Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-20, 2022

Use of the SAM-L2HRA Method for Evaluation and Improvement of SAMG Strategy

Jaewhan Kim*, Soo-Yong Park
KAERI, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, 34057, Republic of Korea
**Corresponding author: jhkim4@kaeri.re.kr*

1. Introduction

One of the major issues in enhancing Level 2 PSA (L2PSA) is an adequate modeling of severe accident management guidelines (SAMGs) into the L2PSA framework. A key technology to achieve the goal is the human and organizational factors reliability analysis (HOFRA) of SAMG strategies and actions which are requested under severe accident conditions [1]. Human reliability analysis (HRA) has been conducted in the PSA to identify and assess human failure events (HFEs) to be incorporated into the PSA model in a probabilistic way.

A new Level 2 HRA method, SAM-L2HRA (i/e., HRA for SAM strategies), was developed on the basis of plant-specific SAMGs [2]. SAM-L2HRA consists of two parts of analysis, i.e., (1) a time uncertainty analysis for estimating the failure probability of a SAM strategy using the convolution between two time distributions, i.e., time available and time required, and (2) task-based analysis of error potential or decision-making likelihood.

2. A Framework of SAM-L2HRA

A SAMG strategy consists of several tasks from the identification of necessity for a strategy, through evaluation of the effectiveness as well as negative impacts, and decision-making on whether to implement or not, to the implementation of the strategy, as shown in Fig. 1.

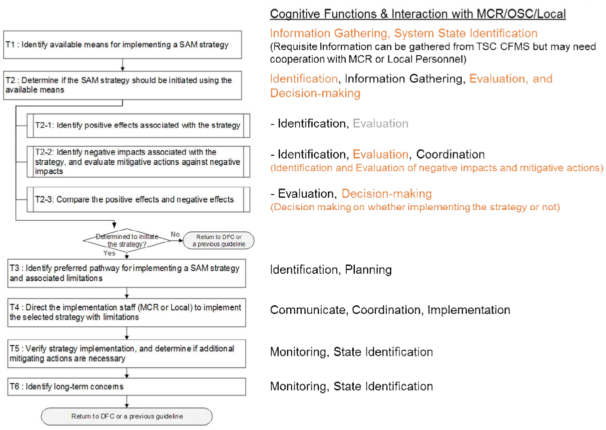
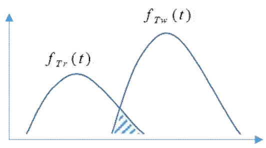


Fig. 1. A task structure of a severe accident guideline (SAG)

For an adequate evaluation of a SAMG strategy, both time-based and task-based assessment of the important aspects associated with the strategy are required. The time uncertainty analysis method is adopted for time-based assessment, which uses the convolution between two time distributions of time available and time required. The distribution of time available takes account of phenomenological uncertainty associated with a severe accident event such as a reactor vessel failure, and the distribution of time required for an individual SAM strategy represents the total integrated time from the entry point of SAMG to the completion point of implementation of a strategy under consideration. Fig. 2 shows the conceptual schematics of the time-based estimation of reliability associated with implementation of a SAMG strategy.



$$P_{Fr} = \Pr(T_r > T_w)$$
$$= \int_0^\infty f_{T_W}(t) \cdot [1 - F_{T_r}(t)]\, dt$$
$$= \int_0^\infty f_{T_r}(t) \cdot F_{T_W}(t)\, dt$$

$f_{T_r}(t)$=*probability density function of the time required for implementing a SAM strategy*
$f_{T_W}(t)$= *probability density function of the time available for a SAM strategy*
$F_{T_r}(t)$=*cumulative distribution function of the time required for implementing a SAM strategy*
$F_{T_W}(t)$= *cumulative distribution function of the time available for a SAM strategy*

Fig. 2. Convolution of two time distributions to obtain time-based reliability for a SAM strategy

The task-based analysis part deals with error potential or decision-making likelihood associated with critical steps or activities needed for decision-making and successful implementation of a strategy. The steps or activities to be analyzed include the availability or survivability of essential information needed for recognition of a strategy implementation and monitoring the effectiveness of a strategy implementation, the effect of negative impacts associated with a strategy on a decision-making and its probability of likelihood, and the reliability of the implementation activity in which coordination and cooperation between distributed organizations such as the technical support center (TSC), the main control room (MCR) and the local operating personnel in charge of actual implementation using installed equipment or portable/mobile equipment are of critical importance to the success of an implementation. Fig. 3 shows the conceptual schematics of the task-based estimation of reliability associated with implementation of SAM strategies. Fig. 4 provides a decision tree for estimating the likelihood of decision-making for a strategy considering positive and negative impacts

