Evaluation of human error probability for cognitive and diagnosis task considering environmental influence under a severe accident condition in npp

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Abstract: When a severe accident occurs at a multi-unit site, the situation of the plant system changes over time as the adjacent unit's system progresses. Consequently, certain factors, such as operator stress and the time available to complete tasks, increase in response to the changing context. However, it is challenging to quantitatively evaluate the impact of these parameters on the human error probability (HEP). Especially in a multi-unit site, the dependencies between units lead to unique environmental changes in the working area, making it necessary to develop a method for estimating the HEP. Therefore, this study utilizes the dynamic master logic diagram and the fuzzy inference method to assess the HEP, taking into account the evolving context during a severe accident scenario in a multi-unit system. Additionally, it examines the influence of operator skills and the manual's readability on the HEP through fuzzy inference. Consequently, the study quantitatively evaluates the HEP under various stress and time margin conditions, considering the operator's skill level and the manual's readability.
Keywords: Human Reliability Analysis, Multi-unit PRA, Human Error Probability, Fuzzy Inference

1. INTRODUCTION

Probabilistic Risk Assessment (PRA) has been used for residual risk to improve the safety of nuclear power plants after the Fukushima Daiichi Nuclear Power Plant Accident in 2011. Some research efforts, such as the refinement of data and assessment of external hazards related events and accident sequences, have been made to improve the accuracy of the PRA methods. In addition to facility and equipment failures, PRAs need to also account for human failure events (HFE), which occur when operators are executing specific tasks and are unable to achieve the task objective or fail to accomplish the task, thereby significantly impacting an accident. The probability of failure for such a task is known as human error probability (HEP), and assessing this probability is a required part of human reliability analysis (HRA).

Conventional methodologies for HRA such as, THERP, and SPAH consider the HFE without considering effect of context changes[1]. However, research has revealed that the HEP is influenced by an environmental change (as known as context) where a task occurs. Thus, estimating the HEP considering a change in context is a key issue in improving the accuracy of the HRA [2-3]. However, some major HRA methodologies, such as ATHEANA, and SPAH-H, using the performance shaping factor (PSF) to evaluate change of context, still have difficulty evaluating the HEP precisely, quantitatively considering a change in the task context. Quantifications of effect of contextual change on HEP are challenging caused by lack of empirical data and vagueness of determining degree of how much changes of certain contextual changes bring changes of HEP [4].

Recently, multi-unit probabilistic risk assessment (PRA) has become one of the important issues in improving the safety of nuclear power plants after the Fukushima Daiichi Nuclear Power Plant accident in 2011. Through that experience, it is recognized that multi-unit dependencies can accelerate the accident progression and worsen the environmental condition. It also becomes an obstacle for the operator's work to mitigate accident sequences [5]. Thus, more complicated contextual changes need to be considered to evaluate the proper HEP. However, the current methodology multiplies a certain discrete number to the nominal HEP to consider the effect of change in environmental conditions.

Therefore, in this study, a method to consider the environmental change in evaluating the HEP become available to consider more complex contextual change using continuous PSF. For this, a dynamic master logic diagram consisting of a Bayesian network structure and a fuzzy inference is used to evaluate the effect of context in HEP quantitatively.

2. DYNAMIC MASTER LOGIC DIAGRAM FOR EVALUATING MULTI-UNIT DEPENDENCY FOR HEP ANALYSIS

In order to consider the effect of context in evaluating the HEP, the following two issues should be clarified quantitatively. Firstly, the degree of change in context caused by events related to multi-unit dependencies, and secondly, the degree of impact caused by the change in context on the HEP. However, insufficient related research exists to evaluate change in context quantitatively. Also, a lack of knowledge and empirical data on human nature makes it challenging to quantitatively evaluate the effect of change in the context of the HEP. Regarding the first issue, even though there is a lack of related data, it is possible to estimate the causal relationship between environmental change and its impact on factors related to the HEP. For example, if debris accumulates and becomes an obstacle on an access route in the site, it negatively impacts the HEP. As a result, the HEP will increase. For the second issue, qualitative estimation on the degree of increase in the HEP caused by a change in context. For example, if an operator feels a high level of stress, a HEP for a specific task becomes higher than the HEP when the operator feels a lower stress level.

