A Case Study of Safety Performance Variations among a General Contractor's Regional Branches

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Abstract:

In construction, contractors' safety performance could differ from each other due to various reasons (e.g., the importance of safety at workplace, the adoption of different safety and health programs, the use of union or non-union workers, etc.). However, it has not been widely recognized that differences in safety performance also exist in the same contractor's regional offices. So far, the impact of regional differences on contractors' safety performance has not been well understood. In a case study of a general contractor's (GC's) newly launched safety management program, variations in safety performance of the same GC's regional branches were noticed. This paper analyzes incidence rates (IRs), safety violation rates (SVRs), and workplace safety climate from the GC's six major regional branches in four states. This research finds apparent regional differences in IR and SVR although the workers' shared perception of how the safety program is implemented (i.e., program-related safety climate) is consistent company-wide. This research also finds that regional IRs, SVRs, and safety climate scores have no correlational relationship. Therefore, integrating all these three factors into a safety management program and its effectiveness measurement is necessary and will lead to a more holistic approach to improving jobsite safety performance.

Keywords: safety performance, regional difference, incidence rate, behavioral violation, safety culture, safety climate

1. Introduction

In the construction industry, contractors' safety performance in terms of incident rates and/or experience modification rates (EMR) could differ from each other to a large degree. Potential causes include, but are not limited to, the importance of safety at workplaces, the adoptions of different safety and health procedures, the uses of union or non-union workers, different percentage of immigration workers in workforce, age differences, etc. (Dedobbeleer et al., 1990; Anderson et al., 2000; Gillen et al., 2002; Siu et al., 2003; Oh and Sol, 2008; Chen and Jin, 2011). However, it has not been widely recognized that differences in safety performance also exist in the same contractor's regional offices although the same safety program and procedures are in place. So far, the impact of regional differences on contractors' safety performance has not been well understood. The underlying reasons for such regional differences are unclear.

In a case study to evaluate the overall effectiveness of a general contractor's (GC's) newly launched safety management program—"Safety4Site," Chen and Jin (2011) found that the 19-month incidence rates (IRs) of the same GC's regional branches varied to a large degree. This inconsistency hurts the contractor's overall safety performance. This motivated researchers to explore underlying reasons for these safety performance variations. This research, at the current stage, focuses on two major factors, namely safety behavioral violation and safety culture/climate that may be related to IRs. These two factors are also considered unconventional safety performance measurements by this study. This leads to a holistic approach to assessing safety performance.

This paper first analyzes data for IRs, safety violation rates (SVRs), and workplace safety climate from the GC's six major regional branches in four states to investigate how much differences exist among these data. Then the paper focuses on presenting a correlation analysis on regional IRs, SVRs, and safety culture/climate. The research findings are expected to offer useful insights to help the contractor enhance the implementation of the safety program and achieve consistent and improved safety records company-wide.

2. Literature Review

Regional Differences

There have been previous work that confirmed the existence of regional differences in IR, best construction practices, and other factors that affect filed safety performance. According to International Association of Oil and gas Producers (OGP), regional differences were evident in the lost time injury frequency (LTIF) performance among their Asia/Australasia, Africa, South America, and Europe regions (OGP, 2005). Data from U.S. Bureau of Labor Statistics (BLS) shows that in the building construction sector, the 2009 IR from each state varied to a large degree. For example, some northern states, such as Iowa and Delaware, had their state IRs higher than 6.5, while some southern states, such as Alabama and Georgia, had their IRs below 3.0. For another four states where the aforementioned GC's regional offices are located, three of them have available IR data from BLS. These data (4.3, 3.8, and 2.2) were also very different (BLS, 2011).

Many factors could play a role in causing regional differences in safety performance. These factors include demographic variation, safety behavior, best construction practices, labor/safety management practices, jobsite climate, etc. For example, previous results showed the impact of racial and ethnic diversities in construction workforce on the safety performance of contractors from different regions. This is because of the higher fatal and non-fatal injury rates among Hispanic construction workers (Anderson et al., 2000; Brunette, 2004). Also, studies have verified that regional differences exist in adopting best construction practices (e.g., ergonomic best practices in masonry construction) or labor/safety management practices (e.g., drug tests, controlling labor turnover, etc.) that have an effect on contractors' safety performance (Hinze and Gambatese, 2003; Hess et al., 2010). In addition, industry practitioners gradually realize the existence of regional needs in developing and implementing safety and health programs and are increasingly aware that safety performance improvements should be aligned with regional and company culture and conditions (Cooper and Phillips, 2004; Choudhry et al., 2007).

