An Analysis of Mental Process within Construction Workforces for Project-level Safety Management

Mingyu Shin[1], Hyun-Soo Lee[2], Moonseo Park[3], Seulbi Lee[4]

[1] M.S., Dept. of Architecture and Architectural Engineering, Seoul National Univ., Gwanak_599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea.
E-mail: hairypoter7@hotmail.com

[2] Prof., Dept. of Architecture and Architectural Engineering, Seoul National Univ., Gwanak_599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea.
E-mail: hyunslee@snu.ac.kr

[3] Prof., Dept. of Architecture and Architectural Engineering, Seoul National Univ., Gwanak_599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea.
E-mail: mspark@snu.ac.kr

[4] M.S. Candidate, Dept. of Architecture and Architectural Engineering, Seoul National Univ., Gwanak_599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea.
E-mail: lee130@snu.ac.kr

Abstract

Safety management parts can be classified into Environment-based Safety Management (ESM) and Human-based Safety Management (HSM). To attain a desired safety level, improving both parts is required. The current safety management, however, is conducted focusing mainly on the ESM, not on the HSM. In order to conduct balanced safety management, a mental process model to support the HSM is a requisite. Thus, this study presents a mental process model which explicates how a worker makes a decision on safe behaviors. The model consists of three sub-models: Model for Worker's Decision-Making on Safe Behavior, Model for Optimistic Recovery, and Model for Habituation. This study has provided a better understanding and a logical basis for the HSM.

Keywords: Mental Process Model, Safety Management, Safety Attitude

Body of Paper

Introduction

Background

Over the past few decades, the construction industry has ameliorated its safety. According to the Korea Occupational Safety and Health Agency (KOSHA, 1974-2010), Accident Frequency Rate (AFR) of the construction industry in South Korea, as shown in Fig. 1, has largely diminished since 1974. However, if its half-life (means that the time required for accident frequency rate to fall to half its value as measured at the beginning of the time period) considered, period 1 (the first half-life) and period 2 (the second half-life) were about 14 years and about 7 years, whereas period 3 (the third and most recent half-life) has not been achieved yet over 15 years. In sum, improvement in construction safety appears to have reached a plateau recently.

One of the major causes for the plateau is thought to be the current biased safety management. Safety management can be divided into two: Environment-based Safety Management (ESM) and Human-based Safety Management (HSM). The ESM is based on the idea that accidents are less likely to occur under various circumstances if all the physical conditions around a worker are safe. Therefore, the ESM focuses on how to improve safety physical conditions such as safety helmets, safety harnesses, and safety nets. The HSM, on the other hand, regards a worker's unsafe behavior as a main cause of an accident and thus emphasizes management over worker's behaviors by safety programs or notifications. The industry typically has emphasized the ESM rather than the HSM. However, due to the fact that there remain few things to improve in terms of safety physical conditions, the further improvement in safety can be hardly made (Donald and Young, 1996). Therefore, in order to overcome the recent plateau in safety management, the construction industry is required to focus on the HSM more.

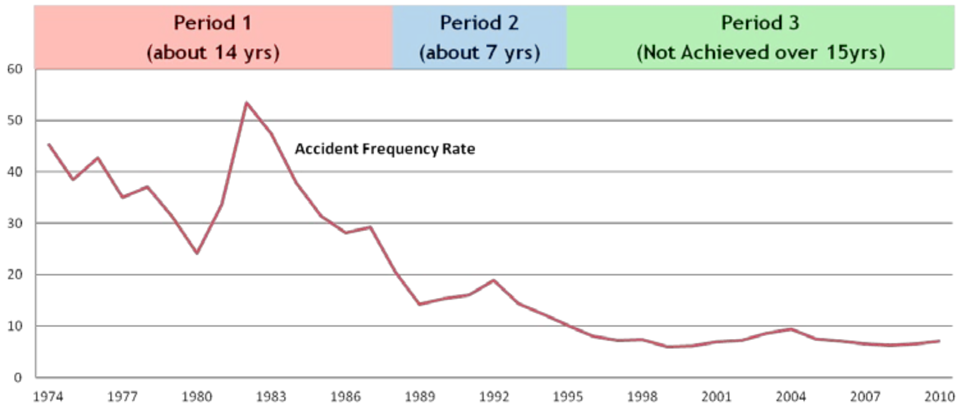

Fig.1 Accident Frequency Rate of Construction Industry in South Korea (KOSHA, 1974-2010)

Objectives and Basic Framework

Prior to suggesting HSM strategies, it is required to develop a model for explicating how workers make decisions on their safe behaviors. Because HSM is to correct workers' behaviors, it is important to understand and manage workers' mental process to behaviors. In addition, an explicative model can provide a better understanding and a logical basis for which management programs and initiatives to select (Cheyne et al, 1998). Although many researchers such as Anderiessen (1978), Purdham (1984), Paul Slovic (1990), Pligt (1996), Reyna (2004), Langford et al. (2000), Mohamed (2002), O'Toole (2002), and Siu et al. (2003) made significant works on safe behaviors and factors affecting the behaviors, there have been a paucity of studies on models which integrate the factors and explain a worker's mental process to behaviors logically. Therefore, this research is to develop a mental process model which can explain how workers' safe behaviors are determined in the construction industry.