Based on the basic concept that an event's occurrence changes the environmental conditions where the operator works, decreasing the operator's performance and causing more errors, we suggest two approaches to overcome the above two issues using: a Dynamic Master Logic Diagram, a Bayesian Network, and Fuzzy inference. Figure 1 shows the whole picture of the model. Evaluating the HEP is divided into two parts.

Dynamic Master Logic Diagram (DMLD) is a logic-based diagram to model the dynamic behavior of a physical system [6]. It is an extension of Goal Tree Success Tree and Master Logic Diagram decomposition method using the time-dependent fuzzy logic. Here, we use DMLD to evaluate the contextual changes quantitatively by defining the degree of change in context by the occurrence of an event based on causal logic using Bayesian Network Structure. Figure 1 shows the DMLS structure used in this study. Here, when multi-unit events occur, it causes context changes in 2 different aspects: time margin and stress, which let an operator make an error more easily. Here, we focus on how contextual changes impact the stress of the operator and the time margin for tasks. These two aspects are also widely used to consider contextual changes to evaluate the HEP as the PSF in the conventional methodology. The DMLG structure evaluates how much some environmental change brought by events brings changes in the stress and the time margin.

For example, here is a scenario in which a huge earthquake hits a site that has two nuclear power plants. The earthquake caused a loss of offsite power and may have been followed by core damage and a fission product release. In this case, an accident mitigation strategy of a containment vessel cooling using a large-capacity portable pump is supposed to consider preventing and mitigating the accident progression. Thus, the operator's task can be divided into three parts: a recognition and diagnosis task, a transport and installation task, and an execution task.

Postulated environmental changes caused by multi-unit-related events are a loss of offsite power and debris on access routes induced by an earthquake. These environmental changes bring the error-forcing context, such as lack of lighting in the working area and debris removal. Also, core damage and fission product release in the target or adjacent units are postulated environmental changes. If these environmental changes occur, it causes increased radiation levels in a working environment, and the operators must wear radiation-protecting clothing, which decreases the operator's working performance results. So, it requires the operator more time to complete the task compared to under the normal condition. Also, knowing that core damage and an FP release take place in the target or adjacent unit makes the operator feel fear; thus, the stress level of the operator increases.

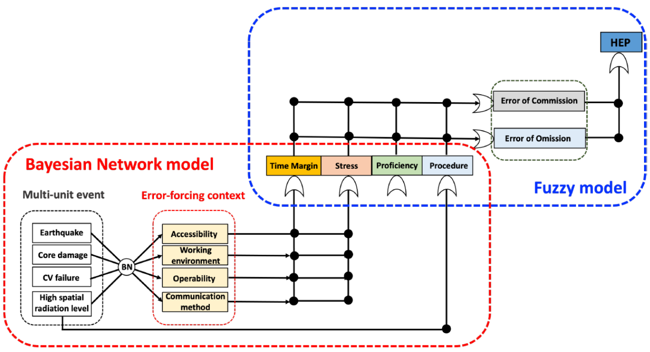

Figure 1 Dynamic Master Logic Diagram for Evaluation of HEP Considering the Context Caused by Multi-unit Events

2.1. Bayesian Network Model for estimation influence of Error-forcing context on time margin and stress

In this study, the context change is considered an error-forcing context. The error-forcing contexts impact a task's time margin and an operator's stress, two main factors related to the HEP. A degree of the influence on the time margin and the stress caused by the change in error-forcing context triggered by the multi-unit events is evaluated based on a causal relationship using the Bayesian Network model. Figure 2, 3 shows Bayesian network structure to represent causal relationship between environmental change and the time margin and the stress.

As mentioned above, if an earthquake generates debris that blocks an access route to the working place where the portable pump needs to be installed, the debris must be removed from the route and takes some time to complete. As a result, the time margin to complete the task decreases. Also, a loss of offsite power brought by the earthquake makes operators work in the dark outside under a lack of lightning in the workplace; it requires more time to complete the task than without a lack of light. Furthermore, suppose the radiation level in the workplace increases because of core damage or a containment vessel failure in the target unit or adjacent unit. In that case, operators should wear radiation protective gear while they are working. This decreases the operator's performance and requires more time to complete the task under normal conditions. For stress, the loss of offsite power causes a lack of lighting in the workplace, and the occurrence of a huge earthquake, core damage, and fission product release makes operators more fearful, which increases their stress.

