SAFETY PERCEPTION AND ITS EFFECTS ON SAFETY CLIMATE IN INDUSTRIAL CONSTRUCTION

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ABSTRACT

Safety management is an important mortal and business function in construction. Contractors have traditionally tracked and reported lagging indicators, e.g. fatalities and lost-time accident rates, to measure their safety performance and stay in compliance with relevant regulations. Over the last several decades, contractors became more proactive in their approach to safety and developed programs that track leading indicators, e.g. safety audits and safety climate. In particular, safety climate measures workers' perception of safety management and its effectiveness in the workplace. Past literatures indicated that, while some industrial construction contractors ignore safety climate measures, others are limited by a lack of a formal means to measure safety climate. In this study, a survey approach is used to measure an industrial construction contractor's safety climate through three key areas: management commitment, job control, and general safety climate. As a pilot study, a total of 214 individuals at a fabrication facility participated in the survey to verify the validity and effectiveness of the proposed survey approach. This survey study also confirms that job control and management commitment have a positive correlation and that worker demographics have an effect on respondents' perceptions of management commitment.

KEYWORDS

Safety climate, job control, management commitment, survey, industrial construction

INTRODUCTION

Safety management is an important mortal and business function in construction. While the construction industry has been striving for a safe work environment toward zero incidences, many organizations solely base their safety policies and procedures on a response to local and federal laws and compliance requirements (Rogers, 2004). As a result, contractors have traditionally tracked and reported lagging indicators, such as fatalities, lost time accident rates, and incidents, to measure their safety performance and stay in compliance with relevant regulations. These safety procedures based on lagging indicators support the effort of building a safer work environment, but they alone contribute little to further reducing occupational accidents to the ultimate goal of zero incidences.

It is an encouraging trend over the last several decades that the construction industry is moving toward a more proactive approach to safety and one that focuses on leading safety factors founded on behavioral and leadership theories. Unlike traditional lagging indicators that measures safety on retrospective data (e.g. fatalities), leading indicators are more proactive and predictive measurements that enable safety condition monitoring, which reduces the need to wait for the system to fail to identify weaknesses and to take remedial action (Flin et al., 2000). Leading indicators include near misses, safety audits and safety culture and climate measures. Misnan et al. (2008) argues that a company's intangible safety culture may be more important than safety procedures or standards. Safety culture refers to a commitment to safety that permeates all levels of an organization from frontline personnel to executive management (Misnan et al., 2008). A subset of safety culture is safety climate, which is the aggregated employee perception of how safety management is being implemented operationally in the workplace and its effectiveness at a particular moment in time (Cooper and Phillips, 2004). To summarize, safety culture is the commitment to safety by all and safety climate is the perception of that commitment to safety.

Past literatures indicated that while some industrial construction contractors ignore safety climate measures, others are limited by a lack of a formal means to measure and analyze safety climate. This study proposes a survey approach in measuring an industrial construction contractor's safety climate focusing on three key areas: management commitment, job control, and general safety climate perception. Management commitment is the perceived commitment level of management through the eyes of the people that work for them. Job control is the level of involvement and decision-making capability a worker has in regards to safely performing his or her work. Job control is ultimately related to the management style and how much control over an employee's environment that their manager allows. This study is intended to not only provide a practical way to measure safety climate for industrial contractors, but also develop a better understanding of how management commitment, job control and employee demographics affect workers' perception of safety.

LITERATURE REVIEW

Safety climate is concerned with safety beliefs, norms, values, procedures and practices (Flin et al., 2000). Survey methods have been widely used to measure an organization's safety climate. Based on a review of literatures and a survey administered to 20 industry organizations, Zohar (1980) confirmed the correlation between safety climate and safety record of an organization. Safety climate is made up of several key indicators, including senior management commitment, management style, management visibility, job control, communications, training, job satisfaction, workforce composition, and the pressure for production (Flin et al., 2000). Among them, management commitment and job control are considered to be two key focus areas in a number of past studies.

Zohar (1980) noted that an employee's perceptions of management commitment and attitude toward safety processes were the most important dimensions in determining safety climate. Zohar concluded that management commitment is the foundation of safety climate, and it plays an important role on defining workers' perception of safety climate. In addition, Michael et al. (2005) explored the relationship of management commitment to safety and non-safety outcomes among workers in the wood manufacturing industry. This study also found that employee safety performance, job satisfaction and organizational commitment were positively related to management commitment to safety.

