# Study on Diagnosis Error Assessment of Operators in Nuclear Power Plants


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**Abstract.** The purpose of this study is to suggest a framework to assess diagnosis error of operators in nuclear power plants. In nuclear power plants, human error caused by inappropriate performance due to inadequate diagnosis of situation by operators have been considered to be critical since it may lead serious problems. In order to identify and estimate the human errors, various human error analysis methods were developed so far. Most human error analysis methods estimate diagnosis error through time reliability curve or expert judgments. In this study, a new framework to assess diagnosis error was suggested. It is assumed that diagnosis error is caused by inadequate quality of data and diagnosis error can be observed by using information processing model of human operators. Based on this assumption, we derived the assessment items for the quality of data and diagnosis error taxonomy here.



**Keywords:** Diagnosis errors, Quality of data, Information processing model.


## 1 Introduction

Diagnosis errors which may cause inadequate actions of operators have been considered to be critical since it may lead fatal problems in the safety critical systems such as chemical plants, airlines and nuclear power plants (NPPs). In NPPs, when operators experience the changing situations of the plants, they may diagnosis the situations. They will interpret the cause of problems, observe the relevant cues, plan the tasks to resolve the situation and expect the consequences. As a result of this process, they will make the decisions and implement the proper actions. In this regards, when operators fail to diagnose the situation correctly, it will lead inadequate implementations of actions and may make the plant in danger.

In order to identify and estimate human errors, various human reliability analysis (HRA) methods have been developed so far. Most HRA methods assess diagnosis errors through time reliability curve (TRC) and expert judgment as shown in Table 1. Thus most HRA methods believe that if operators have sufficient time available to


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diagnose, the diagnosis error may be decreased dramatically. However, diagnosis error can be affected by a diagnostic ambiguity that may arise from various plant responses [1] and the quality of information.

The purpose of the study is to propose the framework to assess diagnosis errors of the operators in NPP main control room (MCR). For the first step of the study, we identified the contributors to diagnosis errors and developed diagnosis error taxonomy.

**Table 1.** Approaches to estimate diagnosis errors in the existing HRA methods

| | TRC | Expert judgment |
|---|---|---|
| The existing HRA methods | -THERP (Swain, 1987)<br>- HCR (EPRI, 1992)<br>- K-HRA (KAERI, 2005)<br>- SHARP (EPRI, 1984) | - INTENT (INL, 1992)<br>- HRMS (B. Kirwan, 1997)<br>- HEART (J.C. Willliam, 1988)<br>- SLIM (BNL, 1988)<br>- SPAR-H (INL, 1995) |

## 2 A Framework to Assess Diagnosis Errors

D. I. Gertman asserted that the cognitive errors stem from erroneous decision making, poor understanding of rules and procedures, and inadequate problem solving and this errors may be due to the quality of data and people's model for processing information [2]. E. Hollnagel said that information processing models of human behavior assume that there are reliable criteria of validity against which it is possible to measure a deviant response [3].

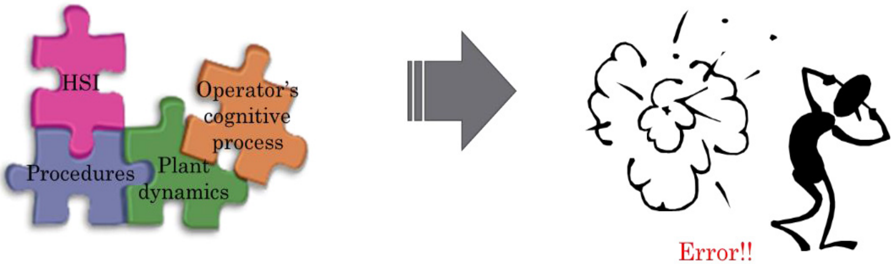


**Fig. 1.** The contributors to diagnosis errors of operators

As shown in Figure 1, we assume diagnosis error can be caused due to the quality of information (inadequate information from human-system interface (HSI) and procedures, the erroneous situations from other causes) and diagnosis error can be observed by people's model of processing information (not qualified cognitive process of operators). Here, we assume that information of HSI and procedure are the contributors to diagnosis error.

In order to derive assessment items for the quality of data, literature review was performed. For developing diagnosis error taxonomy, naturalistic decision making (NDM) and predictive human error analysis (PHEA) were used. For validation of the assessment items and diagnosis error taxonomy, audio-visual recorded data under training session by operators and NPP accident reports from 2010 to 2013 have been analyzed.

