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A Preliminary Study on the Application of System Dynamics Methodology to Organizational Safety in Nuclear Power Plants: Learning from Past Models

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1. Introduction

Besides technical design, organizational and human factor are of increasing interest in literature on nuclear safety. Among the methodologies employed to study these factors, System Dynamics (SD) is considered to be suitable for addressing the complexity and dynamicity of the organizational system in nuclear power plants (NPPs). In the following sections, the method will be described and its several prior applications to studying organizational safety will be introduced. An SD model with emphasis on the role of organizational learning in organizational safety will be presented.

2. Methodology and Results

2.1. Methodology

The SD method essentially describes a system by variables, their influences and feedbacks, in form of stock-and-flow diagram and causal loop diagram. With these components, an SD model attempts to explore various interlocking relationships and their interaction over time. In addition, using the same model structure, one can simulate the behavior of the system under different scenarios, formulated with a certain set of assumptions and study purposes. Thus, SD simulation can be used to examine the outcomes of different options or circumstances, all on a computer. The SD approach for modeling organizational safety is introduced to Korean NPPs by Ahn et al,(2005)[5].

2.2. Applications to organizational safety

To address organizational factors from the safety climate literature, Lyneis et al (2008) developed an SD model that focuses on building a culture of safety where compliance to rules and procedures is at the center. Accordingly, the number of nuclear incidents is dependent on the extent to which *rules and procedures are adhered to*, as well as the *quality of rules and procedures*[4]. These two attributes alone, however, do not guarantee safety. They are also under the influence of a number of organizational factors. In their model, Lyneis et al (2008) define workers' perceived personal threat, management's degree of emphasis on safety and schedule pressure to be the three key factors that affect adherence to rules and procedures. Additionally, the quality, or effectiveness of rules and procedures, is derived from organizational safety knowledge gained from past incidents [4]. The simulation results from the model provide some insights for learning, such as the importance of safety priority to the institutionalization of organizational learning. This model, however, suffers from a drawback which is the focus on short-term response from workers and management. Their commitment to safety, which is built through a longer time span, is not clearly mentioned in the model. In addition, organizational complacency which has been discussed in literature [1] is not indicated in the model.

Still under the topic, Cooke (2002) studied Westray Mine Disaster and set up an SD model aiming to capture the "mental model of the safety system", including the relationships that could have led to conditions that caused the fatal explosion at the mine [2]. Though built in mining industry context, the model can be adapted to nuclear industry as it shares similar organizational factors and system complexity. From this model, Cooke developed another model that focused on learning from incidents [3], in which he points out that workers' commitment to safety, influenced by management's, contributes to the quality of incident investigation and learning gained, whereas management's commitment to safety is related to the application of learning to lower the losses from incidents.

2.3. Model and Results

An SD model has been developed from two above models. The basic causal loop diagram of the model for Korean NPPs is firstly set out below:

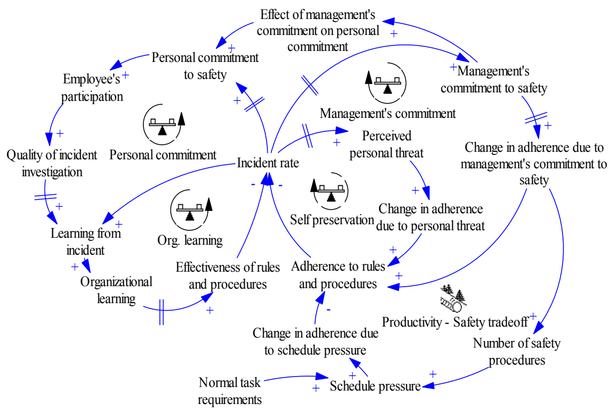

Fig.1. Basic causal loop diagram of organizational safety

In this basic model structure, the degree of *adherence to rules and procedures* is influenced by workers' perceived level of threat, worker's and managers' commitment to safety, and schedule pressure. *Effectiveness of procedures* is dependent upon the organization's safety knowledge, which is increased by the learning from incidents and decreased by memory loss and obsolescence of knowledge. *Incident rate*, resulted from the previous two attributes, feedbacks to these factors in the sense that higher incident rates raise the level of commitment among both employees and management, and adds to the stock of organizational knowledge, which all eventually lower the number of incidents (i.e. *incident rate*).

Based on the above causal loop diagram, a stock and flow diagram has been further developed. The model overcomes the limitations of Lyneis et al's model with the inclusion of workers' and management's commitment to safety and its impact on learning, as well as organizational complacency indicated by the variable inputs (Here, the impact of their commitment on adherence to rules and procedures can be negative, implying the possible decrease in compliance). As an example of SD simulations, Figure 2 shows a result of changes of incident rates after a trip event, with assumed input data to a few variables:

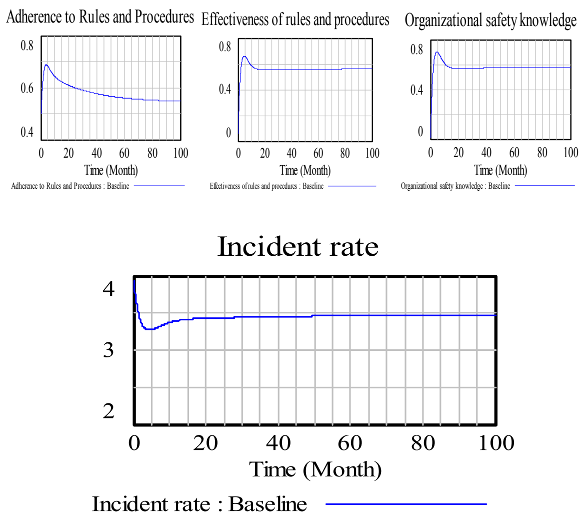

Fig.2. SD Inputs and a Result of Incident Rate Change (from an example SD Simulation)

As can be seen from above, as incident rate increases, the learning from incident also increases which adds to the stock of organizational learning, improving the quality of rules and procedures. Incident rate below acceptable incident rate (assumed to be 4 incidents/ month) causes slight complacency among managers and employees thus erodes their adherence to rules and procedures. However, as the rules and procedures become more effective thanks to learning from incident, the increase in incident rate is negligible despite the decreasing adherence to rules and procedures.

The model simulation shows the normal state of an NPP assuming that schedule pressure is negligible and learning is effectively applied to improve the quality of rules and procedures. Therefore, it can serve as a starting point to introduce more complicated relationships and system disturbances, bringing the model closer to the real context.

3. Conclusions and Future Research

The preliminary result has implied the role of learning in the degree of organizational safety. The model serves as the foundation for our future attempt to explore more sophisticated structure and the mechanism of organizational safety, particularly organizational learning. This fundamental causal structure will be further expanded and refined with the addition of more relationships and more valid underlying assumptions. We also hope to customize this generic model and its inputs to better reflect the context of Korean NPPs. Finally different scenarios will be formulated to test the role and impact of different factors on organizational learning and safety, and lessons or recommendations are expected to be derived.

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