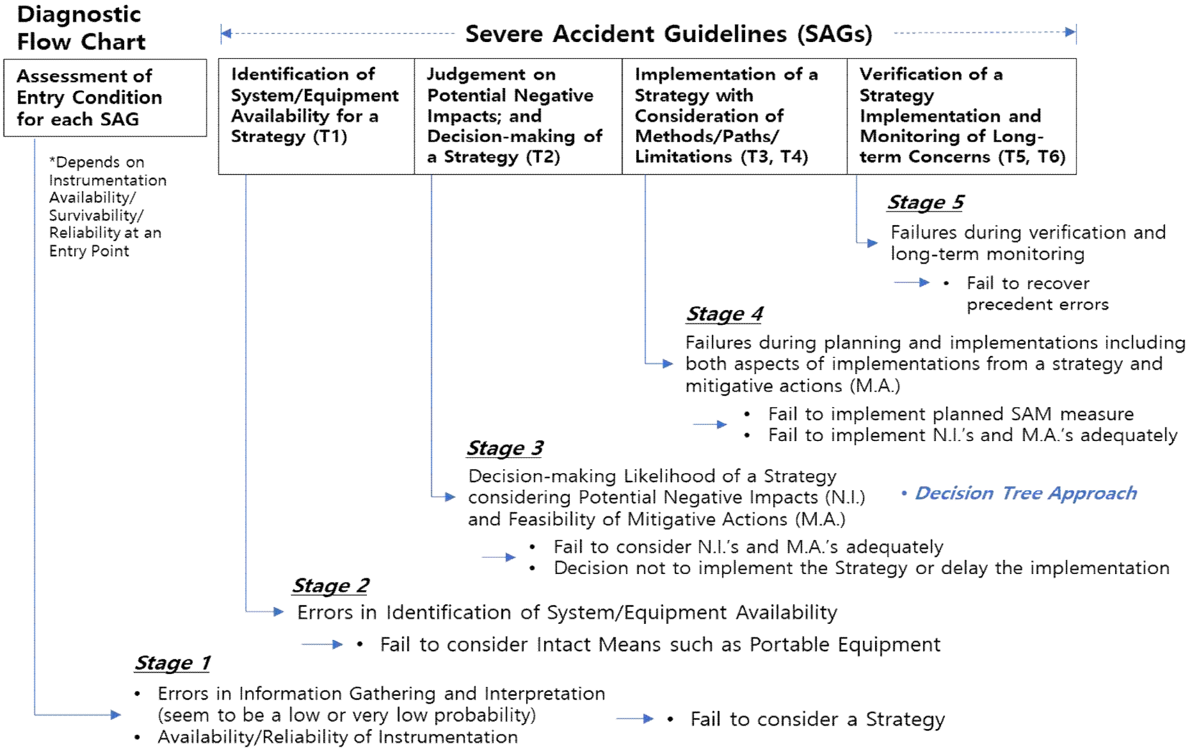


Fig. 3. Task-based analysis of human error potentials and decision-making likelihood of SAM strategies