### 2.1 Identification of Assessment Items for Quality of Data

Literature review have been performed in order to derive the assessment items for the quality of data. Twelve papers related to diagnosis errors were reviewed in nuclear, aviation, and medical domains from 1988 up to now [4-15]. In addition, six general HRA methods were reviewed [16-20]. Most papers asserted that improper information such as inadequate HSI design and poor procedures development, too many alarms and multiple concurrent events are one of major contributors to diagnosis errors. Also, dynamic situation of systems combined with a specific initiator at an earlier time of an event scenario may increase diagnosis errors of operators [1]. We categorized assessment items into three parts: HSI information, procedures and others causes. As a result, eight assessment items for HSI information, six items for procedures, and five items for other reasons have been derived as shown in Table 2.

However, the assessment items derived should be confirmed and validated to whether or not those are suitable to the unique situation of NPPs. For the validation, training data which have been recorded audio-visually and NPP accident reports have been analyzed.

**Table 2.** Assessment items for HSI information, procedures and other causes

| | HSI information | Procedures | Other causes |
|---|---|---|---|
| Assessment items | -The number of alarms alerted (Single/Multiple)<br>-Location (MCR/local)<br>-Directedness<br>-Indicated in procedures or not<br>-Training of HSI<br>-Accuracy of information | -Existence<br>-Including a seperated check sheet or not<br>-AND or NOT wording in the text<br>-Training of procedures<br>-The number of procedures used (Single/Multiple)<br>-Standard or ambiguous working | -Temporal characteristics<br>-Multiple events<br>-Delayed system response<br>- Time available<br>- Training<br>- ... |

### 2.2 Development of Diagnosis Error Taxonomy

In order to develop diagnosis error taxonomy, information processing model of human operators is used. Because information processing models of human behavior assume that there are reliable criteria of validity against which it is possible to measure a deviant response [3]. Among vaious models, naturalisitc decision making (NDM) is selected.

NDM was developed to describe how people actually make decisions as a result of cognitive processing in real-world settings [21]. The study of NDM asks how experienced people, working as individuals or groups in dynamic, uncertain, and often fast-paced environments, identify and assess their situation, make decisions and task actions whose consequences are meaningful to them and the larger organization in which they operate [22]. Here, it is assumed that people does not compare options parallerly. When people meet changing situation, they rapidly search thier experience which is most similiar to the current situation. Based on the prior experience, they suggests the several solutions and evaluate solutions serially. NDM researchers have studied people in filed settings, such as nuclear power plants, navy commanders, anesthesiologist, and airline pilots [23]. F.L. Greitzer [24] and P. Carvalho [25] also examined the cognitive process of the expert operators in NPPs when they make critical decisions and asserted that NDM is suitable.

Recognition primed decision making (RPD) model is most widely used model of NDM [26]. This model describes how people use their experience in the form of a repetoire of patterns. When people need to make a decision, they can quickly assess the situation by matching petterns they have learned. If they find a clear match, they can evaluate what is the most typical course of action by mental simulaton [23]. Thus, RPD model incorporates two cognitive processes: 1) Assess the situation by pettern matching and 2) Evaluate course of action by mental simulation. The detailed cognitive process of RDP model is shown in Figure 2.

In order to develop diganosis error taxonomy, we adopt the human error identification (HEI) techniques. Among various HEI techniques, we selected predictive human error analysis (PHEA).

As a results, we derive eleven diagnosis error modes: cues are not observed, wrong cues are observed, insufficent cues are observed, goal preconditions ared ignored, incorrect goal is set, correct but insufficient goal is set, wrong picture (expectation) is derived, wrong option is generatd, acton is evaluated incorrectly, correct action is generated but too soon/too late, and correct action is generated but wrong order.

However, the diagnosis error taxonomy should be also confirmed and validated to whether or not those are suitable to the unique situation of NPPs. For the validation, training data which have been recorded audio-visually and NPP accident reports have been analyzed.