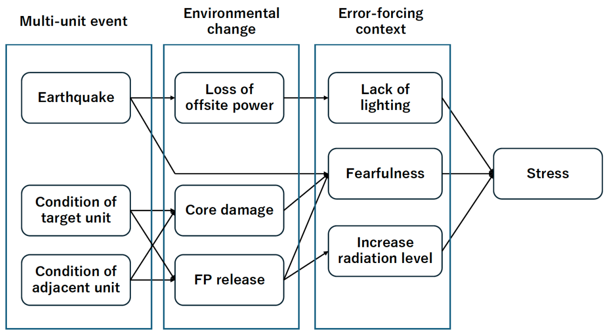

Figure 2 Bayesian network structure to evaluate impact of environmental change on stress

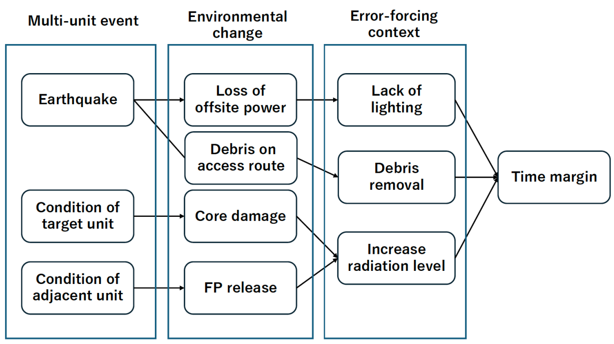

Figure 3 Bayesian network structure to evaluate impact of environmental change on time margin

For the second issue, Fuzzy inference is used to evaluate vagueness in the degree of impact of changes in the context of the HEP. Fuzzy inference is a mathematical approach handling ambiguousness with Boolean algebra with fuzzy sets [7]. the fuzzy inference is used to evaluate the HEP considering the changes in context represented by two factors: the time margin and stress.

Figure 2 shows the causal relationship of an accident mitigation strategy of injection between the error-forcing context using the Bayesian network structure. Here, we only explain accessibility in detail. If a multi-unit related event occurs, it will cause error-forcing conditions, such as a damage on the access route, loss of lighting on the access route, and loss of personnel lighting equipment. These happenings in error-forcing conditions make the accessibility worsen. As a result, the HEP will increase. The relationship between the multi-unit events and the error-forcing context is described based on the causal relationship using the Bayesian network structure. The probabilities that those events occur are estimated using a conditional probability table.

2.1.1. Quantification for Time Margin Evaluation

The availability of time margin to complete the necessary tasks is an important consideration in the risk assessment of the mitigation strategies equipment. To support this effort, a timeline of the necessary actions should be constructed. The individual time elements comprising the timeline are as follows.

- **T_{Sw}** : System time window. The time limit for task completion
- **T_{Delay}** : Cue manifestation time. The period from the occurrence of an initiating event to the occurrence of a cue indicates the need for a task. Normally, it takes operators 5 minutes to take immediate actions associated with the initiating event.
- **T_{Trans}** : Transport time. It is a necessary time for operators to take equipment and bring it to the workplace.
- **$T_{Install}$** : Installation time. This is the time to install equipment in its necessary place. For example, it includes opening valves to align the suction and discharge paths.
- **T_{Exe}**: Execution time. It is the time necessary to start operating equipment to mitigate accident progression.
- **T_{Debris}**: Debris removal time. It is a time required for debris removal.

