Empirical investigation of construction safety management activities and performance in Australia

S. Mohamed*

School of Engineering, Griffith University, PMB 50 Gold Coast Mail Centre, Queensland 9726, Australia

Abstract

The construction industry seems to suffer from a general inability to manage workplace health and safety to a level where an achieved improvement in safety performance by a way of pro-active measures can result in zero accidents. This paper investigates the effectiveness of safety management activities as currently adopted by Australian contracting organisations. A safety management survey has been conducted of contracting organisations operating in the State of Queensland, Australia. Based on a research model depicting statistical analysis techniques, a safety management index reflecting the intensity of level of safety management activities has been developed to provide a means whereby individual organisations can be assessed and graded on their safety management commitment and attitudes. The paper reports on a detailed empirical analysis carried out to examine the relationship between the intensity of safety management commitment and the overall safety performance, pro-activeness and record. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Construction; Contractors; Safety management; Safety performance

1. Introduction

Construction accidents cause many human tragedies, de-motivate workers, disrupt site activities, delay project progress and adversely affect the overall cost, productivity and reputation of the construction industry. Although project safety management is very much a traditional concern for the construction industry, the
industry seems to suffer from a general inability to manage workplace health and safety to a level where a pro-active zero-accident culture prevails. Governments worldwide have maintained an on-going commitment towards establishing a working environment free of injury and disease. This commitment is reflected by establishing performance-based workplace health and safety legislation which sets generalised performance objectives and provides a system of clearly stated responsibilities to encourage greater self-regulation for the construction industry. However, evidence is clear that zero-accident culture cannot be guaranteed by legislation alone. Dawson et al. (1988), for example, found that British construction firms of a medium and small size have not responded well to the performance-based approach. Similar findings were reported in Hong Kong (Rowlinson and Matthews, 1999). What is needed, in addition to legislation, is a change in corporate culture with regard to safety (Butler, 1989). Blockley (1995) advocates that the construction industry would be better characterised as one with a poor safety culture and that attempts to improve the safety record will not be fully effective until the safety culture is improved. Unfortunately, only a few studies (Krause, 1993; Tam and Fung, 1998) have addressed the issue of safety culture in construction. This is in comparison to the many reported studies that have focussed upon safety performance records, type and rate of accidents, and associated cost and lost time (Hinze, 1994; Everett and Frank, 1996; Smallwood, 1997; Tang et al., 1997; De la Garza et al., 1998).

According to Krause (1993) incidents occur downstream of culture (purpose, mission, values, goals, assumptions), management system (accountability, attitude, training, education, resources) and exposure (behaviour, conditions, plant, equipment). Krause maintains that employee behaviour is a direct result of management system and is the final common pathway of most incidents. Management system in turn is influenced by the organisation culture which has a substantial influence on, inter alia, priorities and the allocation of resources to health and safety effort. Therefore, construction site safety culture is viewed herein as a reflection of the three elements identified by Krause, as adopted and promoted by the management of contracting organisations to directly or indirectly enhance the safety of individuals on the job site. This definition is adopted as the process of site safety is usually managed reactively and is the sole responsibility of the contracting organisation (Hinze and Wiegand, 1992).

Wentz (1998) argues that management should encourage and support safety by setting a good safety example; effectively managing health and safety programmes, attending health and safety meetings, performing inspections, investigating near-miss accidents and reviewing safety performance at all levels. With these managerial recommendations in mind, a set of managerial practices have been selected to develop a safety management index (SMI) reflecting the intensity of level of safety management activities adopted by a contracting organisation; i.e. how strong management commitment is towards promoting zero-accident culture. The developed index was then used to check whether a correlation exists between adopted safety management activities and the organisation’s overall safety performance and pro-activeness.
2. Study aims

Organisations neither commit the same amount of effort to accident prevention (Dawson et al., 1988) nor adopt the same safety management strategy. Therefore, it was necessary to establish whether there are statistically significant differences in one or more of the variables that contribute to the organisation’s overall safety performance among a number of safety management clusters. Organisations were classified into cluster ‘groups’ according to the relative value of their respective SMI.

In addition to the above analysis, it was also required to establish whether there are any statistically significant differences in safety performance record, as reported by contracting organisations, among the same number of safety management clusters. In summary, the research study reported herein was conducted with the aim to:

1. develop a SMI to measure the intensity of safety management activities; i.e. safety culture commitment by management;
2. investigate how strongly the overall safety performance is related to the developed index;
3. explore if there are any statistically significant differences in overall safety performance and pro-activeness among a number of safety management clusters; and
4. establish whether there are any statistically significant differences in safety record among the identified safety management clusters.