Job control, as defined by Snyder et al. (2008), is an individual's ability to have control over work activities, work environment and ultimately the outcomes of work activities. Despite the potentially opposing effects of job demands on safety compliance and safety participation, job control can provide employees with opportunities to manage job demands for safe work performance (Phipps et al., 2012). Unlike studies on management commitment, there is limited research that focused on the relationship between job control, safety climate, and safety performance. The available research has mixed outcomes when examining this relationship. A few studies found that safety climate was positively influenced by job control, while others failed to find a relationship (Phipps et al., 2012). Snyder et al. (2008) failed to find a significant relationship between job control and workplace injuries. However, job control and safety climate were found to be positively related. This outcome highlights that when employees feel that safety is being emphasized and they are empowered, they will believe they can minimize injury occurrence and outcomes (Snyder et al., 2008). A similar study conducted by Huang et al. (2006) examined the role of employee job control as a mediator between safety climate and self-reported injury among 18 companies in the transportation, construction, manufacturing, and services industries. A conclusion from this study is that job control moderates the relationship between safety climate and occupational injury.

A significant amount of research has been conducted on safety climate in different industries, but there is no study found to address the industrial construction sector, which involves fabrication and installation of industrial facilities, such as refineries and power plants. Furthermore, there is also a need to study the effect of job control on safety climate in industrial construction as well as how worker demographics affects their perception of management commitment to safety, which have not been fully addressed in previous research.

RESEARCH PROBLEM & METHODOLOGY

This study focused on providing a quantifiable measure of safety climate, and exploring the relationship among safety climate, management commitment, and job control in the industrial construction sector. The research problems and hypothesis can be summarized as follows:

Job Control

- Determine if job control is a modifying factor of workers' perception of management commitment to safety.
    - Hypothesis: Workers with more job control will report positive perceptions of management commitment to safety.
- Determine if workers' perception of safety climate is altered by self-reported job control.
    - Hypothesis: Workers with more job control will report positive perceptions of safety climate.

Management Commitment to Safety

- Determine if workers' perception of management commitment to safety is affected by differences in demographics.
    - Hypothesis: Difference in demographic affect a worker's perception of management commitment to safety.

This study used a survey approach to measure safety climate. The survey instrument must be carefully designed and validated to ensure its reliability and accuracy as a safety-climate measurement tool as well as a data source for subsequent survey data analysis. Interviews were initially conducted to gain a better understanding of safety practices and the status of safety climate in the organization. Preliminary survey questions were developed based on previously validated surveys related to safety climate, management commitment, and job control. The survey was then validated on its face, content, and criterion validities (Burton, 2011). For data analysis and construct validation, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were first used to exam the reliability of measurement data, and identify principle factors in measuring safety climate (Burton and Mazerolle, 2011). Regression analysis and statistical tests were then used to test the hypotheses mentioned above. This methodology is demonstrated in a case study section. The organization involved in this study is an engineering and construction company in the industrial construction sector that is based in Houston, Texas, USA. This case study was intended to develop and test the proposed survey measurement tool, and meanwhile, collect data for hypothesis testing.

SURVEY DESIGN AND VALIDATION

Interviews

Before survey design, the case study company's management including its safety manager was interviewed to understand the current safety climate evaluation process and the goal and scope that the proposed survey instrument must cover. The company currently relies on site walks and conversations with various workers to get a feel of its safety climate. This approach is subjective and ad-hoc in nature, and the management desired a quantifiable, objective, and consistent method in measuring and evaluating company-wide as well as project-specific safety climate. The proposed survey method is expected to be eventually implemented across all of its various business units and facilities, and be used consistently over an extended period of years so benchmarking data can be collected for continuous improvement efforts. The pilot study was intended to design and validate the survey instrument by administering it to a single facility to represent a sample of the total population before the company-wide implementation.