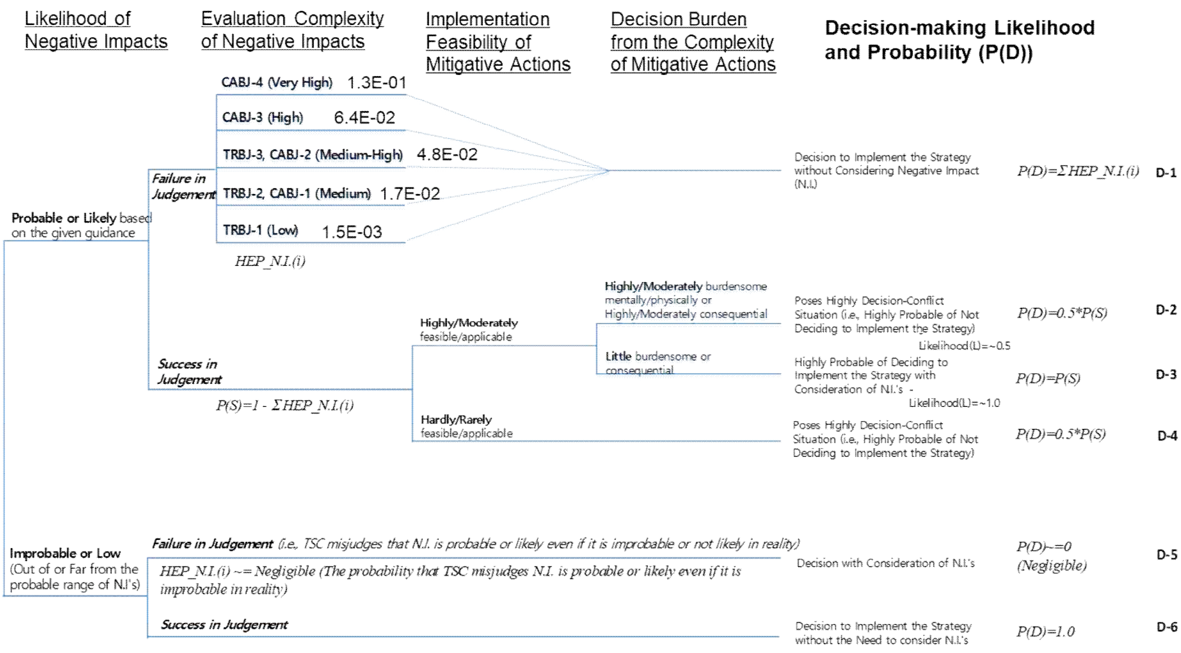


Fig. 4. Decision tree for estimating the likelihood of decision-making

3. Application of SAM-L2HRA to Evaluation and Improvement of SAMG Strategy

The SAM-L2HRA method was tentatively applied for evaluation and improvement of a SAM strategy that uses portable equipment under complete loss of fixed safety systems. The postulated scenario is the RCS low pressure condition, led by the total loss of component cooling water (TLOCCW) and RCS depressurization at APR1400.

The RCS injection strategy using a portable pump as a measure to preserve the integrity of RCS was evaluated. An existing strategy was evaluated first, and an improved measure is suggested and evaluated using the SAM-L2HRA method. Both existing and improved measures with operation conditions are summarized below.

An existing measure for RCS injection:

- RCS depressurization before SAMG entry or at entry point
- Injection of the safety injection tank (SIT) water into the RCS
- RCS injection using a portable pump and isolation of SIT at RCS P1

An improved measure for RCS injection:

- RCS depressurization before SAMG entry or at entry point
- Injection of the safety injection tank (SIT) water into the RCS
- RCS injection using a portable pump and isolation of SIT at RCS P2 (lower than P1)

Fig. 5 shows the time uncertainty analysis results for the available time with success probability for both existing and improved measures. The existing measure needs to be injected within 2h 20m after SAMG entry to assure the RCS integrity. For an improved measure, the time available for RCS injection extends until 6h 20m after SAMG entry. 4h makes an effective improvement in extending the time available for implementing the strategy using a portable pump.

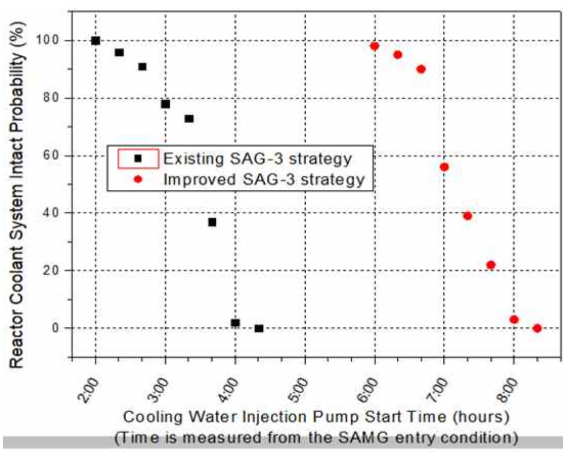


Fig. 5. MAAP uncertainty analysis for the time available for RCS injection strategy with success probability

Fig. 6 compares the time available and the time required for RCS injection using a portable pump for an existing measure. The time required is expected to be much larger than the time available, therefore the strategy is apparently going to a failure to implement within the time limit. As compared with Fig. 6, Fig. 7 gives an extended time available for an improved RCS injection measure. In this case, the time margin, i.e., the time available minus the time required, is sufficiently large, and the time-based assessment of failure probability gives an HEP of 3.2E-2. The task-based failure probability for this case is estimated to be 1.25E-2. This leads to the final failure probability, 3.2E-2, which is determined from the maximum of two HEPs.

Fig. 6. Time comparison between the time available and time required for RCS injection and the resulting HEP for an existing RCS injection measure

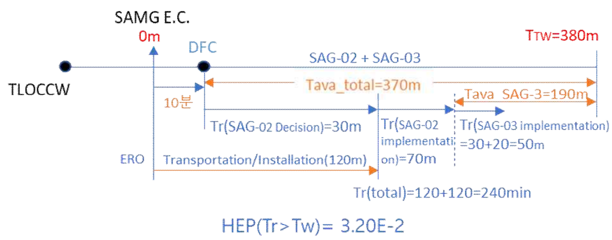


Fig. 7. Time comparison between the time available and time required for RCS injection and the resulting HEP for an improved RCS injection measure

4. Conclusion

The SAM-L2HRA method was tentatively applied to the evaluation of existing and improved SAMG measures which make use of portable equipment. The study showed that the method enables the analysts to identify major characteristics and vulnerabilities associated with a SAM strategy, as well as quantify the probability of failure to successfully complete the strategy.

REFERENCES

[1] Kim J, Cho J, Technical challenges in modeling human and organizational actions under severe accident conditions for Level 2 PSA, Reliability Engineering and System Safety 194; 106239, 2020.

[2] Kim J, Suh YA, Cho J, Jung W, Park J. Level 2 HRA: A SAMG-based Detailed HRA Method. KAERI/TR-8118/2020, Daejeon, 2020.