Managing Construction Safety Using Conceptual Skill

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Abstract

Despite its economic and social significance, the construction industry is notorious for being unsafe in its on-site practices. Recent research indicates the necessity to focus on the human aspects of safety to improve construction safety performance. The aim of the research is to investigate the role of project personnel's conceptual skill as an important human factor in managing construction safety. A conceptual skill questionnaire was developed to achieve the research aim. Data were collected through an online survey from three large construction organisations headquartered in Australia. In total, 273 valid responses were received and analysed using the structural equation modelling method. The results show that the project personnel's conceptual skill construct consists of visioning, and scoping and integration components. The results further show that conceptual skill influences the implementation of safety management tasks, which promotes the development of an appropriate safety climate. The outcome of this research suggests that construction project personnel, in developing their conceptual skill, should first improve the visioning component and follow this up with the scoping and integration component. The implication of this research is that construction organisations should recognise the role of conceptual skill in the management of construction safety, provide training for project personnel to improve their conceptual skills, and include safety management tasks as part of their project personnel's responsibilities.

Keywords

Conceptual skill, construction safety, project personnel, safety climate, safety management tasks.

INTRODUCTION

Current statistical trends imply that safety performance improvement in the construction industry has stalled in recent years and recent research have indicated that human side of safety is a key to further improve this performance (Glendon *et al*., 2006; Reason, 2000). In fact some research has been conducted on the area of human side of safety, such as attitudes, behaviour, motivation, teamwork, leadership, and safety culture (Cooper and Phillips, 2004; Glendon and Litherland, 2001; Lingard and Rowlinson, 2005). However, there is lack of research that investigates the role of project personnel's skills, particularly conceptual skill, in construction safety management. Katz (1974) was the first person who suggested the importance of conceptual skill in organisation management. He defined conceptual skill as "the ability to see the enterprise as a whole" (p.93). In the context of construction project management, conceptual skill is crucial for viewing a project from a big picture perspective, understand the dynamic relationships among different project components, and envision how the project affects its surrounding environment (Chung and Megginson, 1981; El-Sabaa, 2001; Goodwin, 1993). Due to the

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diversity of construction project system, project personnel need conceptual skill to ensure that all project aspects function together as an integrated whole (Goodwin, 1993). For example, when there are changes in certain project aspect, they should consider the impacts of those changes on progress, control strategies, budget, schedule, and stakeholders involved (Katz, 1974).

A safety management task is a definable activity, action, or process that project personnel need to perform to provide safety leadership. According to Dingsdag *et al.* (2006), there are 39 safety management tasks that project personnel should perform. The implementation of safety management tasks will lead to the development of safety climate, which can be defined as "shared employee perceptions of how safety management is being operationalised in the workplace at a particular moment in time" (Cooper and Phillips, 2004, p. 497). Nowadays, safety climate has become an indicator of safety performance over conventional measures, such as accident and incident rates, because of its advantages (Davies *et al*., 2001; Glendon and Litherland, 2001; Seo *et al*., 2004).

Given the above, the main aim of this research is to investigate and discuss the role of conceptual skill, which is considered as one of essential skills in construction management (El-Sabaa, 2001; Goodwin, 1993; Sunindijo and Zou, 2009, 2011), in implementing safety management tasks and developing safety climate in the construction project environment. In other words, conceptual skill is a "tool" for project personnel to manage construction safety and promote safety performance improvement. This research was built upon a study undertaken by Sunindijo and Zou (2009, 2011).

RESEARCH HYPOTHESES AND METHODS

Empirical data were needed to confirm the relationships between conceptual skill (comprising visioning and scoping and integration dimensions), the level of implementation of safety management tasks, and safety climate development as illustrated in the research model (Figure 1). The hypotheses that can be drawn from the research model are:

Hypothesis 1: The higher the conceptual skill level, the higher the level of implementation of safety management tasks.

Hypothesis 2: The higher the level of implementation of safety management tasks, the higher the level of the safety climate.