Assumptions and Research Process

Since this study focuses on workers' behaviors, site hazards are considered as an external factor. Furthermore, it is difficult to regard that the workers in the construction industry think and make decisions disparately from those in other industries. Therefore, it is assumed that researches on human factors and accidents from other industries can be applied for explicating causal links in the model.

To simplify the model, it is also assumed that most of the behaviors are intended through a certain process of decision-making and there are only two types of behaviors which a worker can conduct; safe behaviors and unsafe behaviors. There are no behaviors that belong to neither safe nor unsafe behaviors.

To develop a mental process model, this research reviews researches and previous mental process models which are pertinent to the research objective and extracts meaningful factors and lessons. Based on the factors and lessons from the previous researches, this study develops a mental process model for explicating safety attitudes and accidents. After quantifying the model, the research analyzes the effect of controllable factors. After quantifying the model, the research analyzes the effect of controllable factors.

Previous Research

Basic Concept

In order to develop a worker's mental process model, a basic framework is needed to be identified first. In order to develop a worker's mental process model, a basic framework is needed to be identified first. Behaviors which lead to accidents are intentional (Donald & Canter, 1993), and attitudes are one of the key factors to predict intentions on behaviors (Ajzen, 1991). Moreover, attitudes depend on how people perceive risks (Fisher et al, 1988). A traumatic event may make people perceive loss of safety or increased risk (Foa et al., 1989), and previous experience of accidents influences attitudes towards accidents (Canter, 1980). To sum, a person perceives risks combining various information first. Second, the person establishes his/her attitude toward a safe behavior based on the risks he/she perceived. Third, the person makes a decision to do it or not based on the attitude. Fourth, the person executes the decision. Fifth, the person faces the result of the behavior. Sixth, the outcome becomes an important factor in the person's perceiving. This process is a basic framework for a worker's mental process to behaviors and can be summarized as Fig. 2. The basic framework consists of five factors and six causal links between them. The three causal links between the first four factors and the link from outcome to perceived risk are objects to be managed through HSM whereas the link from behavior to outcome is an object to be managed through ESM. Since a mental process model in this research has provided a better understanding and a logical basis for the HSM, the model is required to focus mainly on the five causal links and to present the causal links and feedback loops effectively.

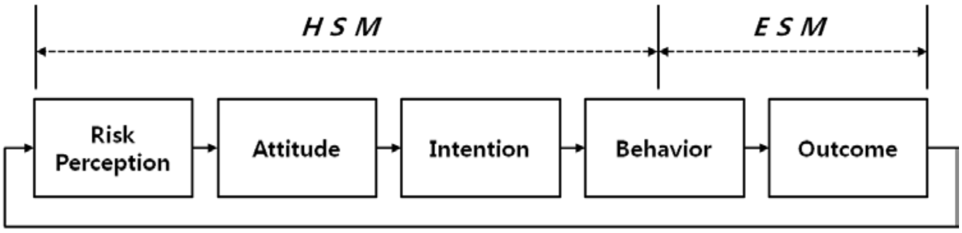

Fig.2 Framework for Mental Process Model

Main Factors

The factors of the framework are considered as main factors composing the mental process model. As shown in Fig. 2, the factors are Risk Perception, Attitude, Intention, Behavior, and Outcome.

Risk perception is defined as a person's subjective judgment on a risk (Lavino and Neumann, 2010). Hence, perceived risks may vary from worker to worker even when workers are addressing a same risk. Whereas an objective worker may perceive a risk as it is, a cautious worker or a bold worker may perceive a bigger risk or a smaller risk than it really is according to the worker's perceiving tendency. In addition, it is worthy of notice that people tend to overestimate their ability and think accidents are controllable, which misleads the people into underestimate risks (Lichtenstein et al., 1978). This fact may explain why workers conduct unsafe behaviors.

Attitude is defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" and the evaluation can be cognitive, affective, or behavioral (Eagly and Chaiken, 1993). Attitude is addressed in an individual worker's level whereas similar concepts, safety culture and safety climate, are addressed in an organizational level (Guldenmund, 2004). In this research, two types of attitudes are addressed: one is attitudes toward risks, and the other is attitudes toward behaviors. As mentioned above, attitudes toward risks tend to be optimistic, but be changed to be pessimistic when a person experiences a traumatic event or an accident. If the accident is not severe, it is assumed that the worker's attitude toward risks will become pessimistic at first but recover gradually to the optimistic state as the worker forgets about the accident. Attitudes toward behaviors, on the other hand, are closely connected with expected utility of behaviors. Expected utility is a combination of expected benefits and cost, which influences people's intention (Raiffa, 1968). There has been an effort to explain a driver's attitudes toward safe behaviors (Blomquist, 1986). According to the research, a driver makes a decision whether to conduct a safe behavior or not based on value of expected risk reduction and inconvenience of the safe behavior.

Intention is a decision on whether to execute a behavior or not. However, although a worker intends to execute a safe behavior, the worker may fail to execute the behavior due to his/her habits against the intention.

