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Research paper

Project characteristics indicating safety performance

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Abstract

Safety performance has been long discussed and assessed in order to ensure less harm identified and reduce accidents in construction projects. Practically, accident rate is one common used key performance indicator to indicate the on-site safety performance in construction projects worldwide. Theoretically, there were various indicators that developed for the assessment of the safety performance of construction projects. These indicators were derived from previous literatures and lack of potential linkage to the project performance of construction projects. Thus, it is worth to explore the project characteristics that identified in construction projects with outstanding safety performance. This study introduced the project characteristics that identified in the construction projects with outstanding safety performance. The project characteristics were firstly identified by the sate-of-the-practice review and verified by panels of experts through structured interview and questionnaire survey. In general, findings of literature and structured interview were consistent. A series of interviews were supplemented the literatures' findings. There were totally 27 project characteristics that indicating outstanding safety performance of a construction project. Eighteen experts were participated in the questionnaire surveys to verify the importance levels of the proposed project characteristics. All experts agreed with project characteristics that indicating the safety performance of the construction projects. The most agreed project characteristics were good housekeeping, more support and commitment from senior management, clear understanding of construction work activities, and good planning of project execution. These are indicative to future development of project management practice and sustainable safety strategies in construction industry locally and globally.

Keywords: *Safety Performance; Construction Industry; Safety Commitment; Safety Audit*

1. Introduction

Construction involves high risk work activities and contributed to 20% of overall industrial accidents during the period between 1996 and 2005 in Japan, South Korea and Hong Kong (Poon, Tang, & Wong, 2008; Yiu & Chan, 2016). Particularly, in Hong Kong, 62% of industrial fatalities in the year of 2015 were constituted from construction sector, and a total of 3,723 accidents were reported from construction sites (Labour Department, 2017). The high accident and fatality rates of construction industry are mainly attributed to its hazardous workplace environment and fast changing work practices (Fan, Lo, Ching, & Kan, 2014; Tam & Fung IV, 1998).

There are a few well-recognized key performance indicators that represent the safety performance in construction industry. Accident rate is considered as a common key performance indicator. Other safety performance indicators and indexes currently available were mostly derived from previous literatures without specification of assumed fitting criteria. The less reliability of the indicators, the fewer construction companies adopted. With the consideration of the limited evidence of safety performance due to the impact of on-site project practices (Bottani, Monica, & Vignali, 2009; Robson et al., 2007), this study aims to identify the project characteristics that indicating outstanding safety performance on construction sites.

Project Characteristics

Journal papers on the topic of construction safety were obtained through systematic searching in Scopus database. Scopus database was commonly reviewed for the research studies in construction management due to its better coverage and accuracy of sources of information (Ameyaw, Hu, Shan, Chan, & Le, 2016; Hon, Chan, & Yam, 2011). Articles containing the most-searched terms 'safety performance' and 'construction' in the 'title/ abstract/ keyword' were considered for review in this research. By reviewing the content of these articles, there were 20 project characteristics identified from the articles. Table 1 shows 20 project characteristics that potentially found in construction project with outstanding safety performance. These project characteristics will then be verified through interviews and questionnaire survey.

Table 1: Key Characteristics to Distinguish Safety Performance in Hong Kong Construction Industry

	Key characteristics to distinguish safety performance in Hong Kong Construction Industry	References
1	More support and commitment from senior management	(Goh & Chua, 2013; Ismail, Doostdar, & Harun, 2012)
2	Better logistic arrangement of site materials	(Moorkamp, Kramer, Van Gulijk, & Ale, 2014; Tam, Fung IV, & Chan, 2001)
3	Clear understanding of construction work activities	(Moorkamp et al., 2014)
4	Lower accident rates	(Bottani et al., 2009)
5	Good planning of project execution	(Bottani et al., 2009)
6	Clear site activities / working sequences	(Tam et al., 2001)
7	Strong financial performance	(Bottani et al., 2009)

