Modeling Effect of Group Norms and Social Identities on Construction Workers' Safety behavior

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1. Introduction

Because vast majority of construction accidents are caused by workers' unsafe behavior, more attentions have focused on determinants of workers' safety behavior (Waehrer *et al.* 2007, Meliá *et al.* 2008, Sacks *et al.* 2009). Recently, a number of researchers have testified that social factors such as group norms play a critical role of in workers' safety behavior (Glendon and Litherland 2001, Zhang and Fang 2013, Goh and Binte Sa'adon 2014). Therefore, safety management policies overlooking social aspect may not produce the effect as much as intended, or may cause an adverse effect on workers' safety behavior. Despite the importance of social aspects in workers' safety behavior, research on the mechanisms underlying the link between social influence and safety behavior is scare. In addition, the characteristics of construction workforce such as complex organizational hierarchy have presented significant hurdles in studying the effect of social influence on workers' safety behavior.

To address these issues, this project aim to study the system level effect of social influence on workers' safety behavior using experimental analysis with agent based model simulations (ABMS) in order to extend the knowledge of the social aspect in workers' safety behavior. To understand social aspect of workers' safety behavior, a causal process model of individuals' safety behavior taking which represents social influence mechanism regarding safety behavior was developed. Then, an experimental analysis was performed to identify the effect of various safety management policies on worker' safety behaviors by running simulations with agent based model. The questions that were addressed through this study are followed: (1) what is the mechanism of social influence in worker' safety behaviors? (2) How can social influence of construction workers' safety behavior be used to reduce workers' unsafe behaviors (i.e., strictness of safety rule, frequency of managers' feedback, and stimulation of project based identity)?

2. Method

In this study, Ajzen (1991)'s theory of planned behavior (TPB) is applied as a theoretical background. TPB has been widely applied in many areas such as traffic safety, health interventions, adolescent behavior, food safety, and information security to explain indiviaudals' intentional behaviors (Goh and Binte Sa'adon 2014). Since construction workers unsafe behavior such as violation of safety rule is also one of intentional behaviors, the theory of planned behavior will be useful to explain workers' safety behavior. The TPB stipulates that an individual's behavior is direct function of behavioral intention and perceived behavioral control. In addition, behavior intention is determined by attitude, subjective norm and perceived behavioral control. According to TPB, attitudes refer to evaluation of a behavior, which could be favorable or unfavorable. Subjective norms describe the individuals' perceived pressure from significant others to perform a specific behavior. Perceived behavioral control is a reflection of an individual's perception of his/her ability to perform a stipulated behavior. Although the theory of planned behavior is widely applied to explain individual's intentional behavior in many arears, there are several limitations to directly apply theory of planed behavior to construction workers' safety behavior.

First of all, theory of planned behavior does not consider different source of social influence. The TPB views subjective norms as a unitary construction. However, construction workers' safety behaviors are influence not only by workgroup norm but also management norm. Construction workers perceive an acceptable level of unsafe behavior by observing manager's feedback on their particular unsafe behavior. For example, if managers ignore a specific unsafe behavior, the behavior is retained as acceptable behavior. Therefore, we need to consider manager's influence on workers' safety behavior. In addition, although the TPB model and related empirical results have shed some light on the extent that workers' group norms, attitudes, and actual safety behavior are associated, the mechanisms for their interactions are still unclear.

Social Identity Theory (SIT) provides a plausible explanation for explanation for how people form/change their behavior in social contexts. According to SIT, the effects of subjective norms depend on whether or not the person identifies him/herself with the target group (Terry *et*

al. 1999). In other words, social norms should have a significant impact on individuals' intentions, particularly for those who identify strongly with the group (Ashforth and Mael 1989, Terry and Hogg 1996, Hogg and Terry 2000, Hornsey 2008). In addition, previous research empirically supports the claim that ingroup norms are usually a more powerful determinant of behavior than out-group norms (Smith and Louis 2009). Therefore, the effect of social norm need to be taken into account and workers' level of social identification with the group can be an important moderating factor of influence of different group norms.