A worker's behaviors are either safe or unsafe, and unsafe behaviors are considered as a main cause of accidents in this study. The concept, unsafe behavior, is a subset of human error. Human error is "A set of human actions that exceeds some level of acceptability" as Rigby (1970) defined, and can be classified into two types according to Reason (1990); "Slip: an unintended error in execution of an otherwise correct plan" and "Mistake: an intentional act that involves incorrect choice of action." Since most of the unsafe behaviors are assumed to arise from unsafe intentions, most unsafe behaviors are equivalent to mistakes. Slips are assumed to be made only by the worker's habits against the intention in this research.

Outcomes are results of behaviors and can be classified into successful outcomes and unsuccessful outcomes. The unsuccessful outcomes include accidents and incidents which are incurred either by the worker or other workers. An accident is a sequence of events leading to undesirable consequence, and an incident is a sequence of events which was triggered but stopped before leading to the undesirable consequence (Svenson, 2001). In order to simplify the model, an incident is not considered in the model.

Previous Mental Process Model

Through reviewing the previous researches that were conducted to explain people's mental process, this study can extract key factors and causal links and overcome limitations the previous researches have. There are two models that are persuasive and meaningful to this study. One model was suggested by Eagly and Chaiken in 1993, and the other was suggested by Mearns and Flins in 1995.

One of the most persuasive mental process models for behaviors is a model by Eagly and Chaiken (1993) as shown in Fig. 3. The model can demonstrate how behaviors are formed with regards to attitudes. Attitude toward behavior influences intention, and intention induces behaviors. There are five factors affecting attitude toward behavior. Among the factors, habit plays an important role by affecting three other factors, which are attitude toward target, attitude toward behavior, and behavior. Although the model is simple, it can explain various mental processes to behaviors. However, the model does not deal with cognitive processes and attitudes toward risks and underestimates the possibility that the outcomes of behaviors can impact on the attitudes again.

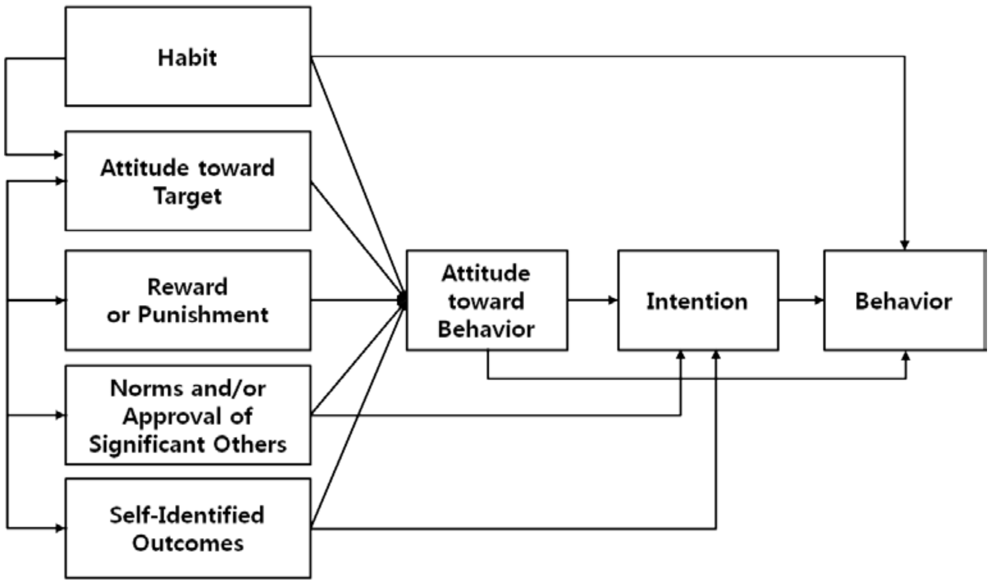

Fig.3 Attitude Formation Process Model (adapted from Eagly and Chaiken, 1993)

Another mental process model is a model by Mearns and Flin (1995) as shown in Fig. 4. The model emphasizes risk perception and thus deals with social and cognitive factors. Since the model has more variables than the model by Eagly and Chainken, the model by Mearns and Flins has advantages in explaining various paths to behaviors over the model by Eagly and Chainken. For example, the model can explain how a worker's knowledge or mastery influences the worker's mental process. Nevertheless, the model still does not present the feedbacks from the outcomes and does not deal with the possibility that others' outcomes influence a person's attitudes toward risks.