Safety Performance Measurements

Traditionally, a contractor's safety performance is measured only through reactive factors including incident rates (e.g., lost time incidence rate, severity rate, and recordable incident rate), experience modification ratings (EMRs), and other quantitative safety performance measures (Jaselskis et al., 1996). In recent years, researchers started to point out that the outcome data (such as accidents) are not a good measure of safety performance because they are insensitive and ignore risk exposure (Glendon and McKenna, 1995). For example, a jobsite with zero accident and yet having a large number of unsafe acts or near misses cannot be considered safe at all. By contrast, proactive approaches that pay special attention to accident prevention were suggested as more accurate methods for measuring safety performance. These approaches include behavior sampling, hazard identification, and safety culture/climate (Stricoff, 2000; Cooper and Phillips, 2004; Choudhry et al., 2007).

Unlike more straight forward accident/incident-based measurements, measuring proactive indicators (such as safety behavior, safety culture/climate, etc.) is difficult, cost- or time-prohibitive, and subjective. Both qualitative and quantitative methods need to be used according to previous studies (Edkins, 1998; Griffin and Neal, 2000; Glendon and Litherland, 2001; Cooper and Philips, 2004; Wu et al., 2007, 2009; Choudhry et al., 2009; Jiang et al., 2010). Safety culture is a top-down organizational attribute approach while safety climate is about workers' perception of the value of safety in the work environment (Neal et al., 2000; Mohamed, 2003). Survey instrument remains the most widely used method in determining organizational culture and workplace climate.

Overview of "Safety4Site"

The "Safety4Site" program was designed and implemented by the aforementioned GC to reduce injuries and workers' exposures in OSHA (Occupational Safety and Health Administration) Focus 4 Hazards, namely falls, electrocution, stuck-by, and caught-in or between (OSHA, n.d.). This program focuses on increasing the safety awareness and accountability of the GC's employees, its subcontractors (Subs), and material suppliers, while achieving positive changes in safety attitude and behavior. The program consists of three basic elements: 1) eye protection, 2) daily "huddle" meetings, and 3) accountability for accidents, incidents, and near misses. Twenty non-negotiable unsafe behaviors related to Focus 4 Hazards were identified in the program development stage and violations were observed and reported during its implementation at the GC's jobsites. Based on the observed violations, certain penalties were applied to involved workers. After two-month probation/warning period, the program was in full effect at the end of May 2008 and has been ongoing since then.

3. Research Methods

The primary objective of this research is to investigate differences in workers' safety performance among the GC's six regional branches and perform hypothesis tests to determine whether these regions' safety violation rates, safety culture/climate, and incidence rates are correlated. A positive answer could imply that safety violations, organizational safety culture, and/or workplace safety climate have an influence on incidence rates. Improvement on these factors can help contractors reduce accidents on jobsites and maintain consistent safety performance company-wide. To achieve this goal, the following research methods were employed.

In the data collection stage, the GC's monthly revenues, numbers of accidents, and numbers of safety violations reported for each region were retrieved. Regional IRs were calculated and compared to determine if the GC had achieved consistent safety performance among construction sites across different states. Another unconventional safety performance measurement—behavioral violation—was also studied for the regional difference. To avoid the influence of fluctuating revenues on the monthly number of safety behavior violations, safety violation rates (SVR) were calculated and used for comparison.

A key part of this study was to compare each region's safety culture/climate on jobsites. Survey questionnaires for craft workers, site management personnel, and top executives of the GC were developed. Except for some general background questions, most of the questions fall into five categories, namely *awareness*, *accountability*, *buy-in/acceptance*, *culture/climate*, and *cost/schedule impact*. To ensure wide participation in the survey, the research adopted both face-to-face and online web surveys. The former was used for field workers and site management personnel, while the latter was used to collect feedback from top executives and site management personnel who either missed the face-to-face survey on jobsites or were not currently assigned to an on-going project. Craft questionnaire was translated to Spanish for Spanish workers. Due to space limitation, this paper focuses on presenting survey results from craft workers, which reflect safety climate (i.e., shared perception among workers of the value of safety in their work environment) on the jobsites. The questionnaire for craft workers consisted of 28 questions in various formats, including multiple-choice, Likert scale, and open questions.

From November 2010 to January 2011, the face-to-face surveys for craft workers were conducted at 31 construction sites across four states, where the GC's regional branches are located. Table 1 shows the number of surveyed workers in each region.