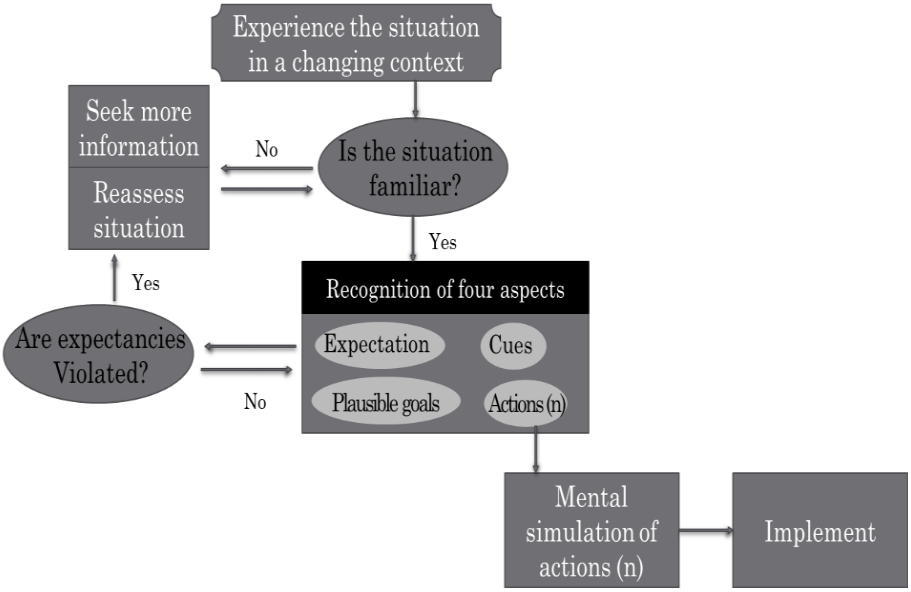


**Fig. 2.** The detailed cognitive process of RPD model

## 3 Case Study

Here, for the case study, simulation data from training session by operating teams were selected. During training session, all communications between operatros were recorded in an audio-visual format and transcribed to the verbal protocol data.

Among many scenarios during training sessions, two scenarios were selected as shown in Table 3. Three same operating teams were participated in both two scenarios. During both scenarios, operators should perform the tasks which are addressed in standard post trip action (SPTA), diagnostic action (DA), and emergency operating procedures (EOP) procedures after the reactor trip.

**Table 3.** Scenario descriptions

| | #1 | #2 |
|---|---|---|
| Scenario | Steam generator tube rupture (SGTR) + Safety injection (SI) actuation failure | Station black out (SBO) |
| # of operating teams | 3 | 3 |
| Procedures (after reactor trip) | SPTA/DA/EOP-03 | SPTA/DA/EOP-07 |

In the scenario #1, during performing SPTA procedures, the signals for SI actuation failure was occurred. Then, operators should follow the SPTA procedures and diagnose the situation to resolve SI actuation failure concurrently. A result of the case study is shown in Table 4.

**Table 4.** The result of case study

| | #1 | #2 |
|---|---|---|
| HSI information | -Multiple alarms are alerted.<br>-MCR information is necessary.<br>-All indicators are addressed in procedures.<br>-All information are accurate. | -Multiple alarms are alerted.<br>-MCR information is necessary.<br>-All indicators are addressed in procedures.<br>-All information are accurate. |
| Procedures | -Procedure is existed.<br>-Procedure does not include separate sheet.<br>-Procedure includes AND logic. | -Procedure is existed.<br>-Procedure does not include separate sheet.<br>-Procedure includes AND logic. |
| Others | -**Multiple events** are occurred. | -**Single event** is occurred. |
| Diagnosis errors | -2/3 teams failed to diagnose correctly.<br>Team 1: Wrong cues were observed.<br>Team 3: Cues were not observed. | -No team was failed. |

As shown in Table 4, all other information for HSI and procedures were same for both scenarios except plant dynamics: Multiple and signle event. However, these difference caused the significant increase of diagnosis errors. In the case of scenario #1, two out of three teams failed to diagnose the SI actuation failure. Only one team diagnosed the situation correctly and resolved the problem. While, in the case of scenario #2, no team failed diagnosis during performing SPTA procedures. In this regards, it is confirmed and validated that multiple event leads diagnosis error obviously.

## 4 Summary and Conclusion

Diagnosis errors may cause inadequate actions and lead the unwanted situation of nuclear power plants. It is crucial to identify and estimate diagnosis error to assure the safety of nuclear power plants. However, most HRA methods assess diagnosis error through time reliability curve or expert judgments. Also, these HRA methods does not consider the situation such as inadequate information is represented in HSI or procedures. In order to incorporate the assessment for quality of information (HSI, procedure, and plant dynamics), the research have been conducted here. For the first step, we derived the assessment items for the quality of data through literature review.

As a results, eight assessment items for HSI information, seven assessment items for procedures, and five assessment items for the other causes were derived. In order to derive diagnosis error taxonomy, recognition primed decision-making model which is most widely used model for naturalistic decision making and predictive human error analysis which is the one of human error identification technique were used. As a result, eleven diagnosis errors were derived.

For confirmation and validation of assessment items and diagnosis error taxonomy, training data and accidents reports have been analyzed. As a case study, two scenarios were compared to validate assessment items for quality of data. This case study represented that multiple event may cause the significant increase of diagnosis errors. Thus, the possibility of multiple events should be considered to estimate diagnosis errors.

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