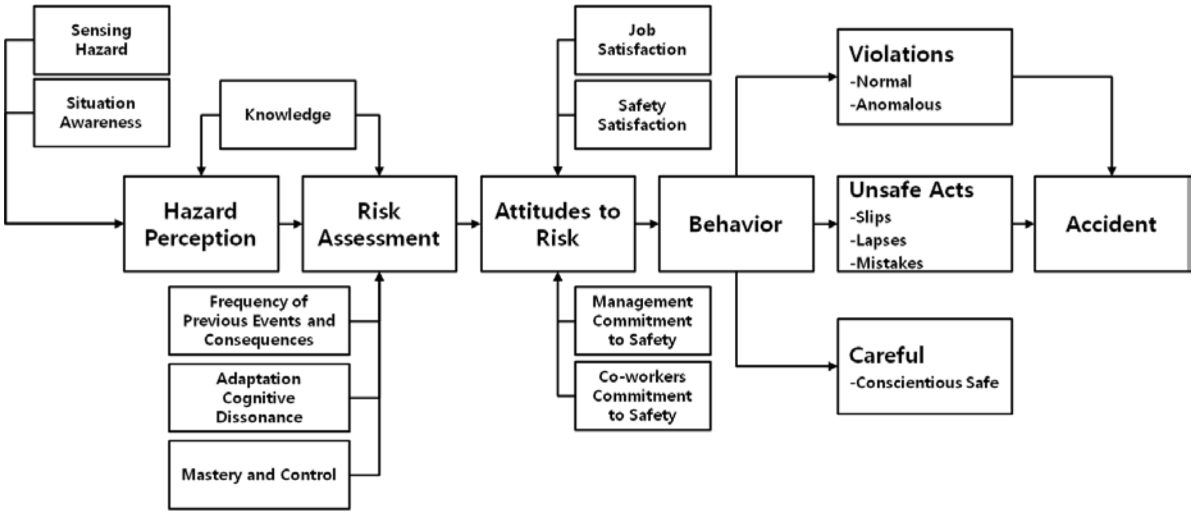

Fig.4 Risk Perception Process Model (adapted from Mearns and Flin, 1995)

System Dynamics

System dynamics is a sort of modeling methods that has the advantage in presenting and understanding complex and dynamic system which contains various interactions and feedbacks (Sterman, 2000). Since safety management copes with a complex and dynamic system, numerous researches have been conducted for better understandings of safety using system dynamics (Cooke, 2003; Abdelhamid and Howell, 2005; Cooke and Rohlede, 2006; Minami and Madnick, 2009; and Han, Lee and Peña-Mora, 2010). Moreover, for the reason that this research focuses on a worker's mental process which is more unpredictable and dynamic compared to researches dealing with the ESM, the system dynamics is thought to be an appropriate method to satisfy the research objective. For a similar reason, system dynamics was applied on a research to investigate how people make decisions on personal protective underuse when spraying pesticide (Feola et al., 2011). Therefore, this study also employs system dynamics to explain various causal relationships.

Modeling a Worker's Mental Process

Model for Worker's Decision-Making on Safe Behavior

A worker perceives risk of accidents based on how dangerous the site is. However, as noted earlier, perceived risk is a subjective concept and thus can differ from worker to worker even in addressing a same risk. Such subjective perceiving tendency is named perceiving coefficient in this study. The perceiving coefficient is defined as “ratio of perceived risks to objective risks”, thus, if the perceiving coefficient is one, the worker perceives risk as it is. In contrast, if the perceiving coefficient is two, the worker overestimates the risk of accidents at the moment. Despite the possibility that some people may evaluate risks abnormally small or big, it is assumed that the perceiving coefficient is approximately in the range of 0.5 to 2.

Another concept of importance when it comes to risks is acceptable risk. Even if two workers perceived same amount of risk, it is uncertain whether the two workers’ acts are same or not. It is because some workers are willing to take the risk while other workers are averse to take it. In other words, their acceptable risks are different. Therefore, when judging on risks, workers need two types of risks. One type is perceived risk the other type is acceptable risk.

Based on the perceived risk and the worker’s acceptable risk, the worker evaluates the utility of safe behaviors to make a decision on his/her attitude toward safe behaviors. Besides the evaluation on risks, how much incentive the worker can expect and how much inconvenience the worker has to endure are the factors affecting the utility of safe behavior. If the utility of safe behavior is calculated, the utility induces how the worker intends and acts, and how the worker acts influences the probability of accidents on the construction site.

If an accident occurs on the construction site, information about the accident will be diffused across workers, but the diffusion rate depends on how much or how often workers communicate on accidents. The perceived accidents have an effect on the worker’s attitude toward risks as the worker recognizes the necessity for modifying how the worker perceives risk of accidents. In this process, how sensitively the worker responds to the accident is a critical factor to determine the change of the worker’s attitude toward risks. In other words, the worker would not respond to the accident seriously if the accident is thought to be irrelevant to the worker. Finally, the modified perceiving coefficient changes the worker’s perception on risks. This loop is a balancing loop (B1) as shown in Fig. 5.

