Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

An Analytic Method to Estimate Task Execution Time based on Task Complexity

Wondea Jung* and Jinkyun Park
Korea Atomic Energy Research Institute, 1045 Daeduck-daero, Yuseong, Daejeon 305-353
**Corresponding author: wdjung@kaeri.re.kr*

1. Introduction

From a human performance management perspective, it is important to understand the amount of time required to execute an emergency response task in a high-stress situation in a nuclear power plant. However, the task execution time (TET) in an emergency situation is highly dependent upon expert judgment due to the lack of field data. This paper proposes an analytical method to estimate the TET of a proceduralized emergency task, which is based on a measure of the task complexity, TACOM. The TACOM was developed by the authors to quantify the amount of complexity in a proceduralized task [1].

2. A Measure of Task Complexity, TACOM

The TACOM is a measure designed to quantify the complexity of a task that is prescribed in the procedures to guide the operations or emergency response of complex systems. It consists of five sub-measures that are related to a complexity factor that addresses a particular aspect of task complexity [1, 2].

Among the five factors, the first three factors represent the complexities that originate from the physical characteristics of the procedural step. The two remaining factors represent the complexities of a subjective load that originate from the cognitive characteristics of a task. Based on the graph entropy concepts [3], TACOM is defined as a weighted Euclidean norm of five factors, as follows:

$$TACOM = \sqrt{(\alpha \times SIC)^2 + (\beta \times SLC)^2 + (\gamma \times SSC)^2 + (\delta \times AHC)^2 + (\varepsilon \times EDC)^2} \quad (1)$$

- SIC: Step information complexity (SIC)
- SLC: Step logic complexity (SLC)
- SSC: Step size complexity (SSC)
- AHC: Abstraction hierarchy complexity (AHC)
- EDC: Engineering decision complexity (EDC)
- $\alpha, \beta, \gamma, \delta, \varepsilon$ are relative weights; even weights were used for this study.

In a previous study [4], the appropriateness of the TACOM was investigated by comparing the TETs for the emergency tasks that were obtained from simulator studies with the relevant TACOM scores. The study showed that there was a significant correlation between the averaged TET data and the associated TACOM scores, as shown in Fig. 1. It means that the average task completion time was proportional to the complexity of the tasks stipulated in the procedures. A high TACOM score implies a high cognitive complexity for the performance of a given task. Consequently, the previous study indicated that the TACOM is a feasible method for quantifying the complexity of proceduralized emergency tasks.

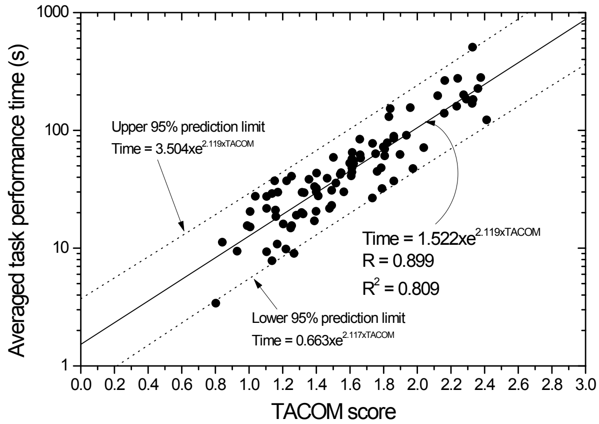

Fig. 1. Correlation between the TETs and the associated TACOM scores

3. An Analytic Equation TET based on TACOM

As described in the previous section, the TACOM exhibits a high correlation with the TET. Accordingly, the TET of a task can be produced by using the regression equation in Fig. 1 if the TACOM score of the task that is being considered is known. The equation for the TET based on the TACOM is defined, as follows:

$$\left.\begin{aligned} TET_{mean}(i) &= 1.522 \times Exp\big(2.119 \times TACOM(i)\big) \\ TET_{95\%}(i) &= 3.504 \times Exp\big(2.119 \times TACOM(i)\big) \\ TET_{5\%}(i) &= 0.663 \times Exp\big(2.119 \times TACOM(i)\big) \end{aligned}\right\} \quad (2)$$

where, TET_k (i) is the estimated k TET of task i (k is mean, 95%, or 5%) and TACOM(i) represents the TACOM scores of task i.

The TET data for any procedural task can be estimated by using Eq. (2) if its relevant TACOM score is available.

To determine if the TET equation is appropriate to estimate the execution time of a task, a validation study was performed by using another set of simulator data. The TET equation was derived from the regression equation between the TACOM scores and the simulator data collected from reference plant A. Therefore, to independently confirm the validity of the TET equation, the crew's performance times that were gathered from reference plant B are compared to the associated TETs that were derived from Eq. (2). An SGTR was then selected as the emergency scenario, and the simulator data was initially collected. Similar to the case of reference plant A, a full-scope simulator of reference plant B was used to secure additional TET data.