8	Well-functioned communication system	(Bottani et al., 2009)
9	Higher education level of workers	(Tam et al., 2001)
10	Strict operational procedures	(Bottani et al., 2009)
11	Higher teamwork spirits	(Tam et al., 2001)
12	Clear safety organization with defined responsibilities and accountabilities	(Ismail et al., 2012; Tam et al., 2001);;
13	Incentives offered for employees' participation	(Bottani et al., 2009; Ismail et al., 2012)
14	Rigorous enforcement of safety regulations	(Ismail et al., 2012; Tam et al., 2001)
15	Availability of site safety manual	(Tam et al., 2001)
16	Innovative technology	(Tam et al., 2001)
17	Project manager with higher safety awareness	(Tam et al., 2001)
18	Top management of the firm with higher safety awareness	(Goh & Chua, 2013)
19	Active participation in OSH activities by employees	(Bottani et al., 2009)
20	Better safety culture	(Goh & Chua, 2013)

2. Research methodology

Based on the literature findings, this study adapted structured interview and questionnaire survey to verify the proposed project characteristics. In the interview, stakeholders of construction sector were invited to participate in the structured interview, namely contractor, client and consultant. Eleven respondents were asked to suggest the key characteristics to distinguish a construction project with 'outstanding' safety performance and a construction project with 'ordinary' safety performance project. A series of interviews were conducted in between 1 May to 30 June 2015. All respondents were registered safety officer and registered safety auditors by profession. They all engaged in sizeable companies with more than 500 employees in a single working day and equipped with at least 8 year working experiences in Hong Kong construction projects. Their viewpoints were expected to supplement the literature findings. Coding the findings from the previous literature and a series of interviews, all project characteristics were categorized by their nature. A list of project characteristics was then verified through the questionnaire survey.

For the questionnaire survey, the respondents were asked to indicate their endorsement of the identified project characteristics based on their previous 12 months working experience in the Hong Kong construction sector. There were two sections in the survey, asking about the background information of respondents in the first section and rating the agreement level of project characteristics in the second section of the questionnaire survey. A five-point Likert rating scale was adopted in the second section of the survey, namely '5' as strongly agree; '4' as agree '3' as neutral; '2' as disagree; and '1' as strongly disagree. I To ensure the representativeness of the collected data, the selection criteria for the experts were strict and covered a wide range of scope in terms of their knowledge, availability and willingness (Ameyaw et al., 2016; Chan, Yung, Lam, Tam, & Cheung, 2001). The target respondents of the questionnaire survey were well-experienced experts with professional recognition in construction sector. There were totally eighteen experts, on behalf of key stakeholders, namely client, contractor and consultant groups. All respondents indicated more than 8 years of working experiences as managerial roles or above in construction projects. They have engaged in diverse nature of construction projects which included building works, civil engineering works and repair and maintenance works. A three-round questionnaire survey was conducted in between September 2015 and April 2016. Experts were showed the mean score of each project characteristic after each round of the questionnaire survey. They could adjust the rating of each project characteristics after each round of the survey. The score of each project characteristic was finalised in the third round due to the mutual agreement of the scores from all participated experts. The final scores of the project characteristics were expected to be the most appropriate and accurate rating (Hallowell & Gambatese, 2009; Yeung, Chan, Chan, & Li, 2007).

Using the software Statistical Product and Service Solutions (SPSS) 24.0, statistical analysis was conducted to analyze the data collected from the questionnaire survey, namely Chi-square test, Kruskal-Wallis test and Kendall's coefficient of concordance. Chi-square was conducted to test consistency of respondents' responses. Kruskal-Wallis test was conducted to check the inter-group responses to see if there are significant differences among respondents from different groups (S. Siegel & Castellan, 1981). Kendall's coefficient of concordance (W) is employed to assess the group agreement of the experts' rankings (S. C. Siegel & Castellan).

3. Results and discussions

The findings of interviews were consistent to literatures' findings. There were seven more project characteristics being identified by experts in the structured interviews. The project characteristics indicating safety performance, that supplemented the literatures, included (1) caring of people, (2) adequate rest time for employees, (3) good housekeeping, (4) good site physical conditions, (5) effective control and review of site activities, (6) better protection to transportation and storage of site materials, and (7) good sense of belonging.