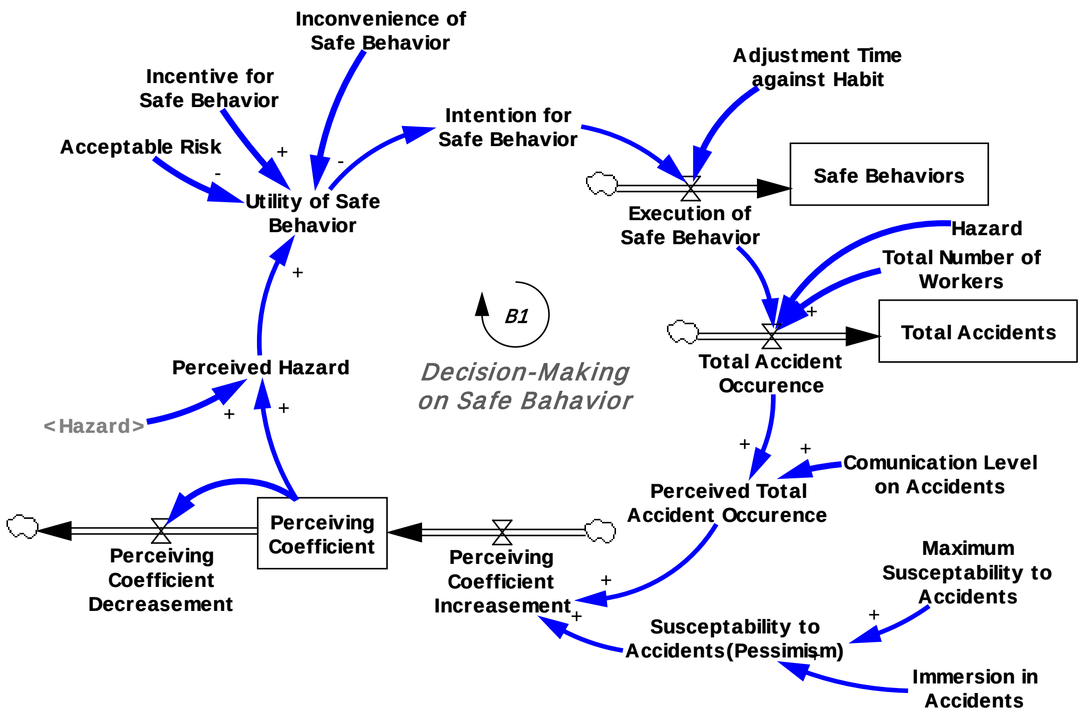

Fig.5 Model for Worker’s Decision-Making on Safe Behavior

Model for Optimistic Recovery

As described above, workers tend to overestimate themselves, which can be described as their perceiving coefficients are less than one. Although such tendency is punctuated by accident occurrences, a worker is assumed to recover from the pessimistic perceiving tendency as the worker forgets about the accidents. Therefore, as some amount of time goes by, the worker gets back to the state that the worker overestimates him/herself in. This loop is a reinforcing loop (R1) as shown in Fig. 6.

Nonetheless, a worker who has experienced or witnessed several accidents cannot fully recover from the effect of the accidents as if the worker had not experienced or witnessed any accident. Thus, a worker's maximum optimistic level is regarded to dwindle as accidents accumulate. This loop is a balancing loop (B2) as shown in Fig. 6.

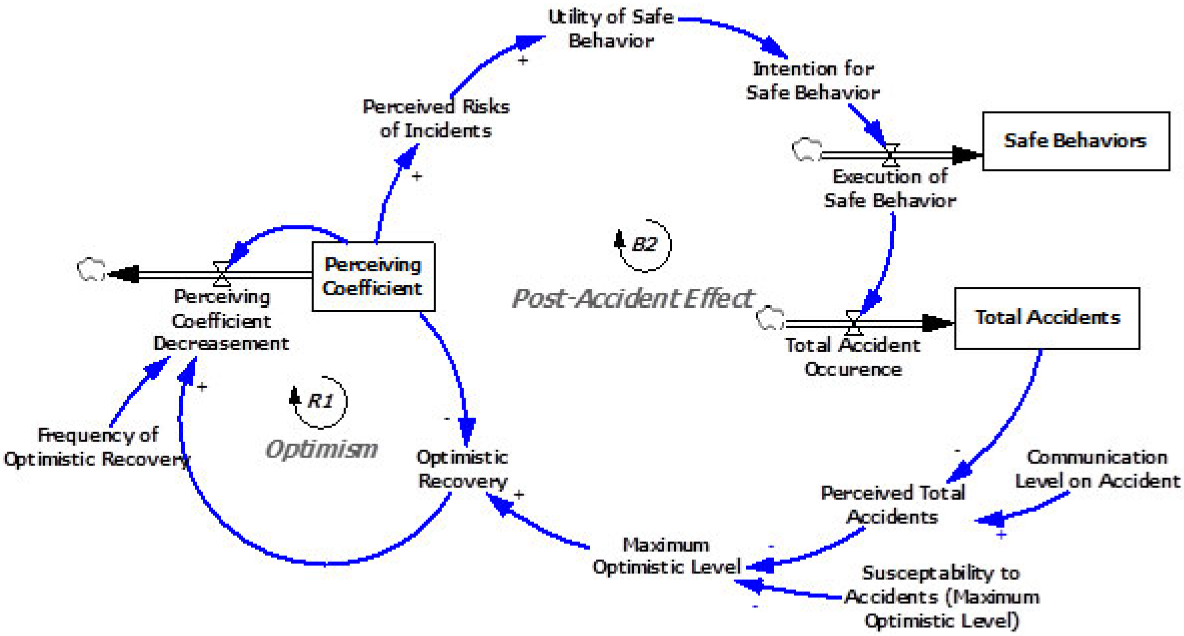

Fig.6 Model for Worker's Optimistic Recovery

Model for Habituation

As Eagly and Chaiken (1993) demonstrated in their model (Fig. 3), a person's habits affect his/her attitude toward behaviors and execution of behaviors. In this context, when a worker is required to act more or less safely compared with what the worker has acted so far, the worker may confront a difficulty in establishing appropriate attitude or in executing what the worker intended to do owing to his/her habits. For instance, although a worker who acts safely two out of ten times suddenly set his rule to act safely nine out of ten times, there is little possibility that the worker achieves exactly what he intended to act because he may not be accustomed with the newly-set rule or may forget the rule. This is a reinforcing loop (R3) as shown in Fig. 7.