Table 1: Number of questionnaires collected from different regions

Region	1	2	3	4	5	6	Total
Number of surveyed workers	33	65	29	53	82	88	350

In the data analysis stage, 15 out of the 28 questions were selected to generate overall safety climate scores. These selected questions were later on divided into two categories, namely **program-related safety climate** (including subcategories of awareness, accountability, and buy-in/acceptance), and **general safety climate**. Scores for all of these categories and subcategories were computed.

After regional IRs, SVRs, overall safety climate scores, and its subcategory scores were obtained, comparison study was performed to determine the deviations and relative variations for these safety performance measurements across six regions. These regions' rankings in IRs, SVRs, and safety climate scores were also checked to see if the rankings were consistent. Finally, the relationships among these safety performance measurements were studied to determine whether they are correlated.

4. Results and Discussions

Regional Difference in Safety Performance

One focus of the "Safety4Site" case study was to compare workers' safety performance among the GC's six regional branches. Regional IRs were first compared to determine the consistency of the contractor's safety performance after the implementation of "Safety4Site." Safety violation rates and workplace safety climate scores, two unconventional measurements for safety performance, were also calculated and compared to determine regional variances. The results are presented below.

Incidence Rates among Six Regions. The incidence rates (GC-and-Subs combined) were computed as:

$$\textit{Incidence rate} = \textit{total recordable accidents} \times 200{,}000 / \textit{employee hours worked}. \quad (1)$$

Recordable accidents are those with non-fatal injuries that require more than First Aid treatment. Employee hours worked were computed based on the assumptions that labor costs account for 40% of the total revenue and workers' hourly rate (including wages and benefits) is $40 on average. Figure 1 shows the overall IRs over the 19-month study period (from 05/2008 to 09/2009) for each region as well as the overall six-regions-combined. Yearly IRs (2008 and 2009) falling into the study period are also shown.

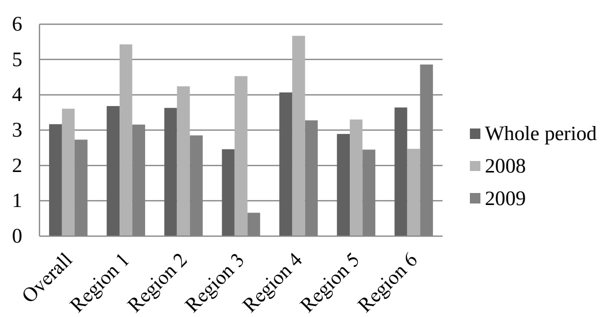

Figure 1: Incidence rates among different regions.

As shown in Figure 1, regional IRs and their yearly values varied to some degree. Region 4 had the highest IR (4.07), 65.45% higher than that of Region 3 (IR=2.46), which was the lowest. Trend of yearly change was also not consistent among different regions. Most regions had lower IRs in 2009 compared to 2008. Region 3 had the largest reduction of 85.43%. Region 6 is the only region that had an increased IR in 2009 by 96.76%. Although this was partially due to the fact that Region 6 had the lowest yearly IR in 2008, this sharp increase in IR as well as being the highest yearly IR in 2009 is unusual and needs further study.

Safety Violation Rates (SVR). The total number of unsafe behaviors observed for each region was generated by summing monthly violation numbers reported by the GC. The U.S. Bureau of Labor Statistics (BLS) showed that the decreases in fatal injury in 2008 and 2009 were partially caused by declines in employment or hours worked. This was especially true in the construction industry (BLS, 2010). Previous research has also confirmed a positive linear relationship between the GC's monthly revenue and violation numbers over the 19-month studied period (Chen and Jin, 2011). To exclude the potential impact of revenue (hours worked) on the violation number of each region, safety violation rate (SVR) was introduced into this study to measure the behavior-based performance, which can be computed as:

$$SVR = \text{number of safety violations} \times 200{,}000 / \text{employee hours worked.} \qquad (2)$$

Similar to IR, SVR denotes the number of violations per 100 workers on an annual basis. Figure 2 illustrates SVRs for six regions. The entire study period for SVR is the same as that for IR (from 05/2008 to 09/2009).

