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Investigations on Human Error Hazards in Recent Unintended Trip Events of Korean Nuclear Power Plants

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1. Introduction

According to the Operational Performance Information System (OPIS) which has been operated to improve the public understanding by the KINS (Korea Institute of Nuclear Safety), unintended trip events by mainly human errors counted up to 38 cases (18.7%) from 2000 to 2011 [1]. Although the Nuclear Power Plant (NPP) industry in Korea has been making efforts to reduce the human errors which have largely contributed to trip events, the human error rate might keep increasing [2, 3]. Interestingly, digital based I&C systems is the one of the reduction factors of unintended reactor trips. Human errors, however, have occurred due to the digital based I&C systems because those systems require new or changed behaviors to the NPP operators. Therefore, it is necessary that the investigations of human errors consider a new methodology to find not only tangible behavior but also intangible behavior such as organizational behaviors.

In this study we investigated human errors to find latent factors such as decisions and conditions in the all of the unintended reactor trip events during last dozen years. To find them, we applied the HFACS (Human Factors Analysis and Classification System) which is a commonly utilized tool for investigating human contributions to aviation accidents under a widespread evaluation scheme. The objective of this study is to find latent factors behind of human errors in nuclear reactor trip events. Therefore, a method to investigate unintended trip events by human errors and the results will be discussed in more detail.

2. Proposed Approach on Human Error Hazards

The practical HFACS framework was developed in investigating aviation accidents by Wiegmann and Shappell [4]. The four levels of HFACS hierarchy consist of unsafe acts, preconditions for unsafe acts, unsafe supervisions, and organizational influences. To apply the framework to the nuclear domain, the HFACS terminology used in aviations is necessary to be modified due to the little different generic nature of the terminology. In this study we modified the HFACS classifications. The categories consist of 12 unsafe acts, 22 preconditions for unsafe acts, 12 unsafe supervisions, and 9 organizational influences (see Figure 1).

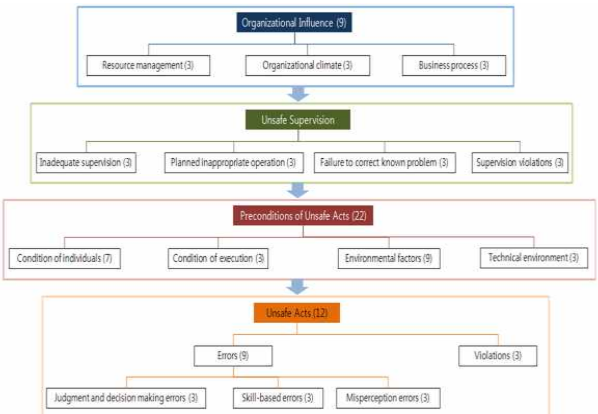

Figure 1. Modified HFACS Classifications

3. Data Coding and Analysis of the Trip Events

Data collected by OPIS were analyzed. The total of 38 significant incidents which were reported by KINS as unintended trip events were involved in these investigations. Coding was conducted over two stages. Firstly, all of the operators' behaviors were extracted from each incident report. Secondly, critical error shaping actions were selected by two human factors experts with discussion. The critical error shaping actions selected by them were totalized into 78 actions.

The 78 critical actions were analyzed in accordance with HFACS framework by a panel of experienced human factors experts. These experts had influence experience in the use of human error identification methods and had general nuclear industry domain knowledge for over 15 years. Each expert independently mapped each HFACS categories to each critical error shaping action. The few disagreements were resolved through discussion with field investigators who were involved in this study as an independent reviewer.

HFACS analysis was performed using frequency counts and chi-square test between each levels. Odds ratio (OR) were calculated to assess the strength of associations between each levels. SPSS 12.0 for Windows (SPSS Inc.) was used in these statistical analyses.

4. Frequency, Associations, & Countermeasures

Most of the critical actions involved one or more factors in each level. Above 100% of incidents involved one or more unsafe acts. The most frequent unsafe act was skill-based errors (55.1%). Skill-based errors involved attention fail (26.9%) and technical error (26.9%). Judgment and decision making errors (32.0%) was discovered as the second frequent unsafe acts. Judgment and decision making errors occurred by mostly procedure error (17.9%).