The questionnaire survey incorporating all 27 project characteristics including the above-mentioned seven project characteristics. Table two shows the results of Kruskal-Wallis test and mean ranks among groups of respondents. All project characteristics, C01-C27, indicated the significant values of Kruskal-Wallis test were larger than 0.05. Thus, there was no evidence established to show the differences among sub-groups for the perceptions of project characteristics showing safety performance. With the consideration of mean rank, the overall rankings indicating by the contractor group were relatively lower than those indicating by client and consultant groups. Client group found C12 effective control and review of site activities and C17 clear safety organization with defined responsibilities and accountabilities as the two most agreed project characteristics that indicating outstanding safety performance. C12 was significant important as one of key project success factors, it indicate that there is a potential linkage of successful project management and outstanding safety management (Sawacha, Naoum, & Fong, 1999). C17 is one of the essential elements of safety management system (Labour Department, 2002). It highlighted that the implementation of safety management system was beneficial to the project performance of construction projects (Yiu, Sze & Chan, 2017). Consultant group found C13 well-functioned communication system and C18 incentives offered for employees' participation as the two agreed project characteristics that indicating outstanding safety performance. C13 was one of the key project success factor for project management, thus it implies the importance of effective communication of site matters for assuring project efficiency and safety performance (Sawacha et al., 1999). C18 was highly depends on the contractual incentives initiated by client and incentives spent by contractors. In general, client and contractor with more commitment on OSH would spend more resources on safety (Yiu, Sze & Chan, 2017).

Table 3 also indicates the ranking of experts' agreement of project characteristics that showing the outstanding safety performance. Seeing that there are more than [7] project characteristics in this questionnaire survey, chi-square was also used to test the consistency of respondents' responses. The experts' rankings were consistent for each group and all experts in the questionnaire survey. The most agreed project characteristics were C03 good housekeeping, C05 more support and commitment from senior management, C07 clear understanding of construction work activities, and C09 good planning of project execution. These project characteristics were considered as observed in construction projects with outstanding safety performance. C03 was physical conditions that observed in construction project. Housekeeping was found important in acci-

dent prevention (Labour Department, 2017). C5 indicated that senior commitment and support were important because it facilitate the resources allocation and thus project management. C5 was also considered as critical success factors for implementation of safety management system. C7 was mostly likely related to the competency profiles of the project teams. No matters the role of project team members, understanding of construction sequences could be beneficial to the overall project management. Certainly, project manager was expected to have strong academic background in construction management while safety practitioner was expected to have relevant working experiences in construction sequences. Client ranked C09 as less important

project characteristics when comparing with consultant and contractor groups. This significant difference might be caused by the different roles ambiguity. The on-site project management was mostly replied on the contractor and consultant, so contractor and consultant expressed a higher importance on good project planning and execution.

Table 2: Kruskal-Wallis Test between the Client, Consultant and Contractor Group on Characteristics of Construction Project with 'Outstanding' Safety Performance

No.	Characteristics of construction project with 'outstanding' safety performance	Mean rank			Significance Level*
		Client	Consultant	Contractor	
C01	Caring of people	11.750	8.500	8.286	.385
C02	Adequate rest time for employees	11.417	8.500	8.571	.518
C03	Good housekeeping	9.500	11.000	8.429	.445
C04	Good site physical conditions	8.167	11.300	9.357	.526
C05	More support and commitment from senior management	8.500	11.200	9.143	.592
C06	Better logistic arrangement of site materials	11.000	9.300	8.357	.630
C07	Clear understanding of construction work activities	9.667	10.200	8.857	.868
C08	Lower accident rates	8.500	11.800	8.714	.481
C09	Good planning of project execution	9.167	9.100	10.071	.908
C10	Clear site activities / working sequences	9.583	9.600	9.357	.994
C11	Strong financial performance	11.750	9.200	7.786	.340
C12	Effective control and review of site activities	12.167	8.800	7.714	.216
C13	Well-functioned communication system	9.667	13.400	6.571	.054
C14	Higher education level of workers	9.833	10.000	8.857	.912
C15	Strict operational procedures	9.917	11.600	7.643	.391
C16	Higher teamwork spirits	10.500	10.700	7.786	.474
C17	Clear safety organization with defined responsibilities and accountabilities	13.167	8.100	7.357	.074
C18	Incentives offered for employees' participation	10.250	12.100	7.000	.200
C19	Rigorous enforcement of safety regulations	11.250	10.000	7.643	.429
2C0	Availability of site safety manual	9.333	9.900	9.357	.979
C21	Innovative technology	11.667	9.800	7.429	.324
C22	Project manager with higher safety awareness	10.417	10.600	7.929	.532
C23	Top management of the firm with higher safety awareness	10.417	10.600	7.929	.532
C24	Active participation in OSH activities by employees	9.083	10.500	9.143	.852
C25	Better protection to transportation and storage of site materials	8.917	8.800	10.500	.798
C26	Good sense of belonging	10.833	9.300	8.500	.681
C27	Better safety culture	10.500	9.600	8.571	.743
	*less than 0.05 which indicates significant statistical differences				