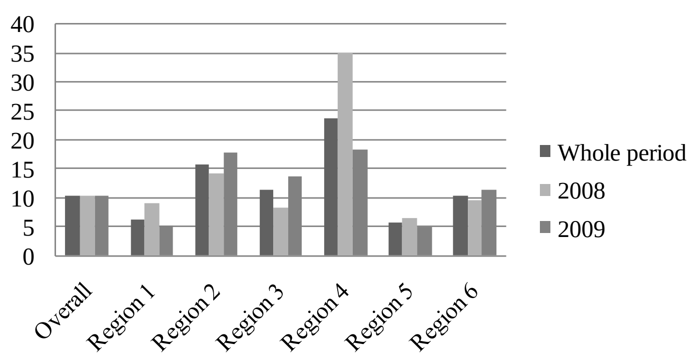

Figure 2: SVRs among different regions.

Similar to IR, SVRs were also inconsistent among different regions during the studied period. Region 5 had the lowest SVRs in the whole study period and yearly data. The whole period SVR from Region 4 was 321.59% higher than that from Region 5. The overall SVRs for the six-regions-combined did not vary much among the whole study period and yearly values. Three regions had lower SVRs in 2009, and the other three had higher SVRs instead. Region 4 had the highest change in yearly SVRs from 2008 to 2009, a decrease by 42.15%. The inconsistencies in regional IRs and SVRs led to a variation study presented later in this paper.

Safety Climate Scores. The overall workplace safety climate score, denoted by Y , was computed by the following linear expression:

$$Y = a + \sum_{i=1}^{15} b_i X_i \ , \quad (3)$$

Where X_i represents the score obtained for the i th selected multiple-choice question, a represents an initial score, and b_i denotes the weight for the i th multiple-choice score. In this study, a is set to zero and $b_i = 1$, for $i = 1,\ldots,15$. Each X_i is upper bounded by one. Hence, the maximum value of Y is 15. More specifically, suppose that there are n choices for the i th question, then X_i is computed as follows:

$$X_i = \sum_{j=1}^{n} p_j q_j \ , \quad (4)$$

where p_j denotes the percentage of the people who selected the j th option and q_j denotes the score earned for selecting the j th option. For example, suppose that there are two options for the first question, and the scores for these two options are 1 and 0, respectively. If 90% of the people selected that they are aware of Safety4Site (represented by score 1), and 10% chose the unaware option (represented by score 0), then the score X_1 is computed as $0.9 \times 1 + 0.1 \times 0 = 0.9$.

Regional Variance Analysis. Table 2 lists all the regional IRs, SVRs, climate scores in various categories, and their associated overall values, deviations, and relative variations.

Table 2: Safety measurement data among regions

Region	IR	SVR	Awareness	Accountability	Buy-in/ Acceptance	Program-related climate*	General climate	Overall climate
1	3.68	6.13	2.41	1.46	4.11	7.98	2.17	10.14
2	3.63	15.83	2.50	1.61	4.30	8.40	1.96	10.36
3	2.46	11.25	2.46	1.37	4.33	8.16	1.91	10.07
4	4.07	23.82	2.57	1.34	4.39	8.30	2.08	10.38
5	2.89	5.65	2.48	1.43	4.50	8.41	2.13	10.54
6	3.64	10.44	2.57	1.45	5.03	9.05	2.24	11.30
Overall	3.17	10.36	2.46	1.45	4.57	8.47	2.11	10.64
Deviation	0.59	6.48	0.07	0.09	0.31	0.35	0.12	0.44
Relative Variation	18.6%	62.55%	2.98%	5.99%	6.84%	4.07%	5.65%	4.13%

* The program-related climate is the sum of awareness, accountability, and buy-in/acceptance.

The overall value for each performance measurement was calculated using Eqs.(1), (2), and (3), respectively, based on the entire sample of six regions. Note that the overall value of each performance category is in general not equal to the arithmetic average of the corresponding scores of six regions. For convenience, the term "deviation" is slightly abused as follows. Let x denote a performance metric, i.e., $x \in \{\text{IR, SVR, Awareness, Accountability, Acceptance, General Climate, Overall Climate}\}$. Also, let $\tilde{x}$ represent the corresponding overall value. Then, the deviation in this work is:

$$\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \tilde{x})^2} \ , \quad (5)$$

Note that Eq.(5) is similar to the standard deviation computation. The difference is that $\tilde{x}$ in all the cases is no longer the arithmetic mean of regional data, but the overall value.