On the other hand, if a worker acts safely as a rule, then the worker may recognize less inconvenience from safe behaviors. Since inconvenience of safe behaviors is one of the important factors to determine the expected utility of safe behaviors, the worker is expected to establish favorable attitude toward safe behaviors. This is a reinforcing loop (R4) as shown in Fig. 7.

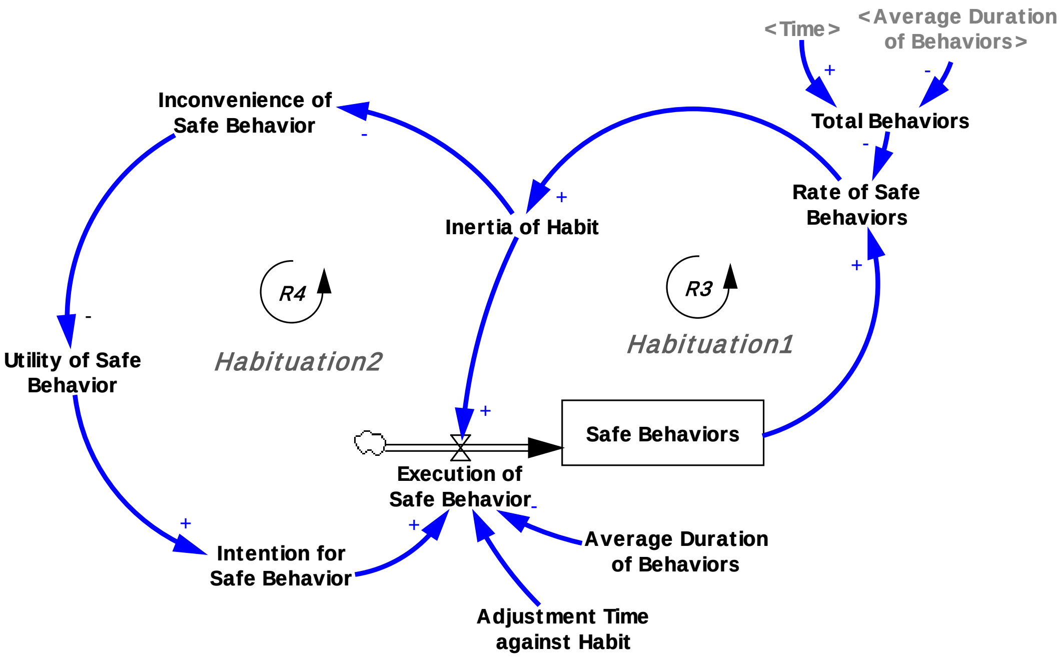

Fig.7 Model for Habituation

Summary

A Based on the basic framework in previous research, a mental process model to explain how a worker decides to act in terms of safety was developed. The model consists of three sub-models.

One is Model for Worker's Decision-Making on Safe Behavior which deals with main process of decision-making.

Another is Model for Optimistic Recovery which describes workers' optimistic perceiving tendency and recovery process from the effect of accidents.

The other is Model for Habituation which explains how a worker's habit influences the worker's decision-making process.

The entire model which includes the three sub-models mentioned above is presented in Fig. 8. After quantifying the model, simulation was conducted to examine the logics of the model and to provide a standard.