Table 3: Ranking of Perceived Benefits of Implementing SMS among Client, Consultant and Contractor Groups

No	Results on Characteristics of construction project with 'outstanding' safety performance	All respond-ents		Client group		Consultant group		Contractor group	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
C03	Good housekeeping	4.83	1	4.83	1	5	1	4.71	1
C05	More support and commitment from senior management	4.61	2	4.50	5	4.8	2	4.57	3
C09	Good planning of project execution	4.61	2	4.50	5	4.6	5	4.71	1
C07	Clear understanding of construction work activities	4.61	2	4.67	3	4.6	5	4.57	3
C04	Good site physical conditions	4.56	5	4.33	13	4.8	2	4.57	3
C10	Clear site activities / working sequences	4.56	5	4.50	5	4.6	5	4.57	3
C22	Project manager with higher safety awareness	4.44	7	4.50	5	4.6	5	4.29	7
C23	Top management of the firm with higher safety awareness	4.44	7	4.50	5	4.6	5	4.29	7
C27	Better safety culture	4.39	9	4.50	5	4.4	10	4.29	7
C17	Clear safety organization with defined responsibilities and accountabilities	4.33	10	4.83	1	4.2	13	4.00	11
C12	Effective control and review of site activities	4.33	10	4.67	3	4.2	13	4.14	10
C13	Well-functioned communication system	4.28	12	4.33	13	4.8	2	3.86	17

Table 3: Ranking of Perceived Benefits of Implementing SMS among Client, Consultant and Contractor Groups (Continued)

No	Results on Characteristics of construction project with 'outstanding' safety performance	All respond-ents		Client group		Consultant group		Contractor group	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
C16	Higher teamwork spirits	4.22	13	4.33	13	4.4	10	4.00	11
C06	Better logistic arrangement of site materials	4.22	13	4.50	5	4.2	13	4.00	11
C01	Caring of people	4.06	15	4.50	5	3.6	22	4.00	11
C24	Active participation in OSH activities by employees	4.06	15	4.00	20	4.2	13	4.00	11
C18	Incentives offered for employees' participation	3.94	17	4.00	20	4.4	10	3.57	20
C19	Rigorous enforcement of safety regulations	3.89	18	4.17	16	4	18	3.57	20
C26	Good sense of belonging	3.89	18	4.17	16	3.8	19	3.71	18
C11	Strong financial performance	3.83	20	4.17	16	3.8	19	3.57	20
C15	Strict operational procedures	3.83	20	3.83	23	4.2	13	3.57	20
C02	Adequate rest time for employees	3.78	22	4.17	16	3.4	26	3.71	18
C25	Better protection to transportation and storage of site materials	3.72	23	3.50	24	3.6	22	4.00	11
C08	Lower accident rates	3.61	24	3.50	24	3.8	19	3.57	20
C21	Innovative technology	3.56	25	4.00	20	3.6	22	3.14	27
C14	Higher education level of workers	3.44	26	3.50	24	3.6	22	3.29	25
C20	Availability of site safety manual	3.28	27	3.17	27	3.4	26	3.29	25
	Number of samples (N)	18		6		5		7	
	Kendall's coefficient of concordance (W)	0.295		0.256		0.389		0.412	
	Chi-Square	138.143		40.008		50.593		75.044	
	Degrees of freedom (df)	26		26		26		26	
	Level of significance (p)	<0.001		0.039		0.003		<0.001	

4. Conclusions

Construction safety is considered to important practically in project management. This study was established a potential linkage between the project characteristics and safety performance of construction projects from the viewpoints of well-experienced construction practitioners. There were 11 experts and 18 experts participated in the structured interview and questionnaire survey respectively. In addition to the 20 project characteristics found in the previous literatures, there were seven more project characteristics being supplemented by the experts during interviews. The identified project characteristics were then verified by the experts through the questionnaire survey in three rounds. The most agreed project characteristics were C03 good housekeeping, C05 more support and commitment from senior management, C07 clear understanding of construction work activities, and C09 good planning of project execution. These project characteristics were considered as observed in construction projects with outstanding safety performance. The results indicated that the close relationship between the project management and safety performance of construction projects. The implementation of site safety management practices could also facilitate the performance of project efficiency in a long run.

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