Survey Design

To assist in the development of the survey, three previously validated survey questionnaires were identified through the review of literatures of closely related studies and those surveys formed the basis in drafting the survey questions. The first survey was a safety behavior survey from the Western Australian mining industry (MOSHAB, 2002) and its management commitment related questions were referenced in the survey. The second survey was a job-control related survey that analyzed workers' adherence to standardized safety work practices in the healthcare industry (Jorgensen et al., 2007). The third survey was a generic safety climate questionnaire from NIOSH (1991). While relevant questions from the above surveys were screened and adopted, some were reworded from a question format to an affirmation statement format to ensure consistency. The developed survey uses a Likert-type scale, with score values of from 1 to 5, with 1 being strongly disagree and 5 being strongly agree. Since all of the questions were positive affirmation statements, the higher the score, the better the respondent's perception of management commitment, job control or general safety climate.

Survey Validation

According to Burton and Mazerolle (2011), a survey must be validated to ensure that it actually measures what it is designed or intended to measure. Partial survey validation was achieved by a safety expert panel review and a comparison to previously published and validated survey results. The panel of experts consisted of 20 safety management personnel from the case study company, who have extensive safety management experience in industrial construction. The panel reviewed the survey's appearance, relevance and representativeness to establish face and content validity. The feedback from the panel was reviewed and incorporated into the survey design to confirm the face and content validity of the survey instrument.

An additional validation performed in this study was criterion-related validity testing. Criterion validity demonstrates the accuracy of the proposed survey measure by comparing its results to a previously established and validated instruments or some other external criterion (Burton and Mazerolle, 2011). This was achieved by collecting the 20 panel members' response to the survey and comparing the results to these of the above-mentioned three validated surveys used during survey design. The first criterion validity test was administered against the results obtained from the management commitment section in the MOSHAB survey (2002). It was observed that the results from both surveys followed the same trend, which confirmed the criterion validity of the management commitment questions. Detailed results of the comparison can be found in Eaton (2012). The second criterion validity test was on the job-control related questionnaire administered to nursing professionals (Jorgensen et al., 2007). The perception of job control among nurses was compared to responses from the expert panel in the survey. It was observed that nurses (90%) perceive to have more control over their jobs than construction professionals (67%). This comparison is understandable due to the profound difference between those two professions. Further, a follow-up interview with the expert panel members also confirmed the impression that they were not completely restricted, but are not given enough control that they perceive a positive amount. The correlation between interview response and results confirmed the criterion validity of the job control questions. Finally, due to the lack of result data from NIOSH (1991), criterion validity test was not performed in this study.

The final version of the survey measured worker's perception on safety climate with three focused areas: Management Commitment (MC), Job Control (JC) and General Safety Climate (GSC). The survey form contained three sections: a location identification section, a demographic section, and a questionnaire section which includes 38 questions, 15 in MC, 16 in JC, and 7 in GSC. Sample questions are: "Employees are encouraged by management to stop unsafe work" (MC); "Employees have influence over the variety of tasks they perform" (JC); and "Safety remains a priority even when the job runs behind schedule" (GSC). These 38 questions were mixed so the respondents would answer the questions without any unintended bias. The final version of the survey can be found in Eaton (2012).

SURVEY DATA COLLECTION

After the development and initial validation of the instrument, the survey was administered to one of the fabrication facilities of the case study company. This fabrication facility housed 214 personnel ranging from welder assistants to fabrication management. The test population encompassed all the job categories of the company, including laborer/tradespersons, support/technical/engineering, foreman, superintendent/supervisors, and project management. The test population also comprised a range of ages, education, and industry experience levels. All laborer/tradespersons and foreman took the survey during their monthly safety meeting where they discuss their safety performance and provide feedback on safety issues. The remaining personnel took the survey in the office building located on site. The researchers were able to achieve a 100% participant rate.

SURVEY DATA ANALYSIS

Collected survey data were analyzed through factor analysis and hypothesis testing using Microsoft Excel and a statistical tool, STATA (2013). The objectives and implementation of the data analysis procedure are presented below.

Safety Climate Scores

The average scores for each key evaluation area of safety climate at the case study company are shown in Table 1 below. Since this was the first time that the safety climate scores were reported, the numbers themselves mean little until several more such scores are reported in different periods and/or different company branches. Regular measurement and reporting of safety climate score will help to establish a benchmarking system for continuous evaluation and improvement of safety climate.