3. Materials and methods

To achieve the above aims, a survey has been developed and forwarded to contracting organisations operating in the State of Queensland, Australia. The target sample included medium and large organisations engaged primarily in the construction and/or building industries. Organisations were selected on the ground of being active members of either the Australian Institute of Building (AIB) or the Australian Constructors Association (ACA). A cover letter explaining the purpose of the study and a self-addressed and stamped envelope accompanied the three-page survey questionnaire was sent to 57 contracting organisations operating in the State of Queensland. The survey targeted managers and officers with current safety management responsibilities. The subjects were informed that for returning the completed questionnaire, they would be entitled to a free summary report of this study. A total of 36 completed responses were received, comprising 63% of the total sample. The essence of the survey is to elicit information which can be used to provide answers to the following three questions:

1. How strongly is overall safety performance related to the intensity of safety management activities?
2. Are there any statistically significant differences in overall safety performance and pro-activeness among a number of safety management clusters?
3. Are there any statistically significant differences in safety records, as reported by organisations, among the identified safety management clusters?

To address the above three questions, a research model depicting statistical analysis techniques has been developed (Fig. 1) to deal with the following three formulated research hypotheses:

1. Hypothesis 1: The intensity of level of safety management activities, operationalised as SMI, is positively associated with the composite measure of overall safety performance and pro-activeness index (SPI).
2. Hypothesis 2: There is no statistically significant difference in safety performance and pro-activeness among safety management clusters.
3. Hypothesis 3: There is no statistically significant difference in safety record among safety management clusters.

4. Hypothesis 1

The intensity of level of safety management activities, operationalised as SMI, is positively associated with the composite measure of overall safety performance and pro-activeness index (SPI). To develop the SMI, respondents were asked about the following notations:

Fig. 1. Research model. LTIFR, lost time injury frequency rate.
Whether a current health and safety policy is in place: while a written commitment is not seen as mandatory, the Division of Workplace Health and Safety (Queensland, Australia) considers it the preferred method of communicating an employer’s goals and undertakings to staff. Such undertakings may be integrated with induction material, incorporated in duty statements, procedure manuals, and so forth. This material is preferably dated within 2 years and subject to review accordingly.

\[ a_i = \begin{cases} 
0, & \text{if a current health and safety policy is not in place;} \\
1, & \text{if a current health and safety policy is in place.} 
\end{cases} \]

Whether safety or any other related term appears in the organisation’s mission statement: written communications, which originate from top management, are an effective way to communicate concerns and priorities. A mission statement of what the organisation is about and what its guiding principles are reflects the organisation’s philosophy to clients as well as all new employees. Top management’s commitment is crucial to the success of any safety programmes (Hinze and Raboud, 1988; Levitt and Samelson, 1993).

\[ b_i = \begin{cases} 
1, & \text{if “safety” or any other related term does not appear;} \\
2, & \text{if “safety” or any other related term appears in the mission statement.} 
\end{cases} \]

Regularity of safety meetings: planning is one of the best means for ensuring that safety will be taken into account along with costs, schedules and other important project goals. As a project progresses, changes will occur resulting in the likelihood of workers taking shortcuts, i.e. sacrificing safety to the pursuit of time. Management should hold and attend regular safety meetings (Levitt and Samelson, 1993).

\[ c_i = \begin{cases} 
1, & \text{if safety meetings are not conducted;} \\
2, & \text{if safety meetings are conducted quarterly;} \\
3, & \text{if safety meetings are conducted monthly.} 
\end{cases} \]

Regularity of internal safety audits: the Division of Workplace Health and Safety (Queensland, Australia) has adopted health and safety auditing as its major focus to assist in employers meeting their duty of care obligations. While the audit programme has an educative and advisory focus it also serves as a measure of compliance with the provisions of legislation.

\[ d_i = \begin{cases} 
1, & \text{if internal safety audits are not conducted;} \\
2, & \text{if internal safety audits are conducted annually;} \\
3, & \text{if internal safety audits are conducted quarterly.} 
\end{cases} \]