Based on discussion so far, this study developed a conceptual framework as shown in figure 1. In this model, workers' safety behavior is a direct function of behavioral intention and perceived behavioral control as discussed in the TPB. Behavioral intention is determined by attitude, perceived behavioral control, and social pressure. Social pressure in this model is divided into workgroup norm and project norm to reflect different sources of social influence of workers' safety behavior. In this framework, observation of crew members' safety behavior is the source for perceiving workgroup norm. In addition, observation of managers' feedback and safety behavior of workers in other crew is the source of perceiving project norm. Finally, two types of social identity such as crew based identity and project based identity were adopted to consider moderating effect of social influence in this model.

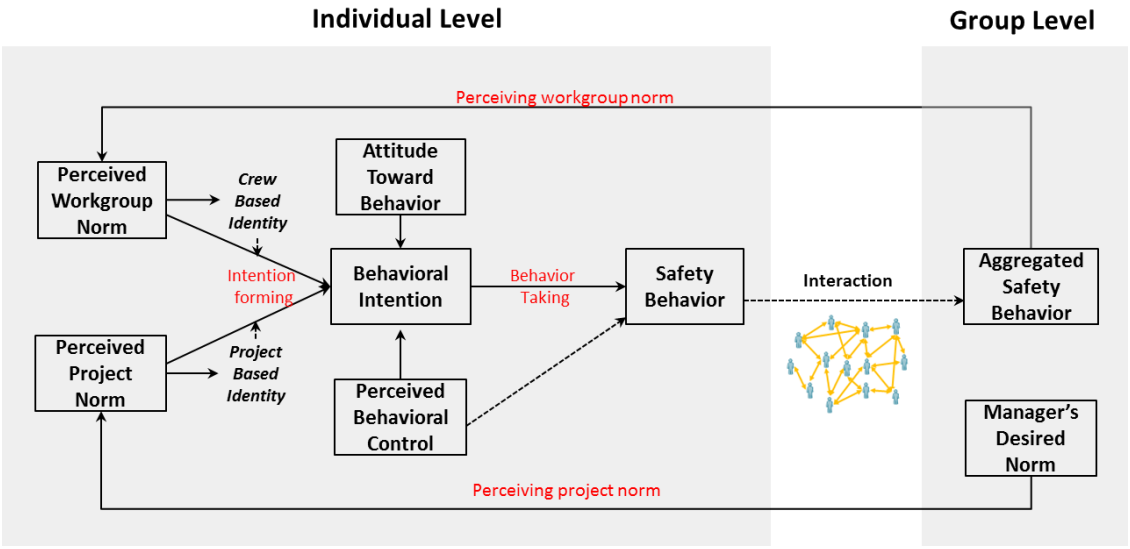


Figure 1. Conceptual Framework

These behavioral rules for the agents are formalized as mathematical equation for use in the agent based model as follows;

$$B_i^{(t)} = w_i^i I_i^{(t)} + (1 - w_i^i)\, C_i^{(t)} \tag{1}$$

$$I_i^{(t)} = (w_i^a A_i^{(t)} + (1 - w_i^a) C_i^{(t)})(1 - \sum_{j=1} n_i s_{ij}^{(t)}) + \sum_{j=1} (n_i s_{ij}^{(t)} G_{ij}^{(t)}) \tag{2}$$

$$G_{ij}^{(t+1)} = (1 - \frac{k_{ij}^{(t+1)}}{m_i})\, G_{ij}^{(t)} + \frac{k_{ij}^{(t+1)}}{m_i} (\frac{1}{k_{ij}^{(t+1)}} \sum_{k=1}^{k_i^{(t+1)}} B_k^{(t+1)}) \tag{3}$$