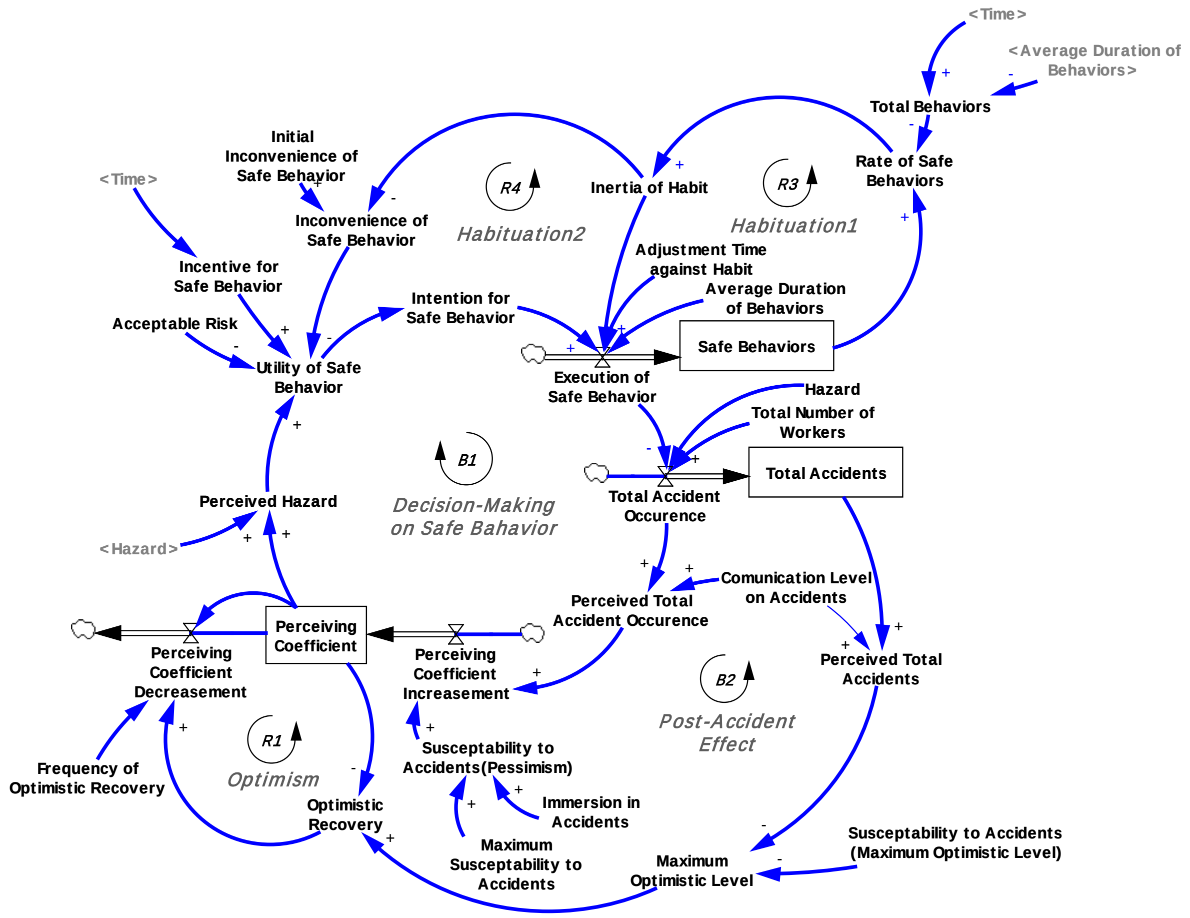

Fig.8 Entire Mental Process Model

Model Analysis

After quantification of the model with several values assumed (Final Time: 2000 Days, Time Step: 1 Day, Communication Level: 0.8, Immersion in Accident: 0.8, and Utility of Incentive for Safe Behavior: 0.3), analysis of the model was conducted. Leading indicators in the model are perceiving coefficient, total accidents, and rate of safe behaviors. The graph in Fig. 9 presents how a worker's attitude toward risks, which is presented as perceiving coefficient, changes. The worker has a minimum perceiving coefficient value of 0.5 as a maximum optimistic level and is predicted to have the value if the worker never perceives accidents. However, accidents happen and affect the worker's attitude toward risks. Thus, the soaring moments present the time when accidents occur. As noted earlier, a worker modifies his/her attitude toward risks when the worker confronts accidents, and thus the perceiving coefficient increases sharply. As the worker becomes insensitive to the accidents, the perceiving coefficient recovers to the value of 0.5 gradually.

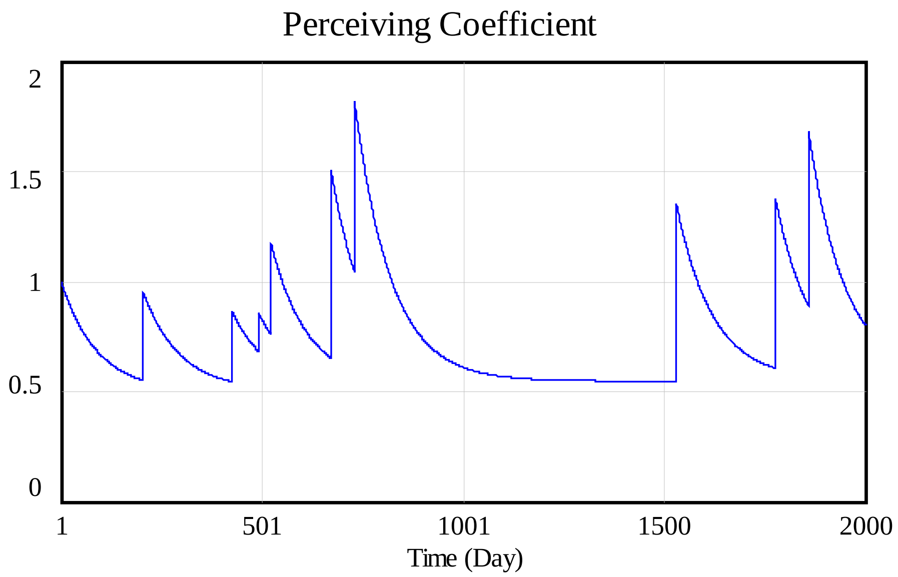

Fig.9 Simulation Result (Perceiving Coefficient) [Unit of the vertical axis is dimensionless. (The value of 1 means that actual risk equals perceived risk.)]

The graph in Fig. 10 presents total accidents on the construction site. Under the assumed conditions, there happened ten accidents. It can be noticed that site hazard is overestimated in this study in order to facilitate an evaluation of influencing factors. Furthermore, the moments of accidents in the second graph correspond to the soaring moments in the first graph.