The level of induction training: the clearest finding from all of the research that has been conducted on safety is that training and orientation of new workers and managers in safe work practices reduces accidents (Levitt and Samelson, 1993).
\[ e_i = 1, \text{ if induction training of staff is not conducted;} \]
\[ e_i = 2, \text{ if basic induction training of staff is conducted;} \]
\[ e_i = 3, \text{ if intensive induction training of staff is conducted}. \]

\[ f_i \]

Whether on-going safety awareness programmes are conducted: on-site personalised training based on an analysis of the required tasks is an indispensable element of the safety policy. This approach stresses work habits and procedures required for safe job performance. On-site training is considered as an important safety tool to mitigate site accidents (Duff et al., 1994; Lingard and Rowlinson, 1994).

\[ f_i = 1, \text{ if on-going safety awareness programmes are not conducted;} \]
\[ f_i = 2, \text{ if on-going safety awareness programmes are conducted}. \]

The following proposition is used to decide the value of SMI for an organisation \( i \), in the sample:

\[ 0 \leq (\text{SMI})_i = (a_i \times b_i \times c_i \times d_i \times e_i \times f_i) \leq \text{max SMI}. \] (1)

The value of SMI assumes a minimum value of zero if and only if \( a_i = 0 \). It assumes a maximum value of 108 if and only if \( a_i, b_i, c_i, d_i, e_i \) and \( f_i \) assume the maximum scaled value. SMI values were then standardised (divided by the maximum value of 108) across the responding organisations, so that:

\[ 0 \leq (\text{SMI})_i \leq 1. \] (2)

To develop SPI, the following six variables (\( X_1 \) and through to \( X_6 \)) were selected, based on the cited literature (see below) and views expressed by safety personnel during two semi-structured interviews. This is to reflect the overall safety performance for an organisation relative to the industry’s norm, and to indicate its pro-activeness in meeting the claimed safety management commitment.

\( X_1 \) Safety performance record with respect to the industry’s norm
\( X_2 \) Including sub-contractors in safety discussions (Lai, 1987)
\( X_3 \) Planning for the detection of potential hazard (Levitt and Samelson, 1993)
\( X_4 \) Rewarding personnel with excellent safety records (Hinze and Harrison, 1981)
\( X_5 \) Appointing only appropriate safety officers and providing them with continual training (Lingard and Rowlinson, 1994)
\( X_6 \) Identifying site employees who are chemically intoxicated and subsequently incapacitated

For each variable, respondents were asked to evaluate their organisation’s performance with respect to the industry’s norm and indicate its rating on a five-point Likert-type scale, i.e. 1, 2, 3, 4 and 5 implying ‘Poor’, ‘Fair’, ‘Average’, ‘Good’ and ‘Excellent’, respectively.
All six variables are assumed to comprise the overall safety performance and pro-activeness dimension of the organisation (SPI) which is then calculated as follows:

$$\text{SPI} = \frac{\sum_{i=1}^{6} X_i}{6}.$$  \hspace{1cm} (3)

4.1. Testing Hypothesis 1

To test Hypothesis 1, the SPI and its six variables ($X_1$ and through to $X_6$) was linearly correlated with the SMI. Two outliers (radically different from the majority of reported scores) were depicted in SMI–SPI scatter plot and subsequently removed. The removal of such discrepant scores is recognised as a means of producing a more reliable correlation analysis (Kinnear and Gray, 1992). Results obtained indicate having a correlation coefficient, Pearson $r$-value, of 0.442 with a level of significance of 0.01 (refer to Table 1 for results of correlation analysis).

In the first instance, the magnitude of the correlation reflects the absence of a strong positive linear relationship between the intensity of level of safety management activities and overall safety performance and pro-activeness. Secondly, no strong positive correlation between SMI and any of the six SPI variables could be detected. As such, one can argue that management commitment (having a current safety policy) and activities (conducting safety training, awareness programmes, meetings, audits), although essential, must be filtered down to all workers on site to have a noticeable impact on safety performance. For example, no matter how comprehensive the induction training is, it can improve safety performance only to a limited extent (Tam and Fung, 1998). This, of course, is highly dependent upon the individual’s attitude and responsibility towards their own safety. As one of the respondents reported:

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Correlation analysis$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SMI</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>SMI</td>
<td>1.000</td>
</tr>
<tr>
<td>$X_1$</td>
<td>0.204</td>
</tr>
<tr>
<td>$X_2$</td>
<td>0.440**</td>
</tr>
<tr>
<td>$X_3$</td>
<td>0.322</td>
</tr>
<tr>
<td>$X_4$</td>
<td>0.267</td>
</tr>
<tr>
<td>$X_5$</td>
<td>0.387*</td>
</tr>
<tr>
<td>$X_6$</td>
<td>0.054</td>
</tr>
<tr>
<td>SPI</td>
<td>0.442**</td>
</tr>
</tbody>
</table>

$^a$ SMI, safety management index; SPI, safety performance and pro-activeness index.