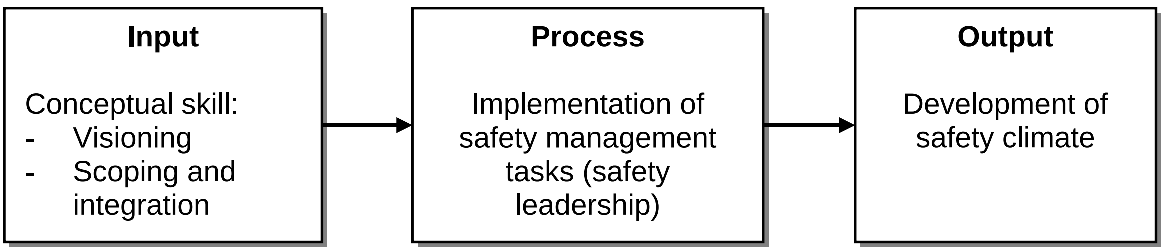

Figure 1. The research model/hypothesis (after Sunindijo and Zou, 2009)

In order to test the research model shown in Figure 1, a large sample of quantitative data was required. Questionnaire survey is the most appropriate data collection method to achieve this purpose. According to the best knowledge of the researchers of this paper, there was no conceptual skill measurement instrument available in the construction management literature. Therefore, a reliable and valid instrument to measure conceptual skill had to be developed first. Based on the review of relevant literature in general management and the nature of construction project management, fourteen items have been identified to represent conceptual skill as follows:

1. I am accurate in preparing the overall/master schedule for the whole project.
2. I am known for my accuracy in estimating initial overall project cost including project profit plan.
3. It is easy for me to develop an overall construction plan/strategy, such as site layout, environmental issues, safety issues, and community issues.
4. I understand the relationships and impacts between one work package and other packages.
5. I am familiar about contractual agreements and their risks imposed to the project.
6. I am able to make decisions from a system wide perspective (understand the impacts of the decisions towards the project).
7. It is difficult to define project scope and objectives.
8. I am good at organising people (such as defining roles and responsibilities, determining who reports to whom and at what level decisions should be made).
9. I understand how to prioritise or making trade-offs among competing objectives and alternatives.
10. I evaluate team performance against standards and goals.
11. I understand how to take corrective actions to improve team performance when necessary.
12. Ambiguous and uncertain situations frustrate me.
13. I am able to develop creative and innovative solutions to problems.
14. I understand the impacts of government regulations to the project.

The questionnaire for measuring the level of implementation of safety management tasks was developed based on the 39 safety management tasks identified by Dingsdag et al. (2006). The questionnaire for measuring safety climate was developed based on previous studies (Zohar, 1980; Dedobbeleer and Béland, 1991; Cox and Cheyne, 2000; Glendon and Litherland, 2001; Mohamed, 2002; Lin *et al.*, 2008). The safety climate questionnaire was finalised consisting of 20 items. All three sets of questionnaires were self-assessed and used a five-point Likert scale response format.

DATA COLLECTION AND ANALYSIS

The questionnaires were distributed to three major construction organisations in Australia through an online survey. Project personnel who were working in construction projects at the time of the survey were invited to participate. In total, 356 respondents participated in which 273 responses were valid and are useful for further analysis. Various types of project personnel have participated in answering the questionnaires, ranging from safety personnel, site supervisors, engineers, site managers, project managers, and construction managers. Most of the respondents have extensive experience in the construction industry with an average experience of more than 18 years.

In the conceptual skill questionnaire development, only those items that provide the best representation of the construct (i.e. conceptual skill) should be retained. Item analysis was performed to evaluate the 14 items identified initially and to retain only those with the highest item-to-total correlations, i.e., item-to-total correlations of 0.40 or greater. As a result, items 7, 12, and 14 were excluded. Next, the remaining items were evaluated further to identify items that could not load to any factors or generating loading that does not exceed 0.4 (Lin *et al*., 2008). Factor analysis with a principal components method and varimax rotation was carried out for this purpose (Nunnally and Bernstein, 1994). The result showed that all 11 remaining items should be retained. In order to determine the factor structure of the 11-item conceptual skill questionnaire, factor analysis with principal axis method and varimax rotation was performed. The result showed that items 3 and 13 could not load to any factor, and therefore were eliminated. The factor analysis was repeated to determine the factor structure of the nine-item conceptual skill questionnaire. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.810 and Bartlett's test of sphericity is significant (p<0.01) indicating that factor analysis is suitable for analysing the data. Based on the results of the factor analysis (Table 1), two components of conceptual skill were extracted and they are accounted for 57.56 percent of the variance. The visioning component consists of four items and explains 41.04 percent of the variance. The scoping and integration component consists of five items and explains 16.52 percent of the variance. The coefficient alpha reliability estimates for the nine-item questionnaire is 0.816 whilst the coefficients of two components are 0.792 and 0.770 respectively. All coefficients are at acceptable levels.