The time margin is calculated using the formula below [8]

$$\text{Time Margin (TM)} = [(T_{Sw}-T_{Delay} - T_{Debris})-(T_{Trans}+T_{Install}+T_{Exe})]/(T_{Trans}+T_{Install}+T_{Exe})\times 100\% \quad (1)$$

These time elements for a task can be obtained from the training data or analytical data operated by utilities. Table 1 shows the nominal time required to complete each task and postulates the increase of time elements caused by environmental change. The required time for the debris removal is defined according to the site and the magnitude of the earthquake. For example, according to a Japanese domestic utility's time estimation to establish an access route under a landslide triggered by an earthquake, it may take 190 minutes to 480 minutes for the debris removal [9]. Thus, in this study, 480 minutes is considered as the debris removal time. Also, while operators are working without using individual lighting devices under the loss of offsite power condition, the operator's performance decreases significantly, and it is assumed to require 50% more time to complete the task than under normal conditions. If the individual lighting device is available under the loss of offsite power condition, the operator's performance may decrease, but the degree is expected to be less than the condition without the individual lighting equipment. Thus, it is assumed that 30% more time is necessary to complete the task than is normal.

A time margin calculated using nominal time elements and Equation1, which means no environmental change is considered, is 113.6 %. According to the conventional approach dealing with the time margin, when the time margin is over 100%, it is considered that the time margin is sufficient, and it decreases the human error probability by half. If a time margin is between 0% and 100%, it is regarded that the time margin is adequate and does not negatively impact the HEP. However, if the time margin has a negative value, it is considered that the task fails, and the HEP becomes 1 because the time is insufficient to complete the task [10].

When environmental changes occur, the time elements are increased. As a result, the time margin decreases to an adequate or even insufficient level, causing an increase in the HEP.

Table 1 Increase time element caused by Error-Forcing Context

Event	Nominal	Debris	Lack of lighting Individual lighting (○)	Lack of Lighting Individual lighting (×)	Increase radiation level
T_{sw}	1440 min				
T_{delay}	30 min				
T_{debris}		+ 190 to 480 min			10% up
T_{trans}	60 min		30% up	50% up	10% up
$T_{install}$	570 min		30% up	50% up	10% up
T_{exe}	30 min		30% up	50% up	10% up

2.2.2. Quantification for Stress level

Stress is also known as another critical factor that increases the human error probability. Generally, it is said that stress is related to the performance effectiveness of an individual operator. In the THERP analysis, stress is divided into four different levels: very low, optimum, moderately high, and extremely high [1]. The performance effectiveness of a task is most high at the optimum level, and the performance effectiveness decreases as the stress level increases. Also, it is assumed that when an operator feels a high stress level, the HEP for a task will increase more than that under a lower stress level. According to a recent CRIEPI report about an HRA guideline, when an operator feels high pressure, the HEP for a related task is regarded as twice the HEP without the pressure [11].

Qualitative analysis of how much stress an operator feels under certain conditions needs to be based on a psychological analysis of human nature. However, no established method or knowledge exists. Therefore, in this study, a relative stress level increase brought by the occurrence of the environmental change is decided from 2 to 5 by comparing the event's relative severeness, which is low, normal, and high as shown in Table 2. If several events occur, the increased stress is assumed to be added to each other. Thus, the relative stress level can be from 2 to ~ 25 (when all error-forcing context occurs).

Here, two methodologies are used to quantify the time margin and stress. However, another difficulty remains: evaluating the change of time margin and stress on the HEP. A fuzzy inference is adopted to overcome this obstacle.

Table 2 Increase of relative stress caused by environmental change

Environmental change	Severeness	Increase of relative stress
Lack of lighting	Low	2
Fearfulness caused by an earthquake	Low	2
Fearfulness caused by core damage in target unit	medium	3
Fearfulness caused by core damage in adjacent unit	Low	2
Fearfulness caused by FP release in target unit	High	5
Fearfulness caused by FP release in adjacent unit	Medium	3
Increase radiation level in target unit	High	5
Increase radiation level in adjacent unit	Medium	3

3. FUZZY MODEL FOR ESTIMATION OF HEP UNDER VARIOUS CONDITIONS

3.1. Membership Function

Fuzzy theory, a practical mathematical approach, adeptly handles ambiguousness by transitioning from a crisp set to a fuzzy set. This transition is facilitated by a membership function, which effectively deals with uncertainty. In the context of HEP estimation, the most challenging aspect is often gauging the degree of HEP increase resulting from a change in context. For instance, if an operator's stress is high and the time margin is sufficient, how much does the HEP increase compared to when the time margin or stress levels are lower.