Table I. A set of the proceduralized tasks and relevant observed TETs for reference plant B

Task ID	Procedure and steps	Time[a]	SD[b]	95%[c]
1	E-0[d], 1~4	41.9	25.5	84.0
2	E-0, 5~6	12.0	2.9	16.8
3	E-0, 7~10	17.9	5.6	27.1
4	E-0, 11~14	33.9	22.3	70.7
5	E-0, 15~19	55.4	27.8	101.3
6	E-0, 19~21	38.9	16.0	65.3
7	E-0, 22~23	34.7	10.3	51.7
8	E-3[d], 1~4	97.0	28.6	144.2
9	E-3, 5~13	77.1	24.1	116.9

[a]Average task execution time (sec).
[b]Standard deviation (sec).
[c]95 upper percentile assuming a log-normal distribution.
[d]E-0: procedure for an SPTA, E-3: procedure for an SGTR.

Table I shows a portion of the emergency tasks to be conducted by a crew in an SGTR scenario in reference plant B. By using timeline analysis, the TETs for nine emergency tasks were extracted with respect to the mean, standard deviation, and 95 upper percentile with an assumed normal distribution.

On the other hand, Table II shows the associated TACOM scores and the estimated TETs that were derived from Eq. (2). Finally, the estimated TETs are compared to the 95 percentiles of the observed TETs in Table I, and Fig. 2 shows the result.

Table II. TACOM scores and estimated TETs for the emergency tasks for reference plant B

Task ID	TACOM score[a]	Estimated TET[b] (sec)		
		5%	Mean	95%
1	1.78	29.1	66.7	153.6
2	1.60	19.8	45.6	104.9
3	1.61	20.0	45.8	105.5
4	1.79	29.4	67.6	155.5
5	1.99	45.3	104.1	239.7
6	1.79	29.6	68.0	156.5
7	1.63	21.0	48.1	110.8
8	2.47	123.8	284.2	654.3
9	2.25	78.0	179.1	412.3

[a]TACOM scores are quantified by equal weights.
[b]Estimated TET is calculated by using Eq. (2).

According to Fig. 2, the 95 percentiles of the observed TETs are distributed within the confidence intervals of the estimated TETs. Almost all of the 95 percentiles are less than or almost equal to the mean values of the estimated TETs. The estimated TETs were compared to the 95 percentile of the observed TETs because the TETs should be determined as conservatively as possible due to the fact that they would be used as input or a criterion for a safety analysis for the design or operation of the NPPs. Additionally, the performance time observed in the simulators tends to be slightly optimistic if it is compared to the actual performance time of a stressful accident scenario. Therefore, the estimated mean TETs that were derived from Eq. (2) are conservative enough to be applied to the given applications, including the safety analysis of NPPs. Consequently, the TET equation is adequate to estimate the TET of a proceduralized emergency task for the NPPs.

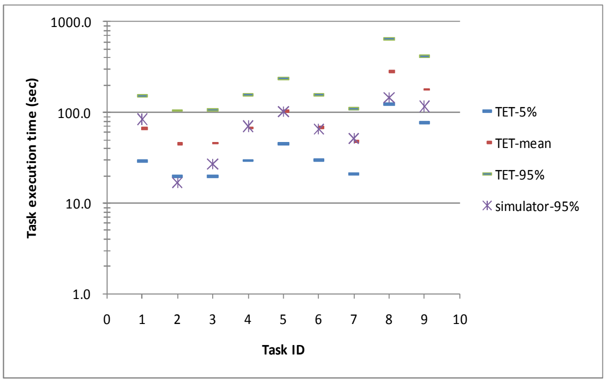

Fig. 2. Comparison between the estimated TETs and the 95 percentiles of the observed TETs

4. Conclusions

This paper suggested an analytic equation to estimate the TET of a proceduralized task in a NPP. The equation was derived based on a measure of task complexity TACOM. This implies that the TET of a procedural task can be estimated if the relevant TACOM score is available.

As a validation study of the proposed method, the estimated TETs of the tasks in the E-3 procedure of a reference plant were compared to the observed TETs that were collected for an SGTR scenario from a training simulator for reference plant B. The validation study showed that the 95 percentiles of the observed TETs were distributed within the confidence intervals of the estimated TETs. Almost all of the 95 percentiles were less than or almost equal to the mean values of the estimated TETs, which is reasonable if the usage of the TETs in the field of safety analysis is considered. Accordingly, Eq. (2) is applicable for estimating the TET of a proceduralized emergency task in the NPPs.

REFERENCES

[1] Park J and Jung W. A Study on the Development of a Task Complexity Measure for Emergency Operating Procedures of Nuclear Power Plants. Reliab Eng Syst Saf 2007;92:1102-1116.
[2] Ham D-H, Park J, and Jung W. Extension of TACOM to the Complexity of Tasks Designed for Abnormal Situations in Nuclear Power Plants. Submitted in Annals of Nuclear Energy; 2009.
[3] Davis JS, LeBlanc RJ. A Study of the Applicability of Complexity Measures. IEEE Trans Software Eng 1988;14(9):1366-1372
[4] Park J and Jung W. A Study on the Validity of a Task Complexity Measure for Emergency Operating Procedures of Nuclear Power Plants—Comparing Task Complexity Scores with Two Sets of Operator Response Time Data obtained under a Simulated SGTR. Reliab Eng Syst Saf 2008;93:557-566.