* Correlation is significant at the 0.05 level (two-tailed).

** Correlation is significant at the 0.01 level (two-tailed).
Regardless of the amount of safety procedures you have in place, training you provide or threats you make, there is always someone out there, that is either stupid, does not care or is willing to take a short cut to save a bit of extra money. These people are successful in practising unsafe work methods without being detected, and when an accident occurs, as per the Workplace Health and Safety Act, the Principal Contractor is liable to a certain degree, regardless.

Generally, survey respondents showed relatively high commitment towards safety management activities (SMI values); however, only 25% of the calculated SPI reflected a good or excellent overall safety performance and pro-activeness. This explains the absence of strong positive correlation between SMI and SPI variables.

In light of comments made by a number of respondents that reward schemes may lead to cover-ups of incidents, the $X_4$ (rewarding personnel with excellent safety records) scores were excluded and the correlation test repeated. Obtained Pearson $r$-value was marginally increased to 0.46 confirming the above findings.

5. Cluster analysis

Cluster analysis is a multivariate statistical technique usually used to group a number of homogeneous observations based on similarity over one or more variables (Kachigan, 1986). By forming clusters, one can determine the characteristics that are shared, as well as those on which they differ. To provide empirically valid safety management clusters, the standardised SMI value was used as a clustering variable.

In developing the research model, shown in Fig. 1, it was considered that having more than two clusters would provide a satisfactory classification. This is to avoid the traditional high–low classification. Based on the calculated standardised SMI values (0–1), the agglomerate hierarchical clustering method with complete linkage was utilised to identify the appropriate number of clusters. A dendrogram resulting from this stage suggested that four clusters would be best to describe the sample. Fewer clusters would combine dissimilar respondents, whereas more than four clusters would result in clusters with insufficient number of members to allow for further analyses.

Number of cases in each cluster and final cluster centres are shown in Table 2. In the following sections, the variations in the SPI and its variables among these four clusters will be discussed.

Table 2
Number of cases in each cluster and final cluster centres

<table>
<thead>
<tr>
<th>Cluster</th>
<th>SM intensity</th>
<th>No. of valid cases</th>
<th>SMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>6</td>
<td>1.000</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>12</td>
<td>0.588</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>12</td>
<td>0.304</td>
</tr>
<tr>
<td>4</td>
<td>Very low</td>
<td>4</td>
<td>0.102</td>
</tr>
</tbody>
</table>

* SM, safety management; SMI, safety management index.
6. Hypothesis 2

There is no statistically significant difference in performance among the safety management clusters. This hypothesis is tested at both the aggregate and disaggregate levels. It follows that there are seven sub-hypotheses.

Hypothesis 2a: There is no statistically significant difference in SPI among the safety management clusters.

Hypothesis 2b: There is no statistically significant difference in an organisation’s safety performance record \((X_1)\) among the safety management clusters.

Hypothesis 2c: There is no statistically significant difference in the inclusion of subcontractors in safety discussion \((X_2)\) among the safety management clusters.

Hypothesis 2d: There is no statistically significant difference in planning for the detection of potential hazard \((X_3)\) among the safety management clusters.

Hypothesis 2e: There is no statistically significant difference in rewarding staff with excellent safety records \((X_4)\) among the safety management clusters.

Hypothesis 2f: There is no statistically significant difference in appointing only appropriate safety staff and providing them with continual training \((X_5)\) among the safety management clusters.

Hypothesis 2g: There is no statistically significant difference in identifying employees who are chemically intoxicated and subsequently incapacitated \((X_6)\) among the safety management clusters.

6.1. Testing Hypothesis 2

To test Hypothesis 2, the univariate analysis of variance (ANOVA) was used. SMI clusters, listed in Table 2, served as the independent variable whilst the six variables \((X_1\) and through to \(X_6)\) as the dependent variables. Table 3 shows the means and standard deviations for the dependent variables in each cluster. By comparing the means of each cluster, it can be seen that the group with high safety management intensity outperforms the other three clusters with respect to all issues relating to overall safety performance and pro-activeness.