Equation (1) – (3) are translation of behavior taking, behavioral intention forming and perceiving social norm in the conceptual framework. The behavior taking step is embedded in equation (1), where *t* is time (e.g., day); $B_i^{(t)}$ is worker *i*'s safety behavior at time *t* (0–1); $I_i^{(t)}$ is worker *i*'s behavioral intention at time *t* (0–1); $C_i^{(t)}$ is worker *i*'s perceived behavioral control at time *t* (0–1); w_i^i weighting factors for behavioral intention (0–1). Equation (2) represents formation of behavioral intention based on attitude, perceived behavioral control, workgroup norm, and project norm; $A_i^{(t)}$ is worker *i*'s attitude at time *t*; $G_{ij}^{(t)}$ is group *j*'s safety norm perceived by worker *i* at time *t*; w_i^a is weighting factors for attitude; $s_{ij}^{(t)}$ is the salience of the group *j* in worker *i*'s mind at time *t*; n_i is worker *i*'s level of norm compliance. Operationally, $\sum_{j=1} n_i s_{ij}^{(t)}$ does not exceed 1. Finally, norm perceiving process is embedded in equation (3); where m_i is worker *i*'s memory capacity; $k_{ij}^{(t)}$ is the number of workers in group *j* observed by worker *i* at time *t*.

The salience of a particular social identity is determined by interaction between the relative accessibility and fit (Turner *et al.* 1987, Oakes *et al.* 1991, Blanz 1999). According to social identity theories, accessibility refers to relative readiness of a perceiver to accept or retrieve a particular self-category to his/her mind. Therefore, the identities that are more familiar or carry emotional valence are more accessible (Kopecky *et al.* 2010, Dimas and Prada 2014). This study applied Dimas and Prada (2014)'s equation for the accessibilty as shown in equation (4) and (5).

$$a_{ij}^{(t)} = a_{ij}^{(t-1)} + s_{ij}^{(t-1)}(e_{ij}^{(t)} - e_{ij}^{(t-1)}) \quad (4)$$

$$e_{ij}^{(t)} = 1 - \left| A_i^{(t)} - G_{ij}^{(t)} \right| \quad (5)$$

where $a_{ij}^{(t)}$ is accessibility of group *j* in worker *i*'s mind at time *t*; $e_{ij}^{(t)}$ is emotional valence of group *j* in worker *i*'s mind at time *t*.

In addition, fit reflects to the extent to which a particular context activates particular identities (Kopecky et al. 2010). The fit of a particular identity is determined by similarity within categories and difference between categories (Hogg and Terry 2000, Hogg and Reid 2006). In this model, weighted average of similarity within group and difference between groups is used for fit as shown in equation (6). α is weighting value for similarity within group and since this study want to more weight to ingroup similarity, this study default to .8.

$$f_{ij}^{(t)} = \alpha \left\{ 1 - \sqrt{\sum_{i=1}^{n_i} \left(\overline{x_i^{(t)}} - x_i^{(t)} \right)^2 \Big/ n_i} \right\} + (1-\alpha) \sqrt{\sum_{i=1}^{n_i} \left(\overline{x_o^{(t)}} - x_i^{(t)} \right)^2 \Big/ n_i} \quad (6)$$

where $f_{ij}^{(t)}$ is fit of a particular group *j* in worker *i*'s mind at time *t*; $\overline{x_i^{(t)}}$ is average behavior of ingroup at time *t*; $\overline{x_o^{(t)}}$ is average behavior of outgroup at time *t*; $x_i^{(t)}$ is ingroup member worker *i*'s behavior at time *t*; n_i is number of workers in ingroup *i*.