Table 1. Factor analysis results showing two components of conceptual skill

No	Item	Visioning	Scoping and integration
1	I am accurate in preparing the overall/master schedule for the whole project.	.086	***.652***
2	I am known for my accuracy in estimating initial overall project cost including project profit plan.	.056	***.678***
3	I understand the relationships or impacts between one work package and other packages.	.258	***.591***
4	I am familiar about contractual agreements and their risks imposed to the project.	.328	***.581***
5	I am able to make decisions from a system wide perspective (understand the impacts of the decisions towards the project).	.368	***.506***
6	I am good at organising people (such as defining roles and responsibilities, determining who reports to whom and at what level decisions should be made).	***.689***	.183
7	I understand how to prioritise or making trade-offs among competing objectives and alternatives.	***.651***	.239
8	I evaluate team performance against standards and goals.	***.735***	.101
9	I understand how to take corrective actions to improve team performance when necessary.	***.622***	.181
	Eigenvalue	3.693	1.487
	% of variance explained	41.04	16.52
	Cumulative % of variance explained	41.04	57.56
	Coefficient alpha reliability estimates	.792	.770
	Coefficient alpha for the 9-item questionnaire	.816	

The hypotheses were tested using structural equation modelling (SEM), which is a statistical methodology that takes a hypothesis-testing approach to the analysis of a structural theory bearing on some phenomenon (Byrne, 2010). This method allows a simultaneous examination of relationships among independent and dependent variables or constructs within a theoretical model (Mohamed, 2002). The SEM software package of this research was AMOS 18 (analysis of moment structures version 18).

After some model modifications whilst maintaining the theoretical background and research model as shown in Figure 1, the best fit model is illustrated in Figure 2. The probability value of the chi-square test is higher than 0.05 (p=0.875) indicating that the model fits the data. The numbers on the arrows are the path coefficients or the unstandardised regression coefficients, which represent the amount of change in the dependent variables per single unit change in the predictor variables (University of

Texas, 2002). All path coefficients are statistically significant providing strong support for the hypothesised model. In addition, a Pearson's correlation analysis was conducted to reveal the relationships between the nine conceptual skill items and the average score of safety management tasks and construction safety climate to gain a deeper insight on the model. The result of this analysis is presented in Table 2.

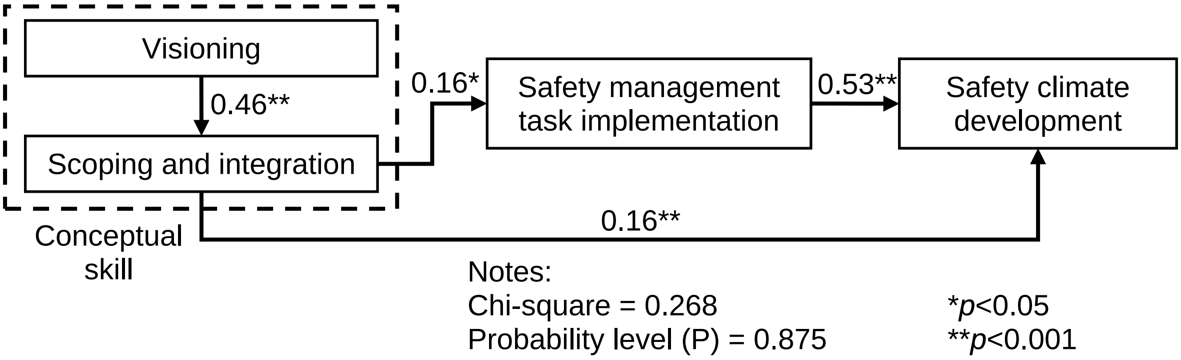

Figure 2. The results of the SEM analysis

DISCUSSION OF RESULTS

The model derived from the SEM analysis (Figure 2) supports Hypotheses 1 and 2. The model indicates that the visioning component is a predictor of the scoping and integration component. Then the scoping and integration component positively influences the implementation of safety management tasks. Finally, both scoping and integration, and safety management task implementation are predictors of safety climate development. The relationships among various aspects of the model with supports from previous literature and the correlation analysis presented in Table 2 are discussed in this section.

