ANALYTIC APPROACH FOR HUMAN RELIABILITY ANALYSIS OF NUCLEAR RESEARCH REACTORS IN ASEAN REGION

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EXTENDED ABSTRACT

Nowadays, digital Instrumentation & Control (I&C) systems are increasingly being implemented in nuclear facilities as human-machine interfaces [1, 2]. These digital systems serve as the core system of nuclear facilities providing operators with monitoring and safety functions for abnormal events as well as automatic protection functions of the reactor core during potential accidents [3]. The transition from analogue system control to human-machine interfaces in the digital Main Control Room (MCR) can significantly impact the changes of crew roles, teamwork, and work performance [4]. Due to the influence of human factors on digital control systems, Human Reliability Analysis (HRA) has become an essential tool for identifying potential human errors and assessing their probabilities as data for regulatory and technical objectives [5].

Similarly, Nuclear Research Reactors (NRRs) in the Association of Southeast Asian Nations (ASEAN) are typically operated using I&C systems. Previously different HRA tools were applied to investigate human errors and estimate their probabilities. For example, Indonesia utilized the Human Factors Analysis and Classification System (HFACS) method to examine Type A human errors from operational experience data from the primary cooling system of the Reaktor Serba Guna G.A. Siwabessy (RSG-GAS) reactor [6]. Regarding the Puspati TRIGA Reactor (PTR) of Malaysia, Type C human errors were analyzed and quantified using the Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H) method [7]. As for Thailand, the HRA team identified human errors in potential initiating events of the Thai Research Reactor-1/Modification 1 (TRR-1/M1) through expert judgment and a specific HRA method [8].

Since ASEAN countries operating NRRs plan to exchange HRA data, in 2023, the Thailand Institute of Nuclear Technology (TINT) proposed an HRA project to the ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) to jointly investigate the operating culture profile and develop and conduct HRA in the region based on the guideline of the Korea Atomic Energy Research Institute (KAERI) [9, 10]. Fig. 1 shows the results of ASEAN NRR operators' cultural profiles compared to operating cultures of commercial Nuclear Power Plant (NPPs) using Hofstede's model. The results of these two cases were oriented in similar directions. The operating cultures of ASEAN NRR operators and commercial NPPs are suitable for studying and sharing HRA data to each other.

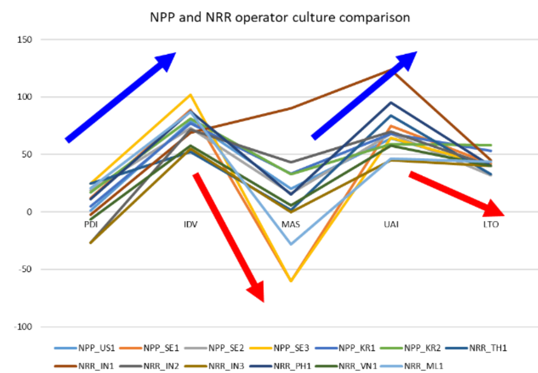

FIGURE 1. ASEAN NRR operators' cultural profiles compared to operating cultures of commercial NPPs using Hofstede's model (TH = Thailand, ML = Malaysia, IN = Indonesia, VN = Vietnam, PH = Philippines, US = United States, SE = Sweden, KR = South Korea)

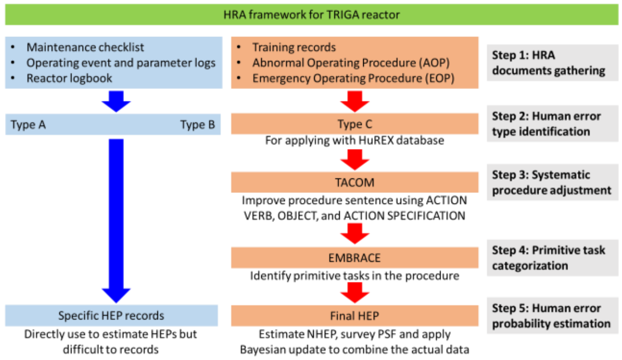

FIGURE 2. HRA practical approach of HRA for NRRs

Fig. 2 shows the HRA practical approach of HRA for NRRs [11]. In 2024, TINT and KAERI together developed a practical approach of HRA for NRRs to estimate prior Nominal Human Error Probabilities (NHEPs) from the Human Reliability data Extraction (HuREX) and updating observed human errors through the Empirical data-Based crew Reliability Assessment and Cognitive Error analysis (EMBRACE). However, the practical approach is not convenient to conduct HRA as an ASEAN NPSR benchmark problem due to the time and resource consumption. Hence, in this study, an analytic approach is suggested as an alternative HRA method to support the HRA benchmark project to support the practical approach. In the analytic approach, as ASEAN NRRs adhere to specific procedures and time for handling emergencies, the Task Complexity (TACOM) score is recommended to estimate NHEPs.

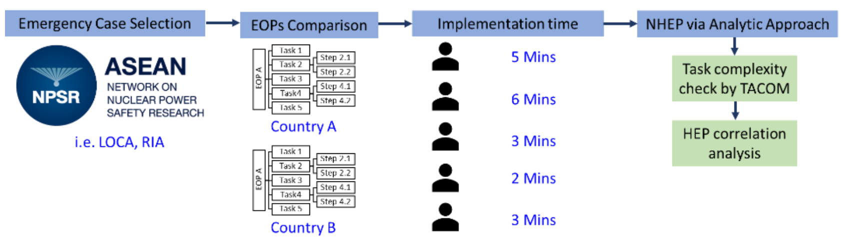

FIGURE 3. INTERNATIONAL HRA BENCHMARK STUDY IN ASEAN NPSR

Fig. 3 shows the scope of the international HRA benchmark study in ASEAN NPSR. To start the international HRA benchmark in ASEAN NRRs in ASEAN, HRA practitioners have to together discuss and select emergencies and accidents that possibly occur in general for NRRs. The complexity score of Emergency Operating Procedures (EOPs) of selected emergencies and accidents will be calculated using TACOM score [12]. The operators will be requested to provide the task performance time of the EOPs.

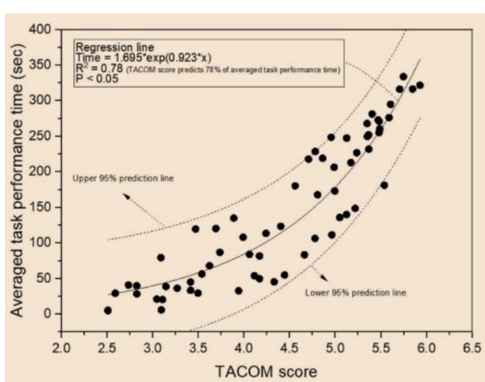

FIGURE 4. CORRELATION BETWEEN TASK PERFORMANCE TIME AND TACOM SCORE OF NPPS

Fig. 4 shows the correlation between task performance time and TACOM score [13]. The HRA implementors will check the correlation between task performance time and TACOM score. If the correlation is consistent with the empirical model of task performance time and TACOM score in Fig. 4. The overall TACOM scores of EOPs be used to estimate possible NHEPs based on the empirical model in Eq. (1) recorded unsafe act database of HuREX [14].

$$p(x) = \frac{1}{1+e^{-(1.901x-9.643)}} \quad (1)$$

where $\boldsymbol{p(x)}$ is the estimated probability of unsafe act and $\boldsymbol{x}$ is TACOM score.

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