"Relative variation" in Table 2 is defined as

$$\textit{Relative variation} = \textit{deviation} / \textit{overall}. \qquad (6)$$

It can be seen from Table 2 that SVR has the largest relative variation (52%), showing an apparent regional difference in workers' safety behavior. The relative variation of overall safety climate is 4.13% and other safety climate subcategories all have relatively small variations, implying that the perception from workers on the implementation of the "Safety4Site" program is consistent in all regions. There is no consistent ranking for each region in terms of its safety performance in IR, SVR, and climate. For example, Region 3 ranks the best in IR, the third in SVR, but the worst in the overall safety climate.

Correlation Analysis of Safety Performance Measurements

The inconsistency in ranking of regional offices' safety performance motivated researchers to study the correlation coefficient among major safety performance measurements including IR, SVR, overall climate and its subcategories for the six regions. Pearson correlation (denoted by *r*) and its related *p* value were used to test the existence of linear relationships (see Table 3).

Table 3: Pearson correlation among safety performance measurements (N=6)

		IR	**SVR**	**Awareness**	**Account-ability**	**Buy-in/ Acceptance**	**Program-related climate**	**General climate**	**Overall climate**
IR	*r*	1	0.53	0.46	0.191	0.06	0.18	0.45	0.27
	p	0	0.28	0.358	0.717	0.91	0.733	0.38	0.60
SVR	*r*		1	0.64	-0.18	-0.03	0.04	-0.33	-0.07
	p		0	0.17	0.73	0.95	0.95	0.52	0.90
Awareness	*r*			1	-0.20	0.72	0.74	0.26	0.69
	p			0	0.71	0.11	0.09	0.62	0.13
Account-ability	*r*				1	-0.08	0.16	-0.09	0.11
	p				0	0.88	0.77	0.867	0.84
Buy-in/ Acceptance	*r*					1	0.97	0.53	0.95
	p					0	**0.002**	0.28	**0.003**
Program-related climate	*r*						1	0.48	0.97
	p						0	0.34	**0.001**
General climate	*r*							1	0.68
	p							0	0.14
Overall climate	*r*								1
	p								0

Data in Table 3 show that there is no linear relationship among IR, SVR, and workplace safety climate (including its subcategories). However, there are strong linear relationships among safety climate categories: Both the program-related climate and overall climate are strongly related to buy-in/acceptance of the safety program. The program-related climate also has a strong linear relationship with the overall climate.

Due to the lack of correlation among IR, SVR, and safety climate, a holistic safety management approach integrating all these three factors/measurements would be necessary for improving jobsite safety performance. They also need to be considered in evaluating the effectiveness of such a safety management program.

Limitations

It is challenging to quantify workplace safety climate in this study. In safety climate score calculation, each of the 15 selected questions was assumed to be equally important. To be more accurate, in the future research, a weighting system for these questions will be developed by surveying contractors' management personnel who will rank the importance of each question using a pre-defined Likert-type scale (e.g., 1-5 from the least important to the most important). Then, the relative weights of the questions can be computed.

5. Conclusions and Future Research

This case study presented information about regional differences in safety performance for a GC after the launch of a new safety program—"Safety4Site." The study included a traditional IR measurement and non-traditional measurements including SVR and workplace safety climate in the analysis. Differences in regional IRs (relative variation = 15.06%) and SVRs (relative variation = 52%) were apparent while the difference in workplace safety climate was minor (relative variation = 4.13%). This implies that the shared perception from workers on the implementation of the "Safety4Site" program is consistent in all regions, an indicator that the implementation of the program is also relatively consistent among regions.

Traditionally, the safety performance is measured by IRs, EMRs and other reactive factors. Safety behavior and safety culture/climate are considered external factors that affect workers' safety performance to some degree. To explore a more comprehensive way to assess contractors' safety performance, this research included SVR and safety culture/climate score as proactive measurements for safety performance. Therefore, a correlational relationship analysis was performed for the six regions to determine whether these three measurements are correlated. The results indicated that these three measurements are independent of each other. As a result, integrating these three factors into a safety management program and its effectiveness measurement is necessary, which will lead to a more holistic approach to improving jobsite safety performance.

This case study will be furthered in the following directions:

- Survey data from top executives and site management personnel will be analyzed to measure the organizational safety culture for the GC. This will complete the holistic approach adopted by this research.
- The current study has not thoroughly explored the factors that could cause regional differences in safety performance. Regional best practices, the effectiveness of

OSHA's supervision, workers' ethnicity and age range, percentage of self-performed and subcontracted work, and other factors could also play a role. Future research will study these potential factors.

- Factors that are significant to the buy-in/acceptance to the program and to the general safety climate on the jobsites will be identified, which could become the focal areas for the GC to further improve the program implementation and jobsite safety performance.

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