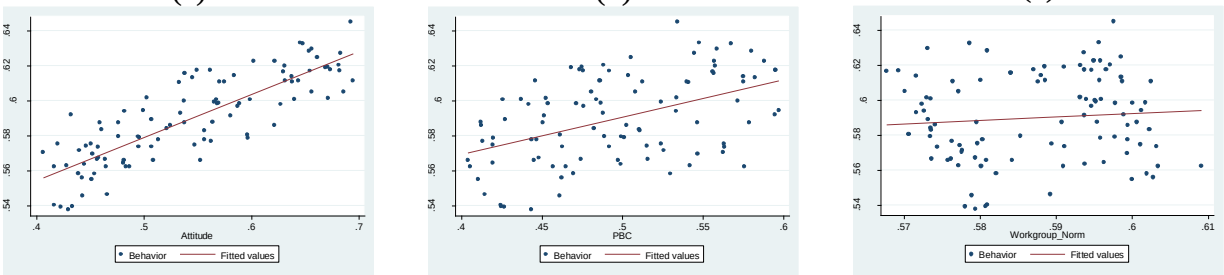
4. Result

Before performing model experiments to answer the research questions raised in this study, a qualitative agreement between the result of the model and empirical findings of the previous literature was tested in order to confirm the validity of the model. In this model, construction project with 10 crews, each of which has 10 workers, is simulated. In the model, space is a two dimensional rectangular grid, and the space is divided into 10 clusters which means a space for a specific crew. Mangers in the model do not have any spatial restriction about their location and their safety behavior level is consist with strictness of safety rule in the model. Therefore, observing managers' safety behavior describes manger's feedback at the construction project. In addition, the number of managers in the model represents frequency of managers'

feedback rather than actual number of manger in the project. The strictness of safety rule is set as .85 and the number of manager is set as 20 for the simulation run. Every worker is distributed to their crew's cluster and then observes their neighbors' behaviors. The observed behaviors are stored in the memory and each worker in the simulation can remember 50 cases of their neighbors' behavior. Among the stored behaviors, their crew members' behaviors are the source of perceived workgroup norm and mangers' behaviors and other crew members' behaviors are source of perceived project norm. After then, the workers determine the level of social identification with crew and project based on fit and accessibility of each group. In the beginning of simulation run, workers are initialized with an attitude that is randomly assigned based on uniform distribution from .4 to .7, and with a perceived behavioral control from .4 to .6. Finally, the value of weight to attitude and weight to intention is determined as .7 and .85 based on the regression coefficient of attitude and intention in Zhang and Fang (2013)'s structural equation model.

To test a qualitative agreement, scatter plots of the result of simulation are represented in figure 2. Figure (a) – (d) represent the relationship between safety behavior and attitude (figure (a)), perceived behavioral control (figure (b)), workgroup norm (figure (c)), and project norm (d)). Figure (e) and (f) demonstrates the relationship between safety behavior and workgroup norm x crew identity (figure (e)) and project norm x project identity (figure (f)). As shown in the figure (a) – (d), the simulation results of the model reaffirm the empirical findings from a number of previous TPB studies that attitude, social norm, and perceived behavior control are associated with individuals' behavior. In addition, figure (e) and (f) represent stronger relations than figure (c) and (d), the simulation model in this study effectively reproduces moderating effects of social identities on group norms influence as described in social identity literature.

(a) (b) (c)



