0.75. Only 9% of the companies with EMR > 1.00 surveyed have perimeter guarding in their safety plans, compared to 70% for EMR ≤ 1.00 companies.

Additionally, training and orientation are found to be particularly important for new foremen. Seventy three percent of the companies with EMR < 0.75 have a training program for new foremen (four-hour duration) compared to 31% of the EMR ≥ 0.75 companies (1.4-hour duration).

Specialty contractor safety management is important as it relates to two factors: (1) The number of general contractor (GC) safety meetings with the specialty contractor; and (2) participation in alcohol and substance testing programs. General contractor safety coordinators meet with specialty contractors about twice as often for better performing companies (3.5 times per month for EMR < 0.75 companies compared to 1.8 times with EMR ≥ 0.75 companies). Forty percent of the GCs with EMR < 0.75 had specialty contractor employees involved in an alcohol and substance testing program, compared to only 15% for companies with EMR ≥ 0.75.

Many company safety program characteristics are similar for all levels of EMR performance, as shown in Table 4. Although these factors are not statistically different, they can nevertheless be used as a benchmark from which to develop an effective safety program. For best company safety performance, inputs in proportion to those found in Fig. 1 and Tables 3 and 4 should be implemented.

Project

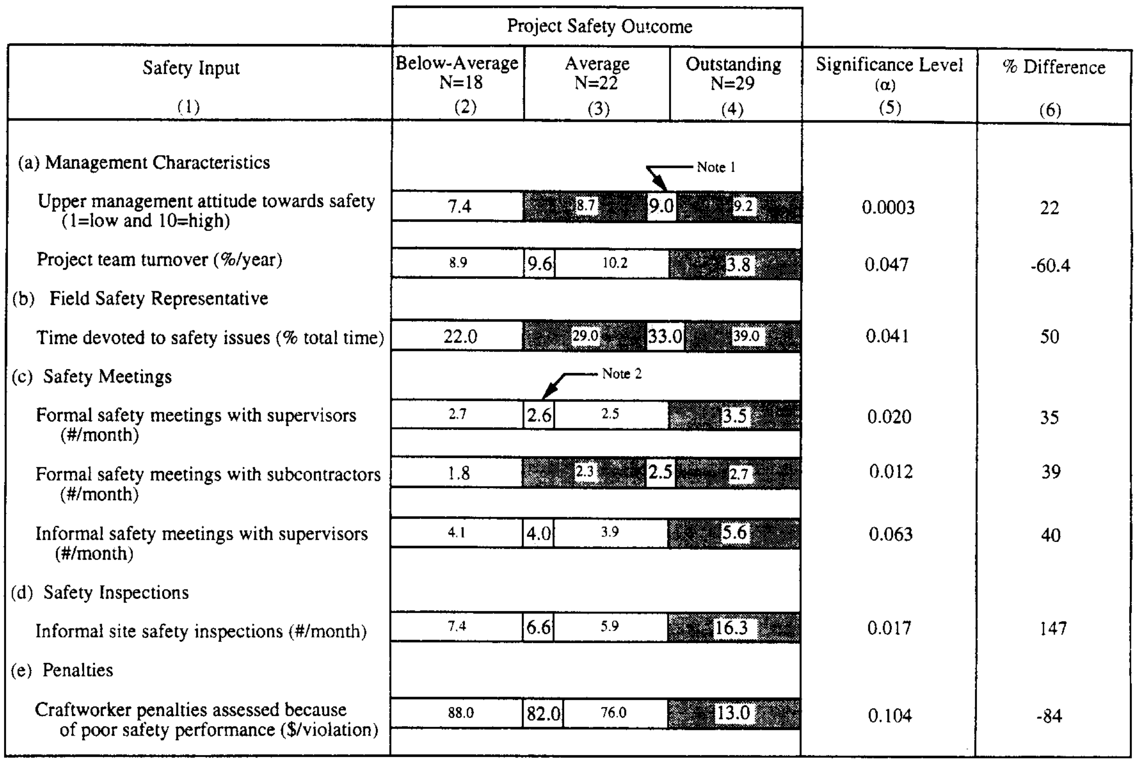
Table 5 reveals average safety program characteristics for projects with below-average ($N = 18$), average ($N = 22$), and outstanding ($N = 29$) safety performance. Most of the projects (50% and greater) relate to building construction, with a smaller percentage associated with heavy/highway, process, and power plant construction. Project cost and duration represent the average values for each of the outcome categories. For example, the average duration for all the outstanding projects in the database is 12.8 months. Safety trends from below-average to outstanding project performance is of significant interest. The OSHA recordable rate drops from 8.00 to 0.94, lost-time rate is reduced from 5.60 to 0.14, and lost workday rate drops from 125.00 to 12.70, respectively. These data indicate that safety coordinators are consistent in classifying projects.