In our HEP estimation, we employ two membership functions, one for stress and the other for the time margin. The time margin is categorized into three types, offering a flexible approach. The first category is 'sufficient', indicating a time margin larger than 100% calculated based on equation 1. The second category is 'adequate', encompassing time margins between 0% and 100%. The third category, 'insufficient', is assigned when the time margin is negative, indicating a task failure due to time constraints. This study maintains the same time margin categories: 'sufficient', 'adequate', and 'insufficient' [10].

For stress, we assume that the initial stress level before multi-unit-related events is the same as 'optimum', which has the most high-performance effectiveness. As multi-unit-related events occur, the stress level will increase. Thus, there are three stress levels: 'moderately high', 'high', and 'extremely high'. For each stress level and related relative stress value, Table 3 explains.

Membership functions for the time margin and stress, as depicted in Figure 4 and Figure 5, are integral to our approach. It's important to note that strict rules do not govern the shape of the membership function; rather, it's a decision informed by experience. Including experiential knowledge in the decision-making process is a key aspect of our approach. By utilizing membership functions with fuzzy sets, we can estimate the ambiguousness around the boundary between two levels, which is challenging to accomplish using crisp sets.

Table 3 Definition of fuzzy set about stress level

Stress level	Magnitude of relative stress	Description
Optimum	Less than 2	A condition that a single environmental change occurred
Moderately high	3 ~ 6	A condition that two or three environmental changes occurred
High	7 ~ 12	A condition that a severe environmental change such as core damage or FP release in the target unit occurred with other environmental changes
Extremely high	Over 13	A condition that multiple severe environmental changes occurred

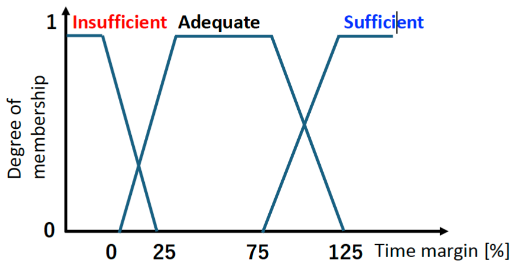

Figure 4 Membership Function for time margin

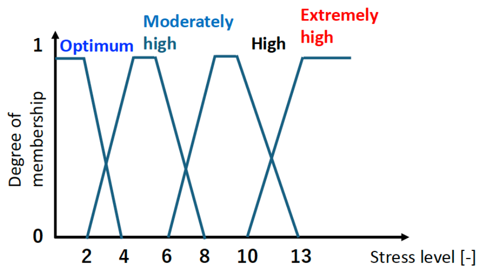

Figure 5 Membership Function for stress

3.1.2. Fuzzy Rule

In order to evaluate the HEP using Fuzzy inference, Fuzzy Rules are necessary. Fuzzy Rules represent a relationship between fuzzy sets. A Fuzzy rule consists of former condition and Latter conditions as follows.

If X is A and Y is B, then Z is C (2)

Here X, Y, Z are parameters/factors like Time margin, stress, HEP. A, B, C represent fuzzy set like time margin is 'adequate', and stress is 'moderately high'. For HEP fuzzy sets and membership functions are decided as shown in Figure 6 and Table 4. The HEP value used for the membership function, decided based on the result of HRA result. The HEPs in the category of medium, high, and very high are decided to become twice, 5 times, and 10 times of the HEP of low to harmonize with conventional HRA method to compare the result from two methodologies. Fuzzy Rules are decided as shown in Table 5. Here, a fuzzy rule is described as an example.

If stress is High and time margin is appropriate, then HEP is medium. (3)

Using these fuzzy rules HEP can be estimated quantitatively under various condition of time margin and stress considering change in context.