Further analysis was undertaken using ANOVA, to detect whether there were any significant differences between a company’s overall safety performance and safety management cluster memberships. Table 4 summarises the results. For a level of significance of 0.05 it is clear that, with the exception of variable \(X_3\) (pro-activeness in planning for the detection of potential hazards), there is no statistically significant
Table 3
Means and standard deviations for safety performance and pro-activeness index (SPI) variables in each cluster

<table>
<thead>
<tr>
<th>Cluster</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM intensity</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>No. of cases</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>$X_1$</td>
<td>4.50 (0.55)</td>
<td>4.08 (0.51)</td>
<td>3.91 (0.79)</td>
<td>4.00 (0.00)</td>
</tr>
<tr>
<td>$X_2$</td>
<td>4.17 (0.75)</td>
<td>3.75 (0.96)</td>
<td>3.33 (0.65)</td>
<td>3.25 (0.50)</td>
</tr>
<tr>
<td>$X_3$</td>
<td>4.17 (0.41)</td>
<td>3.42 (0.41)</td>
<td>3.75 (0.75)</td>
<td>2.75 (0.96)</td>
</tr>
<tr>
<td>$X_4$</td>
<td>3.33 (1.50)</td>
<td>3.00 (1.49)</td>
<td>2.33 (1.30)</td>
<td>2.75 (1.26)</td>
</tr>
<tr>
<td>$X_5$</td>
<td>4.17 (0.75)</td>
<td>3.92 (1.38)</td>
<td>3.58 (0.79)</td>
<td>2.50 (1.29)</td>
</tr>
<tr>
<td>$X_6$</td>
<td>4.00 (0.89)</td>
<td>3.90 (0.32)</td>
<td>3.81 (0.75)</td>
<td>3.25 (1.50)</td>
</tr>
</tbody>
</table>

a SM, safety management.

Table 4
One-way analysis of variance

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Sum of squares</th>
<th>df</th>
<th>F ratio</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between clusters</td>
<td>1.446</td>
<td>3</td>
<td>1.197</td>
<td>0.328</td>
</tr>
<tr>
<td>Within clusters</td>
<td>12.083</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13.529</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between clusters</td>
<td>3.015</td>
<td>3</td>
<td>1.608</td>
<td>0.208</td>
</tr>
<tr>
<td>Within clusters</td>
<td>18.750</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>21.765</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X_3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between clusters</td>
<td>5.485</td>
<td>3</td>
<td>3.719</td>
<td>0.022</td>
</tr>
<tr>
<td>Within clusters</td>
<td>14.750</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.235</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X_4$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between clusters</td>
<td>15.863</td>
<td>3</td>
<td>1.348</td>
<td>0.277</td>
</tr>
<tr>
<td>Within clusters</td>
<td>117.667</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>133.529</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X_5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between clusters</td>
<td>7.775</td>
<td>3</td>
<td>2.180</td>
<td>0.111</td>
</tr>
<tr>
<td>Within clusters</td>
<td>35.667</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>43.441</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X_6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between clusters</td>
<td>7.368</td>
<td>3</td>
<td>0.864</td>
<td>0.470</td>
</tr>
<tr>
<td>Within clusters</td>
<td>85.250</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>92.618</td>
<td>33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

difference among the four safety management clusters. That is, only variable $X_3$ shows significant difference across the SMI clusters.

To pinpoint which clusters differ significantly on variable $X_3$, a post hoc analysis using the Schiffee multiple comparison procedure was run. Results, shown in Table 5, indicate that clusters 1 (high SMI) and 4 (very low SMI) do differ significantly.
(significant < 0.05) on variable $X_3$. This finding clearly confirms the importance of planning to detect potential hazards and its role in affecting the overall safety performance. It is not obvious, however, if significant differences in this variable exists between other clusters (1 and 2), (1 and 3), (2 and 3) and (3 and 4) (Fig. 2).

### 7. Hypothesis 3

There is no statistically significant difference in safety record among safety management clusters. In the construction industry, there are a number of safety indicators which have been nominated and successfully used by both researchers and practitioners to gauge an organisation’s safety performance record. These include accident rate (Tam and Fung, 1998), accident occurrence index (Tang et al., 1997), workers’ compensation claim frequency indicator (De La Garza et al., 1998), accident improvement rate and lost time injury frequency rate. After initial consultation with the local industry, it was decided to use the lost time injury frequency rate (LTIFR) as the safety performance indicator in this study. This is to facilitate comparing safety records independently of the organisation’s size, i.e. small, medium or large. LTIFR is the lost time injuries per 1.0 million hours worked. Respondents were asked to identify their organisation’s LTIFR for the past 12-month, based on the groupings shown in Table 6. ANOVA analysis was subsequently conducted to detect whether there were any significant differences between a company’s most recent safety record (LTIFR) and the already identified safety management clusters (Fig. 1).

