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Scope Preparation for Human Reliability Analysis Benchmark of ASEAN Nuclear Research Reactors

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ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) investigated the operating culture profile of Nuclear Research Reactors (NRRs) operators using Hofstede's culture indices in order to assess the homogeneous operating culture before initiating the Human Reliability Analysis (HRA) benchmark project for sharing the human performance data and together developing HRA methodology. Thailand Institute of Nuclear Technology (TINT) and Korea Atomic Energy Research Institute (KAERI) together developed the specific HRA framework for NRRs to serve the HRA benchmark project. This study aims to show the scope of preparation for the international HRA benchmark in ASEAN NRRs with limited human error data using an analytic approach and a practical approach. In the analytic approach, since ASEAN NRRs follow its specific procedures to manage the task during emergencies, TAsk COMplexity (TACOM) score is recommended as a linkage to estimate Nominal Human Error Probability (NHEP). As for the practical approach, the HRA framework for NRRs suggests simply estimating prior NHEPs from the Human Reliability data EXtraction (HuREX) and updating the observed human errors using the EMpirical data-Based crew Reliability Assessment and Cognitive Error analysis (EMBRACE). A higher HEP between the two approaches is expected to provide the final HEPs as a human error database for the international HRA benchmark in ASEAN NRRs.

Keywords: Human reliability analysis, Nuclear research reactor, HRA benchmark study, ASEAN NPSR

1. Introduction

Nowadays, many nuclear facilities apply digital Instrumentation & Control (I&C) systems to support monitoring and control [Bye 2023]. Digital I&C systems possibly affect human actions through the use of human-machine interfaces such as the relation between crew roles, teamwork, and work performance. In the nuclear industry, Human Reliability Analysis (HRA) is an important tool supporting the identification of nominal tasks and probabilities as well as the consideration of related external factors through Performance Shaping Factors (PSFs).

Regarding Nuclear Power Plants (NPPs), HRA was developed to support the new technology of digital I&C systems in the framework of Probabilistic Safety Assessment (PSA). For example, the Korea Atomic Energy Research Institute (KAERI) developed the EMpirical data-Based crew Reliability Assessment and Cognitive Error analysis (EMBRACE) method which is an advanced HRA tool that was introduced for fully digital Main Control Room (MCR) of commercial NPPs such as Advanced Power Reactor 1400 (APR1400) [Kim et al. 2019; Kim et al. 2020]. As for Nuclear Research Reactors (NRR), the Thailand Institute of Nuclear Technology (TINT) developed the new HRA framework to estimate the Nominal Human Error Probability (NHEP) of the TRIGA research reactor in Thailand based on the EMBRACE method for its partial-digital MCR [Vechgama et al. 2024a].

Previously, the various HRA methods were developed by many countries consistently for the specific objective use or unique operating system of NPPs [Boring et al. 2010; Forester et al. 2014]. To understand the impact of using different HRA methods in NPPs or the same HRA approach in similar NPP types, HRA practitioners from multi-national NPPs initiated an international HRA empirical study. The objective of the study is to show findings and insights for the individual HRA methods in the Halden Reactor Project's Human-Machine Laboratory (HAMMLAB).

However, HRA for NRRs is commonly used from the HRA methods of NPPs with limited human error data, especially in the Association of Southeast Asian Nations (ASEAN). For instance, Indonesia analyzed operational experience data from the primary cooling system of the Reaktor Serba Guna G.A. Siwabessy (RSG-GAS) reactor using the Human Factors Analysis and Classification System (HFACS) method to identify Type A human errors [Santoso et al. 2019]. Malaysia analyzed Type C human errors in the Puspati TRIGA Reactor (PTR) and quantified these NHEPs using the Standardized Plant Analysis Risk Human Reliability Analysis (SPAR-H) method [Hassan et al. 2017]. Thailand identified human errors in potential initiating events of Thai Research Reactor-1/Modification 1 (TRR-1/M1) based on expert judgment and the specific HRA method [Vechgama et al. 2021].

To improve NRRs' HRA research knowledge and collaboration in the ASEAN region, in 2023, the Thailand Institute of Nuclear Technology (TINT) proposed an HRA project to the ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) based on the case study of the Korea Atomic Energy Research Institute (KAERI) [Vechgama et al. 2023]. The first HRA project became an important starting point of HRA research collaboration between the Republic Of Korea (ROK) and ASEAN NPSR Member States as well as the HRA benchmark assessment in the network. ASEAN NPSR countries operating similar NRR' types, namely Thailand, Malaysia, Indonesia, Philippines, and Vietnam, planned to share human performance data with each other for their own HRA implementation. Operating culture survey based on Hofstede's models were used to compared to check and confirm homogeneous operating cultures for supporting the sharing of human performance data in ASEAN NRRs. However, to support better ASEAN regional safety, the identical HRA approach is discussed and proposed to reduce the bias and uncertainty of sharing HRA data in using different HRA methods of ASEAN countries. Thus, the objective of this paper is to provide the scope for the international HRA benchmark in ASEAN NRRs to support the safe and reliable operation of NRRs among the ASEAN region.

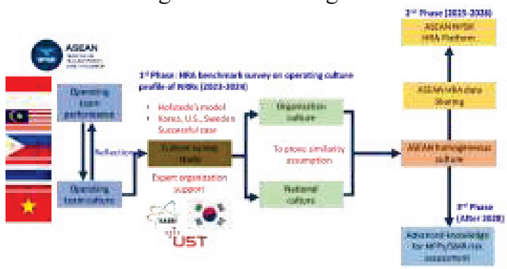

Fig. 1. ASEAN NPSR HRA collaborative research roadmap.

