A study on the application of TACOM to periodic safety review (PSR) – A case study

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1. Introduction

It has been increasingly recognized that a systematic safety review method that can consider the change of the safety of nuclear power plants (NPPs) is necessary because of the equipment degradation due to the increase of operating years. Therefore, International Atomic Energy Agency (IAEA) has suggested periodic safety review (PSR) as a systematic framework for a comprehensive safety review of all the important aspects of operating NPPs [1].

In this study, the applicability of a task complexity measure called TACOM (Task Complexity) for measuring "task workload" that is one of the key elements included in PSR factors is investigated.

2. Background information about PSR

According to the existing guideline, the purpose of a PSR is to provide a comprehensive review process to judge whether the plant is safe by current safety standards and practices [2]. To accomplish this purpose, in total 11 safety factors should be scrutinized at a regular interval, typically 10 years. In addition, each safety factor has several key elements to be meticulously reviewed. For example, key elements included in "Human factors" that is one of 11 safety factors are as below.

- Staffing levels for the operation of a NPP;
- Availability of qualified staff on duty at all times;
- Programs for initial/refresher/upgrading training by the use of simulators;
- Evaluation of human–machine interface, such as the design of a main control room and other work stations;
- Analysis of human information requirements and task workload, etc.

On the basis of the above-mentioned safety factors as well as key elements, since the first PSR for Kori Unit 1 in 2002, in total PSRs for 7 NPPs have been carried out as of 2007.

Unfortunately, according to the experience about PSR, it has been revealed that "human information requirements and task workload" are some of the difficult elements to be properly analyzed. That is, not only it is very difficult to quantify a task workload but also it is difficult to suggest countermeasures (or remedial actions) when a high task workload score is obtained [3]. To unravel this problem, the applicability of TACOM measure is scrutinized.

3. The development of TACOM measure

TACOM measure is composed of five sub-measures that cover five kinds of distinctive decisive factors making the performance of proceduralized tasks complicated. Table 1 summarizes the definition of TACOM measure with all the five sub-measures.

< Table 1. TACOM with the associated sub-measures >

	Definition/Meaning
TACOM	$\left[(\alpha \times SIC)^2 + (\beta \times SLC)^2 + (\gamma \times SSC)^2 + (\delta \times AHC)^2 + (\varepsilon \times EDC)^2\right]^{\frac{1}{2}}$
SIC	Representing the complexity due to the amount of information to be processed by operators.
SLC	Representing the complexity due to the execution logic of the required actions to be sequenced by operators.
SSC	Representing the complexity due to the amount of the required actions to be performed by operators.
AHC	Representing the complexity due to the amount of system knowledge that is necessary to identify the problem space of the required actions.
EDC	Representing the complexity due to the amount of cognitive resources that is necessary to establish proper decision criteria of the required actions.
α, β, γ, δ, ε	Weighting factors for SIC, SLC, SSC, AHC and EDC.

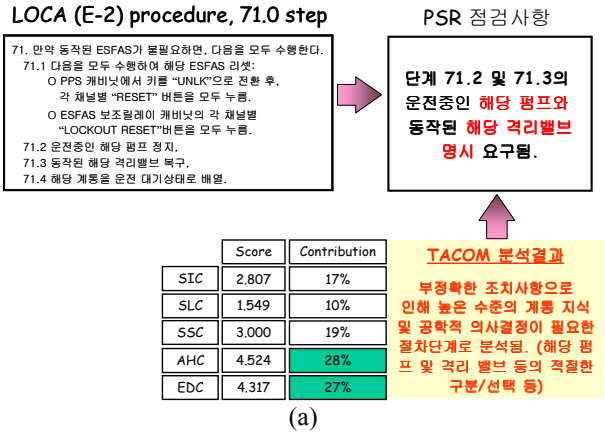
The appropriateness of TACOM measure is verified by several ways including: (1) comparing the estimated TACOM scores with averaged task performance time data, and (2) comparing the estimated TACOM scores with subjective workload scores quantified by NASA-TLX (Task Load Index) technique [4].

From these comparisons, it was observed that TACOM measure seems to be meaningful for quantifying the

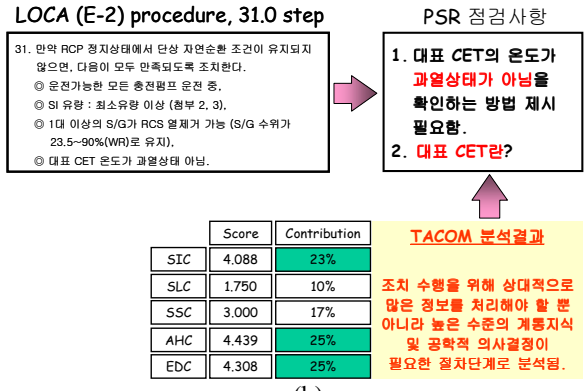
complexity of tasks stipulated in procedures because there is a significant statistical correlation between TACOM scores and the performance of human operators (i.e., averaged task performance time data and subjective workload scores).

4. Case study

As shown in the previous section, it is expected that TACOM measure can be used to quantify "task workload" because two kinds of canonical performance measures (i.e., time and subjective workload) are congruent with the associated TACOM scores. It should be noted that, if a task workload can be measured by TACOM measure, then it is anticipated that countermeasures to reduce a high task workload can be also identified by comparing the contribution of five sub-measures on a TACOM score. To clarify this anticipation, a part of PSR reports of the reference NPP, which deals with one of 11 safety factors – 'Procedures' is used. Fig. 1 summarizes two procedural steps that were revealed as 'a procedural step to be revised' with the associated scores of five sub-measures.



(a)



(b)

< Figure 1. Comparing PSR results with the associated five sub-measures >

Interestingly, as can be seen from Fig. 1 (a) and Fig. (b), it seems that PSR results are compatible with the insights obtained from the relative contributions of five sub-measures. For example, in Fig. 1 (a), PSR result pointed out that this procedural step needs revising because the performance of human operators could be degraded by vague actions. In other words, human operators should additionally make several decisions, such as "which pumps should be stopped in this situation?" and "which valves should be closed in this situation?", etc. Obviously, in conducting procedural steps, these decisions require additional cognitive resources of human operators (i.e., a relatively large contribution of AHC and EDC), which result in the degradation of human performance.

5. Conclusion

In this study, the applicability of TACOM measure for measuring "task workload" was scrutinized by comparing PSR results with the relative contributions of five sub-measures. Although only two cases were compared in this study, it seems that PSR results are congruent with the insights obtained from theoretically expected values by five sub-measures. Therefore, the following conclusion could be drawn carefully – "The TACOM measure could contribute to PSR by quantifying task workload."

References

[1] IAEA, Periodic Safety Review of Nuclear Power Plants, No. NS-G-2.10, 2003.
[2] IAEA, Periodic Safety Review of Operational Nuclear Power Plants, A Safety Guide, Safety Series No. 50-SG-O12, 1994.
[3] 영광 1/2 및 영광 3/4 호기 주기적 안전성 평가 심사 중간보고, 2006. 6. 28, KINS, http://nsic.kins.re.kr/
[4] Jinkyun Park, and Wondea Jung. The development of a quantitative measure for the complexity of emergency tasks stipulated in emergency operating procedures of nuclear power plants, KAERI/TR-3279/2006, 2006.