Table 4 Definition of fuzzy sets about human error probability

HEP	**HEP range**	**HEP value where degree of membership function become 1**
Low	[0.0, 0.01]	5.0E-03
Medium	[0.005, 0.015]	1.0E-02
High	[0.01, 0.05]	2.5E-02
Very High	[0.025, 0.175]	1.0E-01

Table 5 Fuzzy Rules for Human Error Probability Evaluation

		Time Margin		
		Sufficient	**Adequate**	**Insufficient**
Stress	**Moderately High**	**Low**	**Low**	**Failure**
	High	**Low**	**Medium**	**Failure**
	Extremely High	**Medium**	**High**	**Failure**

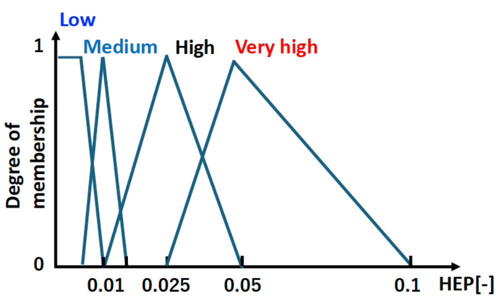

Figure 6 Membership Function for Human Error Probability

4. ESTIMATION OF HUMAN ERROR PROBABILIRY USING FUZZY INFERENCE

4.1. Scenario Description

As mentioned above, in this study, we have a preliminary analysis of a HEP about a seismic-induced accident scenario of a twin-unit system. An initiating event is S6 class earthquake following the Loss of Offsite Power event. For simplicity, each unit consists of components and operations, and if both factors fail for 4 hours, it is regarded as a core damage accident. The FP release will occur after 24 hours from the core damage condition. Two mitigation strategies for each level 1 and level 2 mitigation procedures are considered. An equipment failure or operational failure of both mitigation strategies are failed, it is considered the mitigation for that level is failed. Here, let us consider as an example one operational procedure for the Level 2 mitigation procedure, which is feeding seawater to containment vessel through the condensation tank using a portable fire pump. The estimated time margin using the nominal time elements in Table 6 is 113.6%. However, the estimated time margin decreases 64.3%, or 52.6% ac according to occurrence of the error-forcing context as shown in Table 6

4.2. HEP Estimation using Fuzzy Inference

Table 6 shows the estimated time margin and stress level of postulated environmental changes, considering contextual changes. The nominal HEP under the condition without error-forcing context is 5.0E-03. As the result of fuzzy inference, the HEP becomes 7.6E-03 under the condition that the time margin is 64.3% and the stress level is Moderately high, 1.0E-02, and 1.9E-02 under the time margin is 52.6%. The stress levels are High and Extremely High. However, as shown in Table 7, the estimated HEP change to 7.0E-03, 7.6E-03, 1.0E-2, and 1.9E-02 under the same condition postulated in Table 6 when190 minutes is required for the debris removal. The estimated HEP increases further when the time margin becomes shorter if debris removal requires 480 minutes, as shown in Table 8. These results show that the suggested method appropriately evaluates the change of HEP according to the time margin and stress level considering environmental changes. Figure 7 shows the estimated HEP under various conditions of the stress and time margin. The estimated HEP is between 5.0E-03 to 1.0E-01 and the HEP increase rapidly as time margin decrease less then 100% in the stress larger than 20. When the stress is less than the HEP increase gradually as time margin decreases. The unique feature of the estimated HEP using the suggested method is that the HEP is defined continuously according to a certain value of the stress and the time margin. It means that the suggested method can estimate HEP quantitatively considering various environmental changes compared to the fact that the estimated HEP by using the conventional methodology has only a few discrete values of HEP multiplied several times from the nominal HEP; however, the estimated HEP using the suggested methodology has continuous values with the changes of stress and the time margin. It shows a possibility that the suggested methodology can consider more complex environmental change and even evaluate time-dependent HEP as the environment changes with time progression.

Table 6 Estimated HEP under various condition considering environmental changes (when debris removal time is zero)

Error-forcing context				Time margin	Stress level	HEP
Fearfulness	Lack of lighting	Radiation level increase in target unit	Radiation level increase in adjacent unit			
×	×	×	×	113.6%	Optimum	5.0E-03
○	○	×	×	64.3%	Moderately High	7.6E-03
○	○	×	○	52.6%	High	1.0E-02
○	○	○	×	52.6%	Extremely high	1.9E-02

Table 7 Estimated HEP under various condition considering environmental changes (when debris removal time is 190minute)

Error-forcing context				Time margin	Stress level	HEP
Fearfulness	Lack of lighting	Radiation level increase in target unit	Radiation level increase in adjacent unit			
×	×	×	×	84.8%	Optimum	7.0E-03
○	○	×	×	42.2%	Moderately High	7.6E-03
○	○	×	○	32.0%	High	1.0E-02
○	○	○	×	32.0%	Extremely high	1.9E-02