TABLE 6. Safety Inputs Showing Statistical Significance for Improved Recordable Incidence Rates at Project Level

Safety input (1)	Recordable Incident Rate: <12.5 $N = 46$ (2)	≥12.5 $N = 4$ (3)	Significance level (α) (4)	Difference (%) (5)
(a) Management characteristics				
Project manager construction experience (years in construction)	19.8	8.5	<0.01	133
Project manager experience on projects of similar size (number of projects)	10.8	2.0	<0.01	440
Project team turnover (% per year)	7.3	13.8	0.003	−47
(b) Safety meetings				
Formal safety meetings with project supervisors (e.g., PMs, foremen, and superintendents) (number per month)	3.1	2.5	0.056	24
(c) Safety budget				
Safety budget allocated to safety awards (% of safety budget)	9.3	0.5	<0.01	1,760

Note: PMs stands for project managers.

J. Constr. Eng. Manage., 1996, 122(1): 61-70



Note 1: Represents the average between Average and Outstanding projects

Note 2: Represents the average between Below-average and Average projects

FIG. 2. Safety Inputs Showing Statistical Significance for Improved Project Safety Performance

Table 6 reveals inputs at the project level for projects with recordable incidence rates less than 12.5 and those greater than or equal to 12.5. Greater project manager experience in terms of total years of experience and experience on projects of similar size were related to projects with better recordable incidence rates. Projects experiencing lower recordable incidence rates had project managers with approximately 20 years of construction experience compared to 8.5 years of experience on projects with poorer safety performance. Project managers also had more experience on projects of similar size on projects with better safety performance (10.8 versus two projects). Also, project-management-team turnover was found to be lower on projects with better incidence rates (7.3 versus 13.8%). There were more formal meetings to discuss safety performance with field supervisors and a larger percentage of the safety budget was allocated to safety awards (9.3 versus 0.5%) on projects with better recordable incidence rates.

Fig. 2 shows several factors associated with better project performance using the aforementioned subjective rating scale. Upper management's attitude toward safety was significantly better on outstanding projects. Project-management-team turnover was also significantly lower on outstanding projects (3.8%) compared to below-average and average projects (9.6%). [Turnover occurs when a team member leaves the project and is replaced by another (a 10% turnover would mean that one person out of 10 was replaced on a project in a given period of time).] Field safety representatives spend a greater percentage of their time devoted to safety issues on projects classified as average or outstanding, compared to below-average (33 versus 22%, respectively). A greater number of informal safety meetings per month with supervisors are also conducted on outstanding projects, compared to average and below-average projects (5.6 versus 4.0, respectively). Moreover, outstanding projects have, on average, 16.3 informal safety inspections per month compared to below-average and average projects, which had only 6.6 inspections per month—this represents a 147% difference in the amount of informal safety inspections! Finally, craft worker penalties, measured in terms of dollars per violation, are lower on outstanding projects ($13 per violation) compared to below-average and average projects ($82 per violation).

TABLE 7. Project Safety Program Inputs Not Statistically Significant

Safety input (1)	Mean (2)	Range (3)	Standard deviation (4)
(*a*) Upper-management support			
Upper management site visits (number per month)	4.2	0.17–24	4.9
(*b*) Project safety program			
Safety review during design phase (% yes)	28.0	NA	NA
Amount of time prior to construction start safety made a priority (% of project duration)	13.5	0–50.0	12.6
Informal meetings with specialty contractors (number per month)	3.4	0–20.0	3.5
Amount allocated to project safety (% total project cost)	1.2	0–10.0	1.8
Amount of safety budget allocated to safety awards (% total safety budget)	6.8	0–100.0	16.8
Craft penalty enforced for poor safety performance (% yes)	9.0	NA	NA
Frequency of formal inspections (number per month)	4.4	0–35.0	7.1
Frequency of safety data collection (number per year)	12.8	0–52.0	16.1
Frequency of safety report generation (number per year)	16.0	0–64.0	16.9
Amount of time devoted to investigating lost-time accidents (number of hours per accident)	3.0	0–25.0	5.0

Note: NA stands for not applicable.

