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Can we directly apply existing human reliability data to estimate the human error probability of a digital MCR?[1]

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1. Introduction

Recently, Advanced Power Reactor 1400MWe in Republic of Korea started its commercial operation with a digital main control room (MCR). In addition, several NPPs are under construction (e.g., Advanced Passive 1000MWe in U.S.) with a digital main control room (MCR) in all over the world. Accordingly, in terms of human reliability analysis (HRA) for supporting probabilistic safety assessment (PSA) or probabilistic risk assessment (PRA), it is unavoidable to estimate the human error probability (HEP) of human operators who have to conduct various kinds of safety-critical tasks in these digital MCRs environments.

In this situation, one of the fundamental questions to be technically resolved is the reuse of existing human reliability data that have collected for many decades under an analog environment. There is a strong claim advocating that the existing human reliability data are still valid for the HRA of digital MCRs because the nature of required tasks to be conducted by human operators working in both types of MCRs (e.g., detecting an alarm, reading an indicator, and manipulating a component) are almost identical. In contrast, there is an opposite opinion emphasizing that the update of human reliability data is inevitable because human operators exposed to entirely different working environment compared to that of analog MCRs.

Accordingly, it is urgent to clarify whether or not dedicated human reliability data should be collected from the digital MCRs. In this light, the most straightforward solution would be to compare two sets of human reliability data in the level of basic task types, which gathered from both the analog and digital MCRs along with an identical technical basis.

For this reason, in this study, two sets of human reliability data (one from an analog MCR and the other from a digital MCR) were directly compared with respect to 21 basic task types that were proposed in HuREX (Human Reliability data Extraction) framework. The HuREX framework was established by Korea Atomic Energy Research Institute (KAERI), and it provides detailed processes to extract diverse human reliability data including HEPs from available sources such as simulator experiments and event investigation reports [1].

2. HuREX framework

The HuREX framework proposes four phases to collect human reliability data. They are: (1) preparation, (2) qualitative data collection, (3) quantitative data analysis, and (4) data reporting [1].

Briefly, the first phase aims to initialize the collection of human reliability data by conducting typical activities including: (1) specify the purpose and scope of data collection, and (2) prepare three kinds of information gathering templates (IGTs) to successfully reap raw information from available sources (e.g., simulator experiments), which is crucial for extracting human reliability data. In addition, the HuREX framework considers 23 basic task types that were identified from four kinds of cognitive activities including information gathering, situation interpretation, response planning, and action (or execution). Of them, Table I shows 21 basic task types with the associated human error modes [2].

For example, the basic task type of 'Verifying alarm occurrence' denotes the behavior of human operators who have to verify whether or not a specific alarm is activated. Since the intention of this behavior is related to an information gathering (IG), its abbreviation is assigned as 'IG-Alarm.' Similarly, the behavior of human operators who need to distinguish the status of an indicator (i.e., 'Verifying state of indicator') can be distinguished as 'IG-Indicator.' It should be noted that more detailed explanations about the basic task types of the HuREX framework can be found from Ref. [2].

Based on the catalog of basic task types and three kinds of IGTs, in the second phase, various kinds of qualitative information can be systematically grasped from the available sources (e.g., raw information for describing and/or understanding when and why human operators showed erroneous behaviors). In order to facilitate this process, the HuREX framework designated the catalog of erroneous behaviors with

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predefined rules for their objective identification, which are approved by many subject matter experts (SMEs) of both HRA and the operation of NPPs. The IGTs can be filled out by reviewing these raw information.

Table I: Basic task types of the HuREX framework and the associated human error modes; adopted from Ref.[2]

	Basic task type	Abbreviation[1]	Error mode[2]
1	Verifying alarm occurrence	IG-Alarm	EOO, EOC
2	Verifying state of indicator	IG-Indicator	EOO, EOC
3	Synthetically verifying information	IG-Synthesis	EOO, EOC
4	Reading simple value	IG-Value	EOO, EOC
5	Comparing parameter	IG-Comparison	EOO, EOC
6	Comparing in graph constraint	IG-Graph	EOO, EOC
7	Comparing for abnormality	IG-Abnormality	EOO, EOC
8	Evaluating trend	IG-Trend	EOO, EOC
9	Entering step in procedure	RP-Entry	EOO
10	Transferring procedure	RP-Procedure	EOO, EOC
11	Transferring step in procedure	RP-Step	EOO, EOC
12	Directing information gathering	RP-Information	EOO, EOC
13	Directing manipulation	RP-Manipulation	EOO, EOC
14	Directing notification/request	RP-Notification	EOO, EOC
15	Diagnosing	SI-Diagnosis	EOO, EOC
16	Identifying overall status	SI-Identification	EOO, EOC
17	Predicting	SI-Prediction	EOO, EOC
18	Manipulating simple (discrete) control	EX-Discrete	EOO, WDEV,WDIR
19	Manipulating simple (continuous) control	EX-Continuous	EOO, WDEV, WDIR, WQNT
20	Manipulating dynamically	EX-Dynamic	EOO, WDEV, WDIR, WQNT
21	Notifying/requesting to the outside of MCR	EX-Notification	EOO, EOC

[1]IG (Information Gathering), RP (Response Planning), SI (Situation Interpretation), EX (Execution)
[2]EOO (Error Of Omission), EOC (Error Of Commission), WDEV (Wrong Device); WDIR (Wrong Direction); WQNT (Wrong Quantity)

For example, in the case of simulator experiments, these raw information can be found from audio-visual records. Moreover, additional raw information can be obtained by investigating additional sources such as: (1) the chronological history of important parameters (e.g., pressure, water level, and temperature), (2) the catalog of activated alarms, and (3) the list of components manually operated during simulator experiments. After the collection, the cross-checking of raw information among SMEs should be also performed in this phase.