Table 2. Correlations between the three research variables

Component	Item	Correlation	Safety mgt tasks	Safety climate
Scoping and integration	I am accurate in preparing the overall/master schedule for the whole project.	Pearson Sig.	.165** .006	.217** .000
	I am known for my accuracy in estimating initial overall project cost including project profit plan.	Pearson Sig.	.119* .050	.173** .004
	I understand the relationships or impacts between one work package and other packages.	Pearson Sig.	.068 .262	.182** .003
	I am familiar about contractual agreements and their risks imposed to the project.	Pearson Sig.	.070 .251	.209** .001
	I am able to make decisions from a system wide perspective (understand the impacts of the decisions towards the project).	Pearson Sig.	.079 .194	.165** .006
Visioning	I am good at organising people (such as defining roles and responsibilities, determining who reports to whom and at what level decisions should be made).	Pearson Sig.	.137* .023	.124* .041
	I understand how to prioritise or making trade-offs among competing objectives and alternatives.	Pearson Sig.	.057 .352	.059 .330
	I evaluate team performance against standards and goals.	Pearson Sig.	.029 .629	.029 .637
	I understand how to take corrective actions to improve team performance when necessary.	Pearson Sig.	.031 .609	.153* .011

** significant at 0.01
* significant at 0.05

VISIONING AS AN INITIATOR

The visioning component of conceptual skill is an initiator of the whole relationships. In a construction project, the project team members must coordinate and work together to achieve project objectives. There must be a common vision which serves as guideline whilst clear expectations of the work need to be determined (Ellis, 2005). One of the items of the visioning component is *prioritising* among competing objectives and alternatives. When a construction project starts, project personnel must be able to discern major priorities in the project and remain focused on these priorities in decision making. They need to be aware of how certain decisions can affect other objectives and recognise problems that may arise during the implementation of these decisions. This understanding is a key to identify and evaluate a set of viable alternatives, thus project personnel can select the best alternative for the project (Chung and Megginson, 1981).

The second item of the visioning component is *organising*, which involves determining people's roles and responsibilities as well as setting project goals that have to be achieved. In organising, job characteristics should be matched with the level of willingness and readiness of people to generate an optimal level of work motivation and develop an effective workforce (Chung and Megginson, 1981; Samson and Daft, 2009). *Performance evaluation* is the third item. Throughout the project stages, the performance of the project team should be evaluated regularly to ensure that it still aligns with the vision of the project and the achievement of project objectives. This is known as a management-by-objectives (MBO) approach where performance is reviewed based on accomplishment of objectives critical to successful job performance. MBO is suitable for construction projects where the orientation is always on end results, such as time, cost, quality, safety, and sustainability (Dwyer and Hopwood, 2010). When necessary, *corrective actions* must be done accordingly to guide the performance back on track, which is concerned with the fourth and last item of the visioning component.

VISIONING AS A PREDICTOR OF SCOPING AND INTEGRATION

The visioning component is a predictor of the scoping and integration component, which consists of five items. When a clear vision and a set of objectives have been determined, project personnel have a foundation to develop a realistic schedule to achieve those objectives and complete the project within the required time frame (first item). Furthermore, they will be able to estimate the overall project cost and calculate potential profit for the organisation when it decides to undertake the project (second item). Project personnel should also be aware of other requirements stated in the contractual agreements and include them in their construction and risk management plans (third item). This is an important process in construction projects to managing risks proactively and preparing responses for those risks.

The next two items are closely related. First, project personnel should realise various work packages in a construction project and how they actually relate to one another (fourth item). A change in one work package may bring significant impacts on other work packages. For example, the foundation work of a building must be completed before the upper-structure work can be commenced. Second, when project personnel have a clear understanding of these relationships, they can make decisions from a system wide perspective (fifth item). They would consider the relationships between work packages, the requirements stated in the contracts, the expectations of project stakeholders, and other aspects that may influence project success, before they make those decisions.

SCOPING AND INTEGRATION COMPONENT INFLUENCES THE IMPLEMENTATION OF SAFETY MANAGEMENT TASKS

The next relationship is between the scoping and integration component and the level of implementation of safety management tasks. Safety management tasks are what project personnel need to perform to provide safety leadership or lead safety implementation. In total, there are 39 safety management tasks and each person, depending on his or her position, has its unique list of tasks (Dingsdag *et al*., 2006). As presented in Table 2, two items of scoping and integration are significantly correlated with safety management tasks. This indicates that safety management tasks have to be considered by project personnel in their plans, particularly when they develop project schedule and budget. This can be considered as a proactive approach in managing safety to ensure that safety is integrated as part of key project objectives.