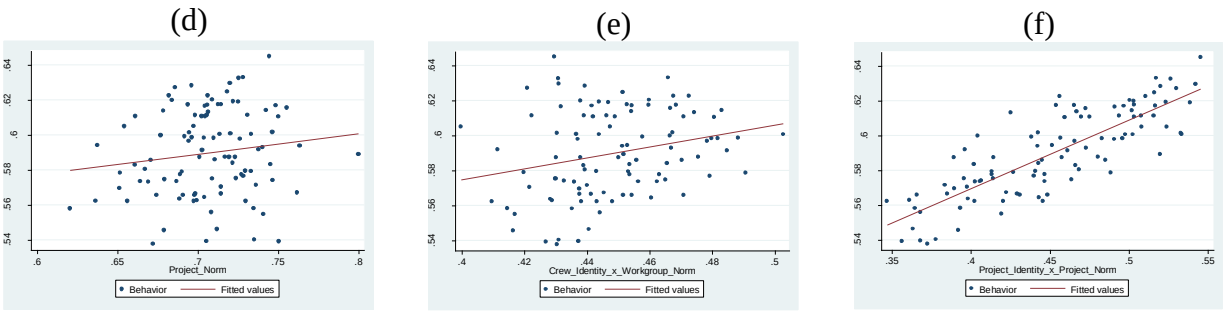


Figure 2. Scatters Plot for the Simulation Result

Then, in order to address the research questions that were raised, the impact of principal parameters (i.e., strictness of safety rule, frequency of managers' feedback, and simulation of project based identity) on the dynamics of organizational safety behavior level were explored. Those parameters refer to diverse managerial actions for improving workers' safety behavior at construction site. For example, strict safety rules are able to increase the level of project safety norm and it can improve workers' safety behavior. In the case of frequency of managers' feedback, frequent managers' feedback can make project norm be more aligned with safety rule because project norm is determined by managers' feedback and observation of workers who belong to other crew. Finally, stimulation of project based identity can lead workers' behavioral intention be more aligned with project norm since social identity moderate the effect of social norms on workers' behavioral intention. However, there are also adverse effects of these managerial actions on workers safety behavior. For example, if safety rule is too strict, social identity of workers with project decreases due to lower value of emotional valence. To address these dynamics, this study performed a model experiment sweeping the strictness of safety rule, frequency of managers' feedback, and simulation of project based identity. Since too low value of strictness of safety rule does not make sense in reality, the range of strictness of safety rule was from .5 to 1.0 in the experiment.

Figure 3 – 5 illustrate the result of model experiment. Figure 3 represents the result of parameter sweep between the strictness of safety rule and frequency of managers' feedback. The x axis in Figure 3 is strictness of safety rule and y axis is frequency of managers' feedback. The colors at each point represent an average level of workers' safety behaviors in each condition. As shown in Figure 3, strict safety rule has positive effect on construction workers' safety

behavior. However, as the safety rule becomes strict, the effect of safety rule on workers' safety behavior is reduced. For the frequency of managers' feedback, it seems there is no effect of frequency of mangers' feedback when safety rule is not much strict. However, as the safety rule becomes strict, the frequency of managers' feedback shows positive relation with workers' safety behavior. It implies that an interaction effect between strict safety rule and frequent managers' feedback is intensified when the safety rule is strict. This is because frequent managers' feedback makes project norm be more aligned with safety rule because workers are more chance to observe managers' feedback than other workers' behavior.

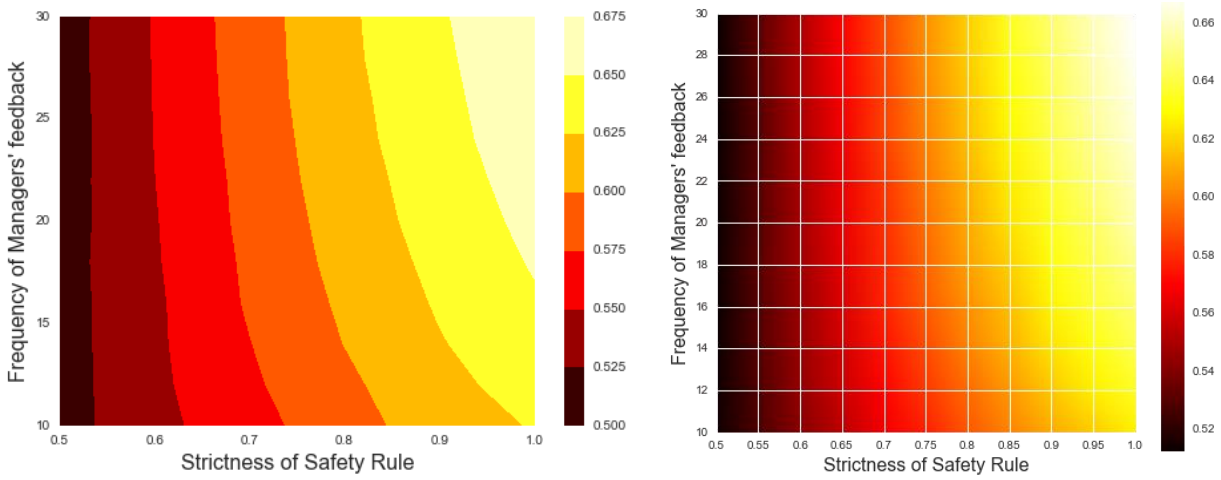


Figure 3 Effect of Strictness of Safety Rule and Frequency of Managers' Feedback on Workers' Safety Behavior