2. ASEAN NPSR HRA Research Project

Fig. 1 shows the ASEAN NPSR HRA collaborative research roadmap. ASEAN NPSR organized the technical meeting on HRA of NRRs supported by TINT to discuss the collaborative research with the five ASEAN countries operating the NRRs namely Thailand, Malaysia, Indonesia, the Philippines, and Vietnam with the experts' guidelines from KAERI [Vechgama et al. 2023]. Overall, the project aims to strengthen research collaboration on nuclear safety and risk assessment and management including HRA research between South Korea and ASEAN NPSR. The HRA project was divided into three phases consisting of 1) Phase 1: HRA benchmark survey on the operating culture profile of NRRs (2023-2024), 2) Phase 2: ASEAN NPSR HRA platform and methodology development (2025-2028), and 3) Phase 3: Research extension of PSA and HRA to power reactor (After 2028).

2.1. *Phase 1: HRA Benchmark Survey on Operating Culture Profile of NRRs*

Five ASEAN NPSR countries operating NRRs namely Thailand, Malaysia, Indonesia, Philippines, and Vietnam started investigating homogenous operating culture using Hofstede's model before sharing operating team performance or human error with each other in the HRA project [Vechgama et al. 2024b].

Homogeneous operating culture is considered important positive evidence to support the idea that HRA practitioners collect, use, and share human performance data in different countries and/or organizations together. ASEAN NPSR HRA practitioners surveyed and analyzed the national culture values of NRR operators to investigate homogeneous culture from five dimensions of Hofstede's models including 1) power distance index (PDI), 2) individualism index (IDV), 3) masculinity index, (MAS), and 4) uncertainty avoidance index (UAI), and 5) long-term orientation index (LTO) using the questionnaire from the successful case study of the RoK. It was found that the high correlations of culture well supported HRA data sharing in ASEAN NRRs.

2.2. *Phase 2: HRA platform and methodology development*

This phase aims to develop an ASEAN NPSR HRA platform and methodology for assessing human risk in NRRs' operations. After TINT and KAERI developed the specific HRA framework for NRRs to serve the HRA benchmark project [Vechgama et al. 2024a]. To implement the international HRA benchmark in ASEAN NRRs, it is important to identify the scope of the international HRA benchmark in ASEAN NRRs. The expectation of the use of convergent HRA analysis in this ASEAN project not only reduces the bias of HRA data transfer but also provides a validated HRA framework in sharing the lesson learned of human error actions in improving EOPs from one NRR to another NRR. Section 3 will explain the expected the scope of international HRA benchmark in detail which is the main objective of this paper.

2.3. *Phase 3: Research Extension of HRA to Power Reactor*

Interest in Small Modular Reactors (SMRs) in ASEAN led to the implementation of a pre-feasibility study, feasibility study, public perception analysis, and related nuclear safety research in the network. Thus it is important to transfer the knowledge from the ASEAN NPSR HRA platform and methodology in Phase 2 to the power reactor when ASEAN MSs decide to go to NPPs' program.

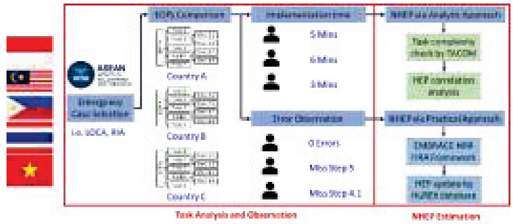

Fig. 2. Scope of the international HRA benchmark study in ASEAN NPSR.

3. Scope of International HRA Benchmark Study in ASEAN NPSR

Fig. 2 shows the scope of the international HRA benchmark study in ASEAN NPSR. The scope of the international HRA benchmark study is simply divided into 1) Task Analysis and observation and 2) HEP estimation.

3.1. *Task Analysis and Observation*

To start the international HRA benchmark in ASEAN NRRs, HRA practitioners would together discuss and select emergencies and accidents that possibly occur in general for NRRs. After selecting the emergency or accident representative, the Emergency Operating Procedures (EOPs) of the accident in each will be extracted and compared. Since each ASEAN NRRs follow its specific procedures to manage tasks or steps during emergencies, the different complexity can affect the different operating performance. ASEAN NRRs will be requested to provide the implementation time of the EOPs and possible human errors while following the procedures. Implementation time and human errors can be extracted from emergency training, simulator, and expert survey. These two data will be used to estimate NHEPs using an analytic approach and a practical approach.

3.2. *NHEP Estimation*

To estimate NHEP using the analytic approach, the TAsk COMplexity (TACOM) method is recommended to estimate the complexity of procedures using the suggested TACOM score [Park, 2009]. The set of TACOM scores of EOPs and the implementation time of NRRs will be compared with the time-complexity correlation of NPPs to provide possible NHEPs based on the recorded unsafe act database [Jang and Park

2022; Jang et al. 2024]. As for the practical approach, the EMBRACE-HRA framework for NRRs suggests simply estimating prior NHEPs from the Human Reliability data EXtraction (HuREX) database [Vechgama et al. 2024a]. The human errors from the EOPs implementation will be considered as the observed evidence to update NHEPs using the Bayesian update. Higher HEP between analytic approach and practical approach will be selected as the final NHEPs.

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