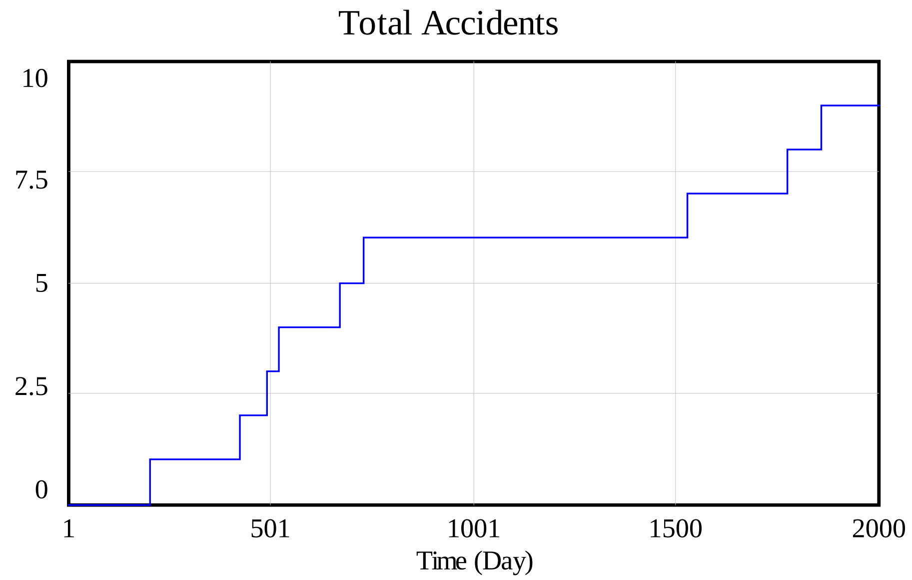

Fig.10 Simulation Result (Total Accidents)

The graph in Fig. 11 presents how many safe behaviors a worker conducts out of the total behaviors. Under the conditions mentioned above, the worker acts safely about six out of ten times. The rate of safe behaviors tends to fluctuate more at the beginning stage, and there are two reasons for the fluctuation. First, the rate of safe behaviors is a value calculated by dividing safe behaviors by total behaviors. As the two factors get bigger, the rate of safe behaviors gets less sensitive to the change of the two factors. Second, habit is a factor that reduces fluctuations in the model but is not fully-established at the beginning stage. As the worker's behavior pattern becomes stable, the rate of safe behaviors also becomes stable.

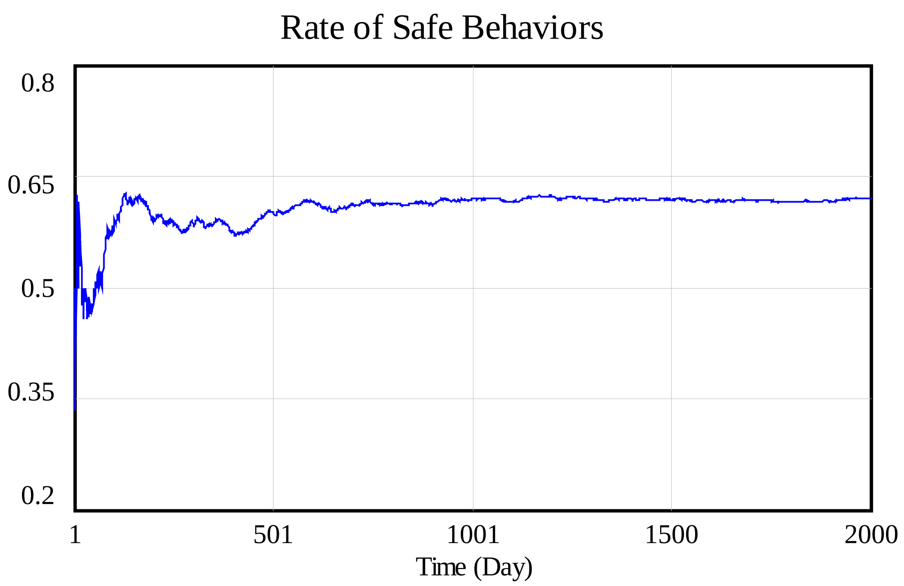

Fig.11 Simulation Result (Rate of Safe Behaviors)

Conclusions

Results and Discussions

The present safety management, Environment-based Safety Management which emphasizes physical conditions reveals its limitations and causes the plateau in improving safety in the construction industry. To solve the problems, Human-based Safety Management which focuses on workers and their behavior is demanded. Although a plethora of researches on HSM have been conducted, there has been little effort for developing a mental process model to support HSM. For this reason, this study suggested a mental process model to explicate how a worker make a decision on safe behaviors based on the factors and causal links that were identified by the previous researches. Since the model was required to deal with several feedbacks, system dynamics was employed as a methodology to describe the relationships.

Contributions

Safety management is one of the important parts in the construction management. However, various statistics are presenting that the present safety management, Environment-based Safety Management, has limitations in making a further improvement of the construction industry. Therefore, Human-based Safety Management is required to be applied more.

This study has provided a better understanding and a logical basis for HSM through suggesting a mental process model to support HSM. The model has several advantages over the previous model in explicating a worker’s mental process.

Acknowledgements

This research was supported by a grant (12TRPI-C064106-01) from R&D Program funded by Ministry of Land, Transport and Maritime Affairs of Korean government.

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