J. Constr. Eng. Manage., 1996, 122(1): 61-70

TABLE 8. Recommendations for Lowering EMR

Lower EMR (1)	Recommendations[a] (2)
From >1.00 to between 1.00 and 0.75	Increase time devoted to safety by company safety coordinators to at least approximately 40%.
	Provide greater detail in the written safety program. Companies with EMR > 1.00 had, on average, 21 activities in the execution plan, while companies with EMR between 1.00 and 0.75 had 28 activities. Some activities that might be added include: perimeter guarding; signs, barricading, and flagging; site safety monitoring; toxic substance guidelines; and work hazard reporting.
Between 1.00 and 0.75 to less than 0.75	Increase the number of safety meetings between upper management and field safety representatives to approximately 14 per year. The total number of contact hours should be at least 15 per year.
	Increase time devoted to safety by the company safety coordinators to approximately 60%.
	Consider delegating the task of handling worker's compensation and general liability claims to someone other than the company safety coordinator to avoid distracting him or her from more important duties such as inspections, training, and information dissemination. This action may be considered more feasible in larger companies that can afford the necessary staff.
	Increase the number of informal inspections made by company safety coordinator to eight per month (two times per week) on every project.
	Increase the number of meetings to discuss safety performance between the company safety coordinator and field safety representatives to at least three per month.
	Consider staffing projects with full-time safety representatives (53% of the companies with EMR < 0.75 used full-time safety representatives).
	Provide greater detail in the written safety program (companies with EMR < 0.75 had, on average, approximately 146 pages in their written safety programs. This translated to about 4.5 pages per activity).
	Implement a new foremen safety training and orientation program (73% of the companies with EMR < 0.75 used such a program). The average duration of new-foremen training programs should be approximately four hours.
	Increase the number of general contractor safety coordinator meetings with specialty contractors to 3.5 times per month.
	Consider implementing an alcohol and substance testing program for specialty contractor employees (approximately 40% of the companies with EMR < 0.75 have implemented such a program).

[a]Most recommendation values are approximations.

TABLE 9. Achieving Outstanding Project Safety Performance

Factor (1)	Recommendation (2)
Upper-management attitude	Strengthen upper management's attitude toward the importance of safety. Projects that achieved average and outstanding project stature had strong upper-management support compared to below-average projects where management support was weaker (9.0 versus 7.4, respectively).
Project-management-team turnover	Reduce project-management-team turnover as much as possible. Outstanding projects experienced lower turnover rates (3.8%) compared to average and below-average projects (9.6%). This suggests that team stability plays a role in achieving better safety performance.
Time devoted to safety by field safety representatives	Field safety representatives should spend 30–40% of their time on safety issues. Expending less time may compromise the project safety outcome.
Number of formal safety meetings with supervisors	Increase the number of formal safety meetings with supervisors to one per week. Outstanding projects averaged 3.5 meetings per month, compared to 2.6 for below-average and average projects.
Specialty contractors	Increase the number of formal safety meetings with specialty contractors to three per month. Below-average projects average about 1.8 meetings per month.
Number of informal safety meetings with supervisors	Increase the number of informal safety meetings with supervisors to 6 per month. Below-average and average projects experienced about four meetings per month.
Site safety inspections	Increase informal site safety inspections to four per week. Below-average and average projects averaged approximately 1.5 informal inspection per week.
Worker safety performance fines	Consider reducing the amount of money fined to workers who exhibit poor safety performance. Outstanding projects fined workers an average of $13 per violation compared to $82 for below-average and average projects. This suggests that workers respond better to positive approaches when trying to comply with company safety policies.

Table 7 reveals project safety program inputs that did not show any statistical difference between levels of project safety performance. As with the company data, this information can be used as a guideline to establish a base level for a viable safety program. To achieve better than average performance, other factors will need to be modified according to the results in Fig. 2 and Table 6.