Table 1 - Overall safety climate scores

Management Commitment:	80.22%	4.01
Job Control:	71.26%	3.60
General Safety Climate:	82.12%	4.11
Total Survey Score:	*77.51%*	*3.88*

Factor Analysis

Factor analysis is to identify a relatively small number of non-observable, underlying factors that characterize underlying constructs (e.g. management commitment to safety) (Cooper and Phillips, 2004). These factors can then be used to represent relationships among many sets of inter-related perceptual questions about safety. The identified factors simplify interpretation of these relationships by reducing the observed correlations into as few constructs as possible. Specifically, an Exploratory Factor Analysis (EFA) evaluates the variables (i.e. survey questions) and determines which factor or construct (e.g. MC, JC, or GSC) that defines them. A Confirmatory Factor Analysis (CFA) evaluates the fit of each variable (i.e. survey questions) in its defined construct (e.g. MC, JC, or GSC). EFA and CFA were first applied on JC and MC questions and then on GSC questions. This was done to limit the number of constructs evaluated each time. Additionally, since management commitment (MC) is such a large part of GSC, running EFA and CFA with MC and GSC questions together would skew the results.

EFA was first applied to the 31 MC and JC questions to help to limit the number of survey questions and eliminate those that contain large response variance. Questions with a high variance will be eliminated because such questions do not accurately determine the factor that it is trying to measure in a survey. For example, if the responses for a MC question had a large variance, then it would not accurately show if the respondents had a strong or weak perception of MC because the answers would have no observable trend. Variation was evaluated using the uniqueness value (STATA, 2013). Large uniqueness values illustrate a higher variance. For this study, an initial threshold of 0.6 was used, and as a result, 6 questions with a value over 0.6 were eliminated. Once an initial solution was obtained, a factor rotation procedure, Varimax, was applied to repeat the above process to arrive at a solution with the best simple

structure (Burton and Mazerolle, 2011). After 4 iterations, 18 survey questions were retained for two factors: Factor 1 was the construct for JC and Factor 2 was the construct for MC. In addition, a CFA was applied to further assess the fit of each variable in the JC and MC constructs (STATA, 2013). It was found that all variables fit into one of the two factors except two questions. One question (Q17), which described an employee's influence over the quality of work, was clearly a JC question, but the EFA assigned it to the MC factor. The other question (Q18), which described management providing recognition for working safely, was evidently a MC question, but the EFA consigned it to align with JC. Since they did not fit into their respective constructs, they were eliminated from the survey. Similar EFA and CFA procedure was then performed on GSC questions as discussed above. 3 out of the original 7 questions were retained after EFA and CFA. Due to the fact that the MC construct was closely related to the GSC construct, two previously eliminated questions were tested to determine their fit with the GSC factor and the test came back in affirmation. The same test was done on two other questions with the MC factor and it also came back in affirmation. These questions were therefore added to GSC and MC constructs accordingly.

Hypothesis Testing

Questions that were retained after the EFA and CFA procedure were used for testing hypotheses defined in the research problem section. Data analysis and results are discussed in the following sections.

Job Control Hypothesis

Correlation and regression analysis were used to determine whether a relationship exists between the perceptions of JC and MC. Figure 1 shows a scattergram of JC scores and corresponding reported MC scores. Coefficient of determination denotes the strength of the linear association between two factors, which were JC scores and MC scores in this study. Its value can range from 0 and 1 and as the value approaches 1, the greater the statistical significance. In this study, the coefficient of determination value was 0.5471, which indicated a moderate to strong positive correlation. This value can also be interpreted as about 55% of the total variation in MC scores can be explained by the linear relationship between JC scores and MC scores. This relationship can also be observed in the scattergram in Figure 1. It is concluded that there is a moderate to strong positive correlation between a workers' self-reported job control and his/her perception toward management's commitment to safety.