The third phase is a crucial part of the HuREX framework because various kinds of quantitative human reliability data (e.g., HEPs) can be visualized by analyzing the contents of IGTs in detail. However, even though a huge amount of human reliability data were extracted from the third phase, they are less meaningful unless they are not able to sufficiently inform HRA practitioners. This means that the fourth phase is also critical in terms of collecting human reliability data. In other words, it is indispensable to contemplate how to actually customize human reliability data obtained from the HuREX framework into useful insights or data that can directly support HRA practitioners. For this reason, KAERI is now spending a huge amount of effort to elaborate how to bolster HRA practitioners using human reliability data extracted by the HuREX framework.

3. Human reliability data collected from both an analog and digital MCR

KAERI conducted a large campaign of human reliability data collection based on the full-scope training simulators of domestic Korean NPPs. These full-scope training simulators are the replica of actual MCRs that installed in commercial NPPs. In addition, since these NPPs were constructed in 1980s, the training simulators are equipped with analog monitoring and control devices (e.g., alarm tiles, indicators, charts, knobs, buttons, and switches). Human operators working in the MCR of domestic Korean NPPs participated in this campaign [3]. During this data collection campaign, it was observed that a total of 10,768 basic task types were conducted by human operators. In addition, it was revealed that the number of human errors identified from this data collection campaign were 129. Of them, the number of EOOs (Error Of Omissions) and EOCs (Error Of Commissions) is 83 and 46, respectively. Based on the opportunity of basic task types and the associated human errors, KAERI calculated the catalog of HEPs, which is one of the representative human reliability data.

After the campaign of human reliability data collection from an analog MCR, KAERI initiated a follow up campaign with the collaboration of KHNP (Korea Hydro and Nuclear Power company), of which the main objective is to secure human reliability data from a digital MCR. In this regard, the full-scope training simulator of APR1400 was used with the cooperation of human operators working in commercial

NPPs. The full-scope simulator of APR1400 is equipped with up-to-date monitoring and control devices (e.g., alarm system, soft control, and information display system), which were developed by digital technologies [4]. From this data collection campaign, it was observed that a total of 44,568 basic task types were conducted by human operators. In addition, it was revealed that the number of human errors identified from these simulations were 251. Of them, the number of EOOs (Error Of Omissions) and EOCs (Error Of Commissions) is 158 and 93, respectively.

4. Discussion and conclusion

From these two kinds of data collection campaigns, it is possible to directly comparable human reliability data because they were extracted from the identical basis (i.e, the HuREX framework). This implies that these two sets of HEPs calculated from these data collection campaigns could be a good reference that clarifies several key questions pertaining to the installation of a digital MCR, such as 'can we directly apply human reliability data obtained from an analog environment to conduct the HRA of a digital MCR?' In this regard, Table II shows a part of comparison results.

Table II: Part of HEP comparisons between an analog and digital MCR (task types pertaining to information gathering)

ID	Basic task type	Abbreviation	Error[1]
1	Verifying alarm occurrence	IG-alarm	-67%
2	Verifying state of indicator	IG-indicator	+300%
3	Synthetically verifying information	IG-synthesis	-63%
4	Reading simple value	IG-value	-82%
5	Comparing parameter	IG-comparison	-99%
6	Comparing in graph constraint	IG-graph	-96%
7	Comparing for abnormality	IG-abnormality	-88%
8	Evaluating trend	IG-trend	-89%

[1]Relative error calculated by the following formula: (HEP from digital MCR - HEP from analog MCR)/HEP from analog MCR

For example, in the case of the first basic task type ('Verifying alarm occurrence'), the relative error of these two HEPs can be calculated as -67%. In other words, the median HEP in the digital MCR is 67 percent smaller than that of the analog MCR. In contrast, in the case of the second basic task type, the relative error denotes that the median HEP in the digital MCR is 3 times higher than that of the analog MCR. In this regard, in general, it can be said that human reliability data of the digital MCR are very different from those of the analog MCR. From this insight, therefore, it is possible to conclude that the dedicated set of human reliability data should be collected in order to conduct the HRA of a digital MCR. In addition, since the difference of HEPs between the analog and digital MCR probably means that the contexts of a task exposed to human operators are distinguishable, it is necessary to develop a new HRA method that can properly capture the effect of unique characteristics in the digital MCR on the likelihood of human errors.

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