RECOMMENDATIONS

This section includes recommendations for improving both company and project safety performance. Company recommendations relate to lowering the recordable incidence rate below the industry average, lowering EMR from >1.00 to between 1.00 and 0.75, and lowering EMR from between 1.00 and 0.75 to <0.75. Recommendations for improving a company's recordable incidence rate include providing more detail to the written safety program (companies with better safety records had, on average, 143 pages in their written safety program), expending greater monetary resources on safety programs (0.0021% of the company revenues were allocated to safety for companies with better performance), providing additional training to part-time safety coordinators (approximately 24 hours per year for coordinators working on projects with better safety performance), providing better indoctrination to new foremen related to company policies and guidelines (foremen received, on average, three hours of training for companies with better recordable rates), increasing the number of meetings to discuss safety performance with field supervisors (on average, three meetings were held per month for companies with lower recordable rates), and increasing the number of informal inspections on each project (companies experiencing better recordable rates had, on average, 6.2 informal safety inspections per month). Table 8 presents recommendations for lowering EMR.

Recommendations for improving individual project recordable rates focus on several issues related to management characteristics, safety meetings, and safety budget allocations. Hiring project managers with more experience appears to be a significant factor associated with improved project recordable incidence rates. Projects with recordable incidence rates below the industry average had project managers, with an average of approximately 20 years of experience in the construction industry, who have worked on about 11 projects of similar size in the past. Further, reducing project team turnover to approximately 7% is advisable since projects with better recordable incidence rates maintain this level of turnover. Increasing the number of formal safety meetings with supervisors to approximately three times per month also has a positive impact on the recordable rate. Finally, increasing the amount of money

J. Constr. Eng. Manage., 1996, 122(1): 61-70

expended on safety awards has a positive impact on recordable incidence rates (projects with better than the industry average recordable rates expended about 9% of the safety budget toward awards). Table 9 shows recommendations for achieving outstanding project safety performance.

These recommendations provide quantitative guidelines to help companies establish effective safety programs to achieve their goals in the most efficient manner. The costs associated with implementing these recommendations has not been assessed, but may be minimal, especially for companies with well-established and formal safety programs. For these companies, implementation may simply mean visting jobsites more frequently, adding new subject matter to an existing new-foreman training program, or implementing a substance-abuse program. Costs will certainly increase for companies that are developing their safety program. This research can help these companies by providing them with direction in terms of what is truly important in achieving desired safety results. It is believed that the benefits of an effective safety program should far exceed the costs. Some benefits of an effective safety program include reduced EMR, lower jobsite incidence rates, increased productivity, lower project costs, and improved reputation with project owners.

LIMITATIONS

Because of a limited amount of data, it is not possible to segregate the data into different types of construction companies (e.g., steel erection, electric, mechanic, etc.). Most of the companies in the sample are general contractors responsible for building and industrial projects. Furthermore, it was only possible to investigate safety inputs using recordable incident rates, EMR, and a subjective rating at the project level; due to the lack of data regarding the lost time and severity rates, it was not possible to provide comparative analysis using these additional safety measures.

CONCLUSIONS

This paper provided quantitative strategies for achieving better construction safety performance at the company and project level. Numerical profiles of companies and projects with varying levels of safety performance were presented. Several factors were significant for improving safety performance based on the recordable incidence rate and EMR. Among the more significant company-related factors are upper management support (as it relates to the amount of time spent with field safety representatives); time devoted to safety issues for the company safety coordinator; number of informal safety inspections made by the company safety coordinator; meetings with the field safety representatives and craft workers; length and detail of the company safety program; safety training for new foremen and safety coordinators; specialty contractor safety management (as it relates to the number of meetings and participation in an alcohol and substance testing program); and company safety expenditures.

At the project level, several factors are important for achieving better safety performance: increased project manager experience level, more supportive upper management attitude towards safety, reduced project team turnover, increased time devoted to safety for the project safety representative, more formal meetings with supervisors and specialty contractors, more informal safety meetings with supervisors, a greater number of informal site safety inspections, reduced craft worker penalties, and increased budget allocation to safety awards.