#### Table 5

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Cluster</th>
<th>Cluster</th>
<th>Mean difference</th>
<th>S.E.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_3$</td>
<td>1</td>
<td>2</td>
<td>0.750</td>
<td>0.351</td>
<td>0.228</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>0.417*</td>
<td>0.351</td>
<td>0.705</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.417*</td>
<td>0.453</td>
<td>0.035</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the 0.05 level.

Fig. 2. Multiple comparison procedure: cluster groups versus variable $X_3$. 

Fig. 2. Multiple comparison procedure: cluster groups versus variable $X_3$. 

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Safety Management Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

Significant differences among/between these clusters were found.

No significant differences among between these clusters, at least at (sig. = 0.05).
7.1. Testing Hypothesis 3

For a level of significance of 0.05, ANOVA results reflect clearly that the dependent variable, safety record, varies across the four safety management clusters. A further post hoc analysis was conducted with key results tabulated in Table 7. The results indicate that significant differences (significant < 0.05) in safety record exist between clusters 4 (very low SMI) and any of the other three clusters. However, no significant differences in safety records between clusters (1 and 2), (1 and 3) and (2 and 3) could be detected at the same level of significance (Fig. 3). This finding clearly demonstrates a strong association between having a minimum level of safety management commitment and relatively poor safety performance record.

8. General discussion

The analysis presented in this paper must be viewed with regard to sample size. It is a generally accepted statistical principle that the larger a sample the more reliable the output. The findings of this study are not indicative of the results reported in

<table>
<thead>
<tr>
<th>Group number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTIFR</td>
<td>0</td>
<td>1–10</td>
<td>11–30</td>
<td>31–50</td>
<td>51–70</td>
<td>71–90</td>
<td>&gt; 90</td>
</tr>
</tbody>
</table>

Table 6
Lost time injury frequency rate (LTIFR) groups

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Cluster</th>
<th>Cluster</th>
<th>Mean difference</th>
<th>S.E.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety record</td>
<td>4</td>
<td>1</td>
<td>3.250*</td>
<td>0.902</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>4.167*</td>
<td>0.807</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>2.833*</td>
<td>0.807</td>
<td>0.015</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the 0.05 level.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Safety Management Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

Fig. 3. Multiple comparison procedure: cluster groups versus safety record.
other published studies on the effectiveness of construction safety management activities. Nevertheless, it sheds some light on a number of important issues, considered prerequisites for promoting a zero-accident safety culture in the construction industry. For example, it was alarming to learn that almost 40% of survey respondents rate their pro-activeness in including sub-contractors in safety discussion as average or below. More than 46% of the respondents rate their policy towards rewarding safety officers with excellent safety records as poor or fair. Only 25% of respondents felt that their policy towards appointing appropriate safety personnel is excellent.

Organisations involved in this study have generally shown a commitment to providing a reasonable-to-high level of safety management activities. This, however, has not been reflected in the way they view their safety performance and pro-activeness with respect to the industry’s norm nor in how they implement these activities as a safety management package. As mentioned earlier, no strong positive correlation between safety management commitment and any of the safety performance and pro-activeness variables could be detected.

From the above it is clear that what is needed is a change in the safety culture, i.e. redesigning how organisations view and approach safety management activities. The process of on-site hazard detection and management, in particular, needs to be thoroughly analysed in terms of its basic activities, i.e. planning, detection, action and feedback to employees with a view to examine how these four activities interact with each other. This should, in turn, lead to a more effective way to detect and manage hazards.

The author acknowledges that there is much work to be done in the understanding of the effectiveness of safety management activities on overall safety performance. A number of questions remain to be answered. For example, do the activities used to develop SMI, measure the safety management commitment independently or do they interact in a synergistic way? To what degree, if any, do they overlap? Similarly with the development of SPI, it can be argued that responses are purely subjective in nature casting some doubts on how respondents might have perceived ‘the industry’s norm’. These questions are currently the subject of a more detailed research investigation.

References