Table 8 Estimated HEP under various condition considering environmental changes (when debris removal time is 480minute)

Error-forcing context				Time margin	Stress level	HEP
Fearfulness	Lack of lighting	Radiation level increase in target unit	Radiation level increase in adjacent unit			
×	×	×	×	40.9%	Optimum	7.0E-03
○	○	×	×	8.4%	Moderately High	4.7E-02
○	○	×	○	0.6%	High	7.3E-02
○	○	○	×	0.6%	Extremely high	9.2E-02

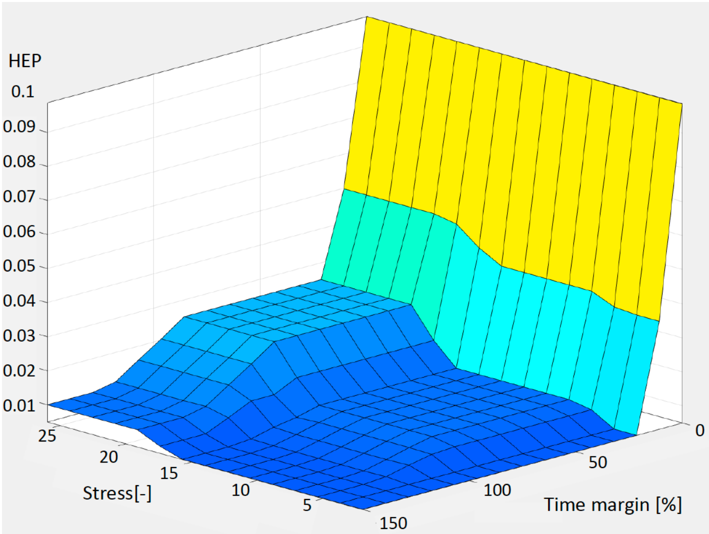

Figure 7 Estimated HEP under various time margin and stress condition using fuzzy inference

4.3. Effect of Proficiency and Procedures

In HRA research, proficiency and emergency operation procedures are key factors related to the HEP. However, in the conventional methodology, there is yet to be an established method to evaluate quantitatively the effect of proficiency and the difficulty of procedures on the HEP. Here, we suggest a new idea to handle the effect of proficiency and procedure on HEP. For example, if an operator is proficient in a related task, in other words, the operator is familiar with the procedure of the task. It can be expected that the operator has high-performance effectiveness and gets a limited influence by increasing stress and decreasing the time margin compared to a non-skilled operator. Also, a skilled operator is not required to follow the procedure closely while working on completing the task, and less time is required. Thus, a skilled operator impacts stress and time management less from the exact environmental change as a non-skilled operator. However, an operator with low proficiency more easily fails as the stress increases, and they need to check the procedure more closely while working on completing it. Thus, if the procedure is hard to read, it makes the operator an error for the task. In other words, a low-skilled operator gets more influenced by changes in the time margin and stress. However, in conventional methodology, it is hard to define the degree of change in HEP quantitatively according to proficiency and procedure. The impact of the proficiency and procedure on change in HEP can be quantitatively evaluated by changing the fuzzy rules. The revised fuzzy rules are shown in Table 9. Suppose the fuzzy rules shown in Table 5 are considered a fuzzy rule for the skilled operator when a non-skilled operator works with easy-to-read and understand procedures. In that case, each fuzzy rule becomes one lower grade than the fuzzy rules for the skilled operator. As shown in Table 10, if an operator has lower proficiency and the procedure is difficult, then the HEP under the same condition become two grades lower than the condition shown in Table 5. Figures 8 and 9 show the estimated HEP using fuzzy inference, considering the fuzzy rules in Tables 9 and 10. Compared to Figure 7, the HEP has a higher value under the same condition. However, the general tendency between the two results is almost the same. The tendency in HEP in Figure 7 correctly shows that a non-proficient operator has higher HEP than a skilled operator under the same condition, and increased HEP becomes distinguished in a severe condition where the time margin is low, and the stress level is high. These features are more clearly seen in Figure 8. The result shows appropriately that a non-skilled operator is likely to fail in a task under all conditions, but especially in a severe condition where the time margin is low and the stress level is high compared to the HEP of a skilled operator. It suggests that some critical PSFs that are hard to define and evaluate quantitatively because of their vagueness can be evaluated using fuzzy inference, giving some changes in the fuzzy rules.