When project personnel prepare project schedules, safety management must become an integral part of the organisation's procedures (Wang *et al*., 2006). For example, the schedule must take into account the necessary time to conduct safety training, safety inductions, and safety meetings. Safety risks can also be attached to each activity in the project schedule, thus the right resources can be allocated, safety constraints can be considered and alleviated in advance, and safety control can be improved (Wang *et al*., 2006). Likewise, project budget must include necessary safety investments, such as personal protective equipment, safety training, and other safety measures, to support the implementation of safety management tasks. These investments may appear to be expensive, but studies have confirmed that effective safety management system is profitable for construction organisations (Zou *et al.*, 2010). Lastly, Table 2 shows that there is a significant correlation between the organising item of the visioning component and safety management tasks. This is logical because project personnel need to include safety management tasks when they are defining roles and responsibilities of others. For themselves, they also need to be aware that performing certain safety management tasks is actually part of their responsibilities.

CONCEPTUAL SKILL FOR SAFETY CLIMATE DEVELOPMENT

The implementation of safety management tasks influences the development of safety climate. This relationship is straightforward and has been anticipated as stated in Hypothesis 2. When project personnel perform the required safety management tasks, they provide safety leadership in their projects, thus positively influencing the attitudes and perceptions of others towards safety. These attitudes and perceptions shape safety climate in construction projects.

An interesting relationship is present between the scoping and integration component and safety climate. By looking at the correlation table (Table 2), all items of the scoping and integration component are significantly correlated with safety climate. When project personnel include safety issues in the development of project schedule and budget as well as incorporating safety requirements in contract agreements (or part of tender requirements), other stakeholders will realise that safety is an important aspect in the project, thus positive attitudes and perceptions towards safety will be developed. Understanding the relationships between work packages is closely related with the last item in the visioning component, i.e., making decision from a system wide perspective. When project personnel consider safety as equally important as the other aspects in decision making, it will encourage others to have the same attitudes and perceptions towards safety.

Finally, the two items from the visioning component, which are organising people and taking corrective actions, have significant correlations with safety climate. When safety becomes part of project personnel's responsibilities, this will automatically create positive attitudes and perceptions towards safety. The same applies when project personnel also include safety as part of the responsibilities of others. Furthermore, when there are safety issues or problems in the project and project personnel take immediate actions to remedy the situations, then the others will see the safety commitment and as such construction safety climate will be developed.

CONCLUSION

Project personnel's conceptual skill is considered as an important skill in construction management. The findings of this present research provide empirical evidence that conceptual skill influences the implementation of safety management tasks, which consequently promotes the development of safety climate. This research also developed an instrument in the form of a questionnaire to measure the conceptual skill of construction project personnel, which has not been done in previous research. The nine-item conceptual skill questionnaire was finalised in which psychometric tests showed that the questionnaire is reliable and valid. One finding from the factor analysis suggests that there are two components of conceptual skill, namely visioning, and scoping and integration.

Another finding of this research provides an understanding on the approach for project personnel to improve their conceptual skill in relation to construction safety management. Project personnel should start by improving their visioning component, which includes prioritising, setting visions and goals, organising people by communicating clear expectations, and managing performance using an MBO (management by objective) approach. After focusing on the visioning component, project personnel should progress by improving their scoping and integration component. This can be achieved by considering various project aspects which may influence the development of project schedule and budget; learning various contractual agreements and their impacts on the projects; understanding the stages, processes, and activities in construction projects from initiation to completion; and improving decision making based on a project system perspective. Project personnel can contribute to safety climate development by improving their conceptual skill as long as they include safety as one of the important aspects when performing their roles. This attitude towards safety will improve the implementation of safety management tasks and promote the development of safety climate.

The implication of the research outcomes is that construction organisations should consider improving the conceptual skill of their project personnel. Further, construction organisations also need to recognise that safety management tasks should become part of the responsibilities of project personnel in performing their job. Through this strategy, it is expected that safety climate will be developed which will lead to safety performance improvement.

The authors of this paper noted that past research has not focused much on the issue of developing project personnel's conceptual skill. This is an interesting research topic that should be considered in future research. In addition, the conceptual skill questionnaire developed in this research could be used to explore the impacts of conceptual skill on other project objectives, such as time, cost, quality, and sustainability.

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