Figure 4 shows the result of parameter sweep between the strictness of safety rule and stimulation of project identity. The x axis in Figure 4 is strictness of safety rule and y axis is stimulation of project identity. The colors at each point represent an average level of workers' safety behaviors in each condition. As shown in Figure 4, there is a positive relation between strict safety rule and safety behavior when safety rule is not much strict. However, safety rule shows limited effect on workers safety behavior as safety rule becomes strict. For the stimulation of project identity, it is difficult to find relationship between stimulation of project identity and safety behavior, but, as the safety rule becomes strict, stimulation of project identity shows positive relation with workers' safety behavior. It implies that although stimulation of project identify does not have much effect on workers' safety behavior when safety rule is not much strict, it can make synergy as safety rule become more strict. This is because an increased project

identity makes workers be more aligned with project norm which is significantly related with safety rule.

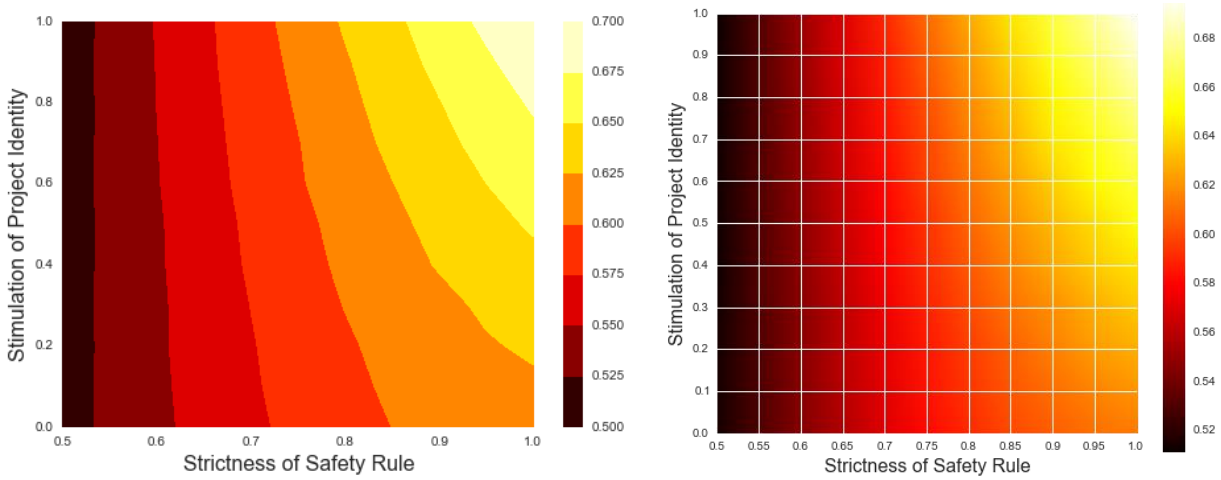


Figure 4 Effect of Strictness of Safety Rule and Stimulation of Project Identity on Workers' Safety Behavior

Figure 5 shows the result of parameter sweep between the frequency of managers' feedback and stimulation of project identity. The x axis in Figure 5 is strictness of safety rule and y axis is stimulation of project identity. The colors at each point represent an average level of workers' safety behaviors in each condition. Figure 5 describes a strong interaction effect between frequency of managers' feedback and stimulation of project identity on construction workers' safety behavior.