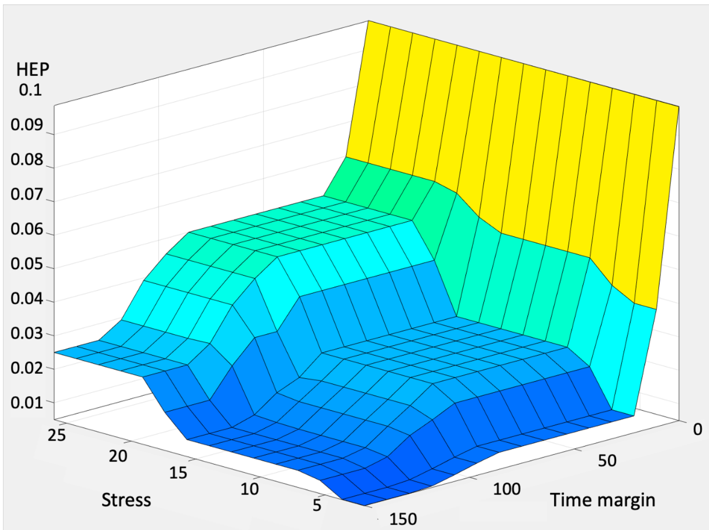

Figure 8 Estimated HEP when proficiency is low, and procedure is easy to read

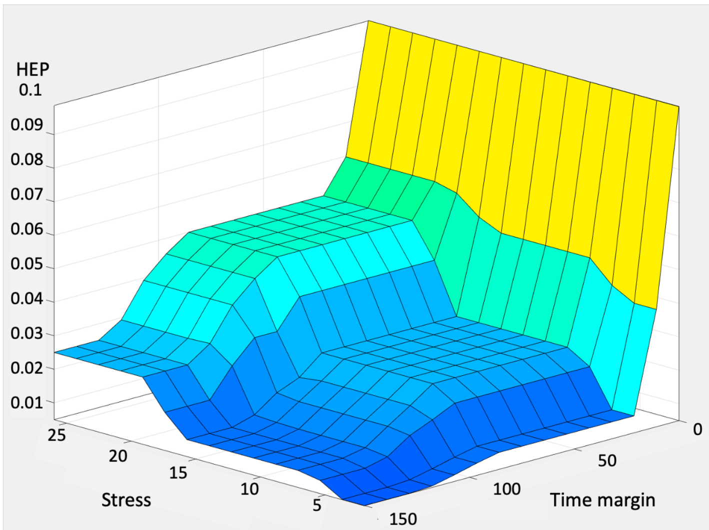

Figure 9 Estimated HEP when proficiency is low, and procedure is easy to read

Table 9 Fuzzy rules when proficiency is low, and procedure is easy to read

Proficiency: Low **Procedure : Easy**		**Time Margin**		
		Sufficient	**Adequate**	**Insufficient**
Stress	**Moderately High**	**Low**	**Medium**	**Failure**
	High	**Medium**	**High**	**Failure**
	Extremely High	**High**	**Very High**	**Failure**

Table 10 Fuzzy rules when proficiency is low, and procedure is difficult to read

Proficiency: Low **Procedure : Difficult**		**Time Margin**		
		Sufficient	**Adequate**	**Insufficient**
Stress	**Moderately High**	**Medium**	**Medium**	**Failure**
	High	**High**	**Very High**	**Failure**
	Extremely High	**High**	**Failure**	**Failure**

4. CONCLUSION

In this study, we suggested a method using DMLD to evaluate the HEP considering context change for multi-unit accident scenarios. Bayesian network structure was used to evaluate environmental change caused by multi-unit events. Fuzzy inference was used to evaluate the ambiguous effect of contextual change on HEP. The results of HEP under various stress and time margin conditions can be evaluated quantitatively considering the change in context. It shows that the suggested method can afford to consider more complex environmental changes when evaluating the HEP, even under a complex accident scenario.

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