In case of preconditions of unsafe acts above 100% of incidents involved one or more preconditions of unsafe acts. The most frequent precondition of unsafe acts was condition of individuals (63.0%). Condition of individuals involved mostly poor skills (32.1%) and attention deficit (15.4%). Environmental factor (24.4%) was also found as one of the frequent conditions of unsafe acts. Environmental factors involved task complexity (5.1%), and unrecoverable task (3.8%).

Unsafe supervision and organizational influence are generally classified as the organizational factors. These organizational factors did not influence lower levels one or more. Most of the organizational factors were selected just one factor to influence lower level factors individually. The most frequent unsafe supervision was inadequate supervision (48.7%). Unsafe supervision involved training fails (21.8%) and instruction fails (15.4%). In case of organizational influence the most frequent factor was business process (44.8%). Business process involved task procedure (26.9%) and safety program (11.5%). The second frequent factor was resource management (35.9%). Resource management involved mostly personnel resources (29.5%).

Associations of failures across the levels were discovered through chi-square analysis to determine how the presence of factors at higher levels predicts the presence of lower levels. Table 1 presents all significant odds ratios and significant value (p-value). Ultimately, this approach is to determine countermeasures against human errors through eliminating latent factors such as organizational influence. However, the absence of an association between each level does not mean that it is not important. This is because these associations just appear when the incident data involved significant value statistically. Therefore, associations should be are used as a reference to determine countermeasures. Table 2 shows an example of countermeasures which are derived by the panel of human factors experts.

5. Discussions and Conclusions

In this study we investigated the hazards of unintended trip events using a classification scheme based on HFACS framework. HFACS developed in aviations has been specially utilized in various industries such as railway, maritime, civil aviation, mining, etc. In nuclear power industry, however, there is no case which is investigated using HFACS yet because most of the human factors researchers have considered that the characteristics of human errors in nuclear industry are different from other industries. This study is the first trial to adapt the HFACS methodology to nuclear industry to provide investigators with useful analytic frameworks.

Over the past two decades, to reduce human errors has been a main issue, and human-machine interfaces and work environments have been targets to be improved. However, fundamental hazards of human errors were not unveiled clearly because of insufficient methods which could deal with latent factors of human errors. In this study we determined countermeasures against human errors through dealing with latent factors such as preconditions of unsafe acts, unsafe supervisions, and organizational influences. The countermeasures were drawn by analyzing associations between these latent factors statistically.

The main limitation of this study is due to the completeness of HFACS classifications which are consist of 4 hierarchical levels. Generally the fact that causes and routes of human errors are very complex and latent makes these kinds of limitations. A domain specific classification scheme is to be developed to cope with the limitation. Especially nature terminology should be set by domain experts. For the future researches the framework and classification adopted from HFACS should be validated through more field studies.

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Table 1. Significant Odds Ratios between HFACS levels

Preconditions of unsafe acts (Level 2)	Unsafe acts (Level 1)	OR	p-value
Attention deficit	Attention fail	5.20	0.013
Poor skills	Technical error	11.75	0.000
Unsafe supervision (Level 3)	**Preconditions of unsafe acts (Level 2)**	**OR**	**p-value**
Other oversights	Attention deficit	44.8	0.000
Instruction fails	Communication fail	16.0	0.004
Defect detection fail	Bad habits	16.50	0.003
No enforcement provisions	Bad habits	7.44	0.079
Training fails	Poor skills	6.16	0.002
Procedure correction fails	Poor skills	3.87	0.051
Organizational influence (Level 4)	**Unsafe supervision (Level 3)**	**OR**	**p-value**
Personnel resources	Other oversights	11.59	0.002
Personnel resources	Training fails	49.69	0.000
Line of command	Instruction fails	10.67	0.024
Safety culture	Defect detection fail	16.50	0.003
Technical resources	Defect detection fail	7.44	0.079
Safety culture	No enforcement provisions	7.44	0.079
Task schedule	No enforcement provisions	15.56	0.031
Task procedure	Procedure correction fails	Infinity	0.000

Table 2. An Example of Countermeasures against Human Errors

Acts(A)	OR(A/P)	Preconditions(P)	OR(P/S)	Supervision(S)	OR(S/O)	Organization(O)
Attention fail	5.20*	Attention deficit	44.8*	Other oversights	11.59*	Personnel resources

Countermeasures

1. More strong aptitude test aspects of focused attention
2. Differential task assignment in accordance with individual attentiveness
3. Development of supervisory manual for monitoring worker's attentiveness
4. Development of training program for improving individual attentiveness

*: p-value >0.05