Future research in improving construction safety performance should adopt several strategies. More data should be collected on specialty contractors, in order to develop trade-specific safety profiles. Key safety success factors for steel erection contractors, for example, may be different from the success factors for a mechanical specialty contractor. Incidence rates (e.g., lost-time rate and severity rate) should be used as a measure of safety performance for company safety performance to provide the basis for comparing the results of this study.

Further, a better understanding of accidents from a worker's perspective must be developed. It appears that much of the research to date has focused on the management's role in reducing accidents. This does not include factors from a craft worker's point of view; in other words, the worker has been largely ignored in the overall equation related to improving construction safety performance. Thus, data should be collected from a worker's viewpoint and correlated with safety performance.

ACKNOWLEDGMENTS

The writers thank several people who assisted in this study. A special thanks to all of the survey respondents who provided the critical data necessary to perform this study. In addition, we thank Tomas Lastovka, who helped prepare and disseminate some of the surveys, and Mohammad Swan for entering the data into a database. We also thank several of the industry reviewers who provided comments to draft copies of this paper: Dennis Warth, a loss control specialist with Holmes-Murphy; Phil Mercuris, safety consultant with the Master Builders of Iowa; and Jack Walsh, of Cobb-Strecker-Dunphy & Zimmerman, Inc., Madison, Wisconsin.

APPENDIX. REFERENCES

Everett, J. G., and Thompson, W. S. (1995). "Experience modification rating for workers' compensation insurance." *J. Constr. Engrg. and Mgmt.*, ASCE, 121(1), 66–79.

Hinze, J. (1978). "Turnover, new workers and safety." *J. Constr. Div.*, ASCE, 104(4), 409–417.

Hinze, J., and Figone, L. A. (1988a). "Subcontractor safety as influenced by general contractors on small and medium sized projects." *Source Document 38*, Constr. Industry Inst., Univ. of Washington, Seattle, Wash.

Hinze, J., and Figone, L. A. (1988b). "Subcontractor safety as influenced by general contractors on large projects." *Source Document 39*, Constr. Industry Inst., Univ. of Washington, Seattle, Wash.

Hinze, J., and Gordon, F. (1979). "Supervisor-worker relationship affects injury rate." *J. Constr. Div.*, ASCE, 105(3), 253–261.

Hinze, J., and Harrison, C. (1981). "Safety programs in large construction firms." *J. Constr. Div.*, ASCE, 107(3), 455–467.

Hinze, J., and Pannullo, J. (1978). "Safety: function of job control." *J. Constr. Div.*, ASCE, 104(2), 241–249.

Hinze, J., and Parker, H. W. (1978). "Safety productivity and job pressures." *J. Constr. Div.*, ASCE, 104(1), 27–35.

Hinze, J., and Raboud, P. (1988). "Safety on large building construction projects." *J. Constr. Engrg. and Mgmt.*, ASCE, 114(2), 286–293.

Hinze, J., Bren, D., and Piepho, N. (1995). "Are EMR's effective measures of safety performance." *J. Constr. Engrg. and Mgmt.*, ASCE, 121(4), 455–458.

Levitt, R. E., and Parker, H. W. (1976). "Reducing construction accidents—top management's role." *J. Constr. Div.*, ASCE, 102(3), 465–478.

Levitt, R. E., and Samelson, N. M. (1987). *Construction safety management.* McGraw-Hill Book Co., Inc., New York, N. Y.

Liska, R. W., Goodloe, D., and Sen, R. (1993). "Zero accident techniques." *Source Document 86*, Constr. Industry Inst., Univ. of Texas at Austin, Tex.

1993 Accident Facts. (1994). National Safety Council, Itasca, Ill.

Samelson, N. M., and Levitt, R. E. (1982). "Owner's guidelines for selecting safe contractors." *J. Constr. Div.*, ASCE, 108(4), 617–623.

The workers' compensation crisis . . . safety excellence will make a difference. (1991). Business Roundtable, New York, N.Y.

"3rd quarterly report—insurance rates." (1974). *Engrg. News Rec.*, 193(13), 76–77.

"3rd quarterly report—insurance rates." (1994). Engrg. News. Rec., 233(13), 40–41.

J. Constr. Eng. Manage., 1996, 122(1): 61-70