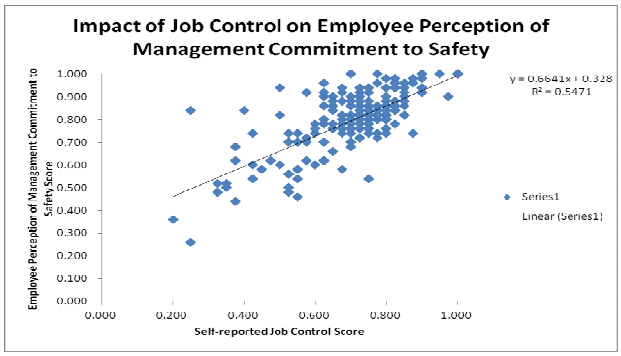


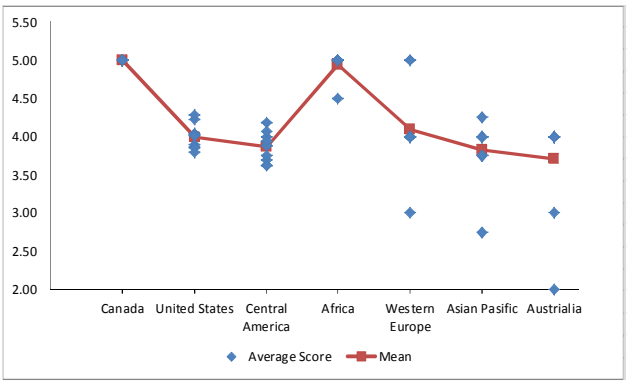
Figure 1 – Impact of JC on workers' perception of management commitment

Similar analysis is used to verify whether workers with more job control will report positive perception of safety climate. The scattergram did not indicate a relationship between JC scores and GSC scores. This was also confirmed by a low value of the coefficient of determination as 0.1867. Therefore, a statistical significant relationship between JC and GSC could not be verified.

Management Commitment Question Results

Another objective of this study was to evaluate how employee demographics would affect their perception of management commitment to safety. Demographical variables considered in this study include age, gender, region of origin, education level, job position, years of experience, and the number of job sites worked. A standard analysis of variance (ANOVA) technique was used to compare the responses from different demographical groups. ANOVA provided a statistical test of whether or not the means of several groups were all equal. To achieve that, ANOVA evaluated a statistic test value, F, and the associated critical value. If F was less than the critical value, then the null hypothesis was accepted, which means the responses from different demographical groups were equal. On the other hand, if F was larger than the critical value, then the null hypothesis was rejected, which indicated that a difference was detected in responses from different groups.

Figure 2 depicts the large mean variance between the respondent's perceptions of management commitment based on their region of origin. The test value F (19.87) was much higher than the critical value (2.25), which indicated that the null hypothesis was rejected. This implies the potential affect that a respondent's region of origin could have on their perception of management commitment at the surveyed facility. A possible explanation was that worker's origin may imply that their diverse cultures, beliefs, and socioeconomic status influenced their perception on safety and management commitment. It should also be noted that responses from several regions were relatively low. This issue is expected to be alleviated when the survey is administered to the entire case study company.



ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17.57484	6	2.929141	19.87434	7.08E-13	2.246408
Within Groups	9.285133	63	0.147383			
Total	26.85998	69				

Figure 2 – Perception on management commitment by workers' region of origin

The same procedure was used to analyze the influence of demographical factors, e.g. workers' education level, job position, and number of jobsites worked. From the education level perspective, the study demonstrated a trend that, when a respondent's education level increase, so does their perception of management commitment. The F test value also confirmed this observation: The F value was 10.44 which was greater than the critical value 2.58. In term of job position, there was a noticeable trend in both the graph and the testing results. It appeared that people who hold higher management positions perceived that management had a greater commitment to safety. However, due to the potential biased evaluation, this inference about job position and management commitment perception could not be confirmed. Workers' past experience was measured in the survey by the years of industry experience and number of job sites worked. The study demonstrates a trend that, when respondent's number of job sites worked increases, so does their perception of management's commitment. However, there was a very weak to no difference in management commitment perception detected among different groups defined by the years of experience. Also, no difference was detected among different age and gender groups.

CONCLUSIONS

This study provided a structured and quantitative survey approach in measuring safety climate through three key areas: management commitment, job control, and general safety climate. This approach had been applied to the industrial construction sector and tested through a pilot study with a total of 214 participants to verify the validity and effectiveness of the proposed method. It reported numerical safety climate scores, which provided a snapshot of an organization's safety climate at a particular point in time. When this method is consistently applied, it can help an organization to track and benchmark its safe climate for continuous improvement.

This research also studied the effect of job control on safety climate as well as how worker demographics affect their perception of management commitment to safety. It confirmed that there is a moderate to strong positive correlation between a workers' self-reported job control and his/her perception toward management's commitment to safety. Practically, it implies that an organization should involve their employees in developing safety practices and empower them take control of their work for safety. The study also observed that worker demographics (e.g. region of origin and education level) affect workers' perception to safety, and thus, training should be customized for different worker groups.

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