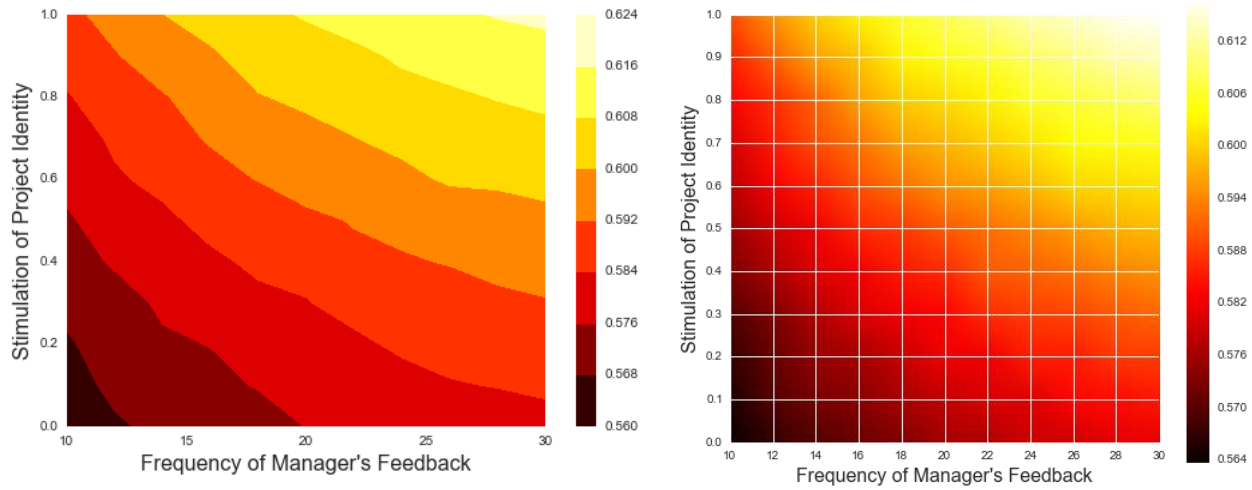


Figure 5 Effect of Frequency of Managers' Feedback and Stimulation of Project Identity on Workers' Safety Behavior

In addition to the qualitative analysis of model experiment results, a regression analysis is also performed to identify the effect of strictness of safety rule, frequency of managers' feedback, stimulation of project identity on workers' safety behavior. To identify interaction effect of stimulation of project identity and strictness of safety rule as well as stimulation of project identity and frequency of managers' feedback, two interaction term was included in the regression model. The result of regression analysis is represented in Table 1. As shown in Table 1, all regression coefficients are statistically significant. However, since variables in the model does not have specified practical meaning, it is difficult to directly interpret the value of regression coefficient likewise general regression analysis. For example, it is difficult to interpret an exact meaning of one unit increase in strictness of safety rule in reality. Rather than, we can confirm the result of qualitative analysis by using this regression analysis.

Table 1 Result of Multiple Regression Analysis

Variables	B	SE (B)	t	R^2
Strictness of safety rule	.1718	.001	124.782	
Frequency of feedback	.0010	.001	29.418	
Stimulation of project identity	-.0946	.000	-44.402	.968
Strictness of safety rule x Stimulation of project identity	.1396	.002	59.868	
Frequency of feedback x Stimulation of project identity	.0007	.000	11.316	

5. Conclusion

In this study, an agent based model representing a workers' safety behavior taking process has been constructed by drawing on the theoretical and empirical findings from the literature. By running simulations on the model with different conditions for focused parameters, it has been demonstrated that (1) strict safety rule can work as a force to increase workers' safety behavior; (2) when safety rule is strict enough, frequency of managers' feedback and stimulation of project identity can lead to increase of workers' safety behavior; (3) interaction between stimulation of project identity and frequency of managers' feedback can lead worker's safety behavior regardless of strictness of safety rule. The model experiment extends our knowledge of

the dynamic relationship among workers' safety behavior, social norm (i.e., workgroup norm and project norm), social identities (i.e., crew identity and project identity), and diverse managerial actions (i.e., strictness of safety rule, frequency of managers' feedback, and stimulation of project identity). Those findings will provide a firm foundation for a new view of safety management emphasizing socio-psychological aspect of safety behaviors.

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