Evaluating the Verification Method of RAM Analysis Model by Using Markov Process

Jang-Wook Hur, Han-Sol Kim and Myeong-Seok Lee

Abstract---A RAM analysis model should be able to predict RAM characteristics from a system perspective and resource requirement comprehensively. Moreover, it should be able to analyze a specific time as well as a normal state. This study verified the validity of RMA analysis model for Markov Process Simulator (MPS), which was developed based on Markov process. The verification was conducted by using a mathematical method and an advanced model. Both methods showed that the deviation of operating availability would be within 2.3%, indicating that MPS model was valid.

Keywords--- Evaluating, Verification, Method, Markov, Process

I. Introduction

The reliability, availability, and maintainability (RAM) of a weapon system is a factor directly affecting the combat readiness and the maintenance cost. Therefore, it is very important to consider the design satisfying the RAM target value during the research and development. However, RAM_Sim or RAM V&V, the conventional RAM analysis techniques, only consider the normal state so it is limited to accurately analyze the condition before entering into the stable state after a weapon system is deployed in the field.

Various techniques, analyzing the availability according to the operating time of a system, have been applied to overcome the limitation. Among them, Markov Process has an advantage that it can model and simulate by using each state and information such as a failure rate, maintenance time, and time used for supports. However, it is needed to be verified to be used as a RAM analysis model since it is one of the methodologies.

The objective of this study was to verify the validity of RAM analysis model based on Markov Process Simulator (MPS), developed by using Markov process. The study conducted verification by comparing and analyzing the results after applying a mathematical method and an advanced model used in major developed counted.

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II. System Configuration

A. Markov Process

The analysis methods of existing RBD and FTA only consider the physical characteristics of the target system, whereas the Markov process can define various initial states and analyze the influence of them (Fig. 1).

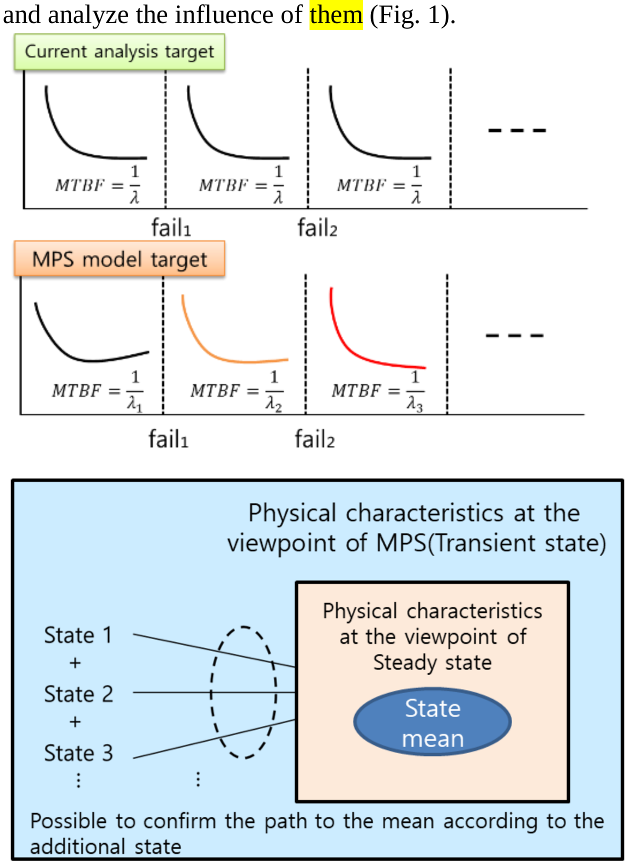
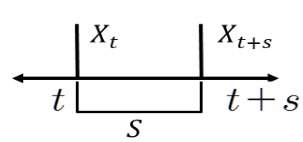


Fig.1: The boundary of a system by the viewpoint of an analysis.

The analysis of system reliability using Markov process is based on the following three assumptions. When the occurrence of a failure is equal to X_t, the failure occurrence at time X_t and that at time X_{t+s} are independent (Fig. 2). If the average failure rate is constant, a failure X_t occurs at time t once and it does not occur more than twice at time t.



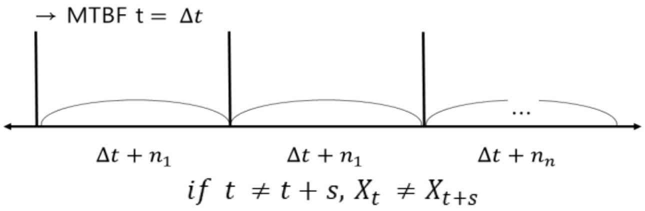


Fig. 2: The independence of each failure on the time axis and an average failure rate

The condition satisfying the above properties mathematically is called HPP and it is the assumption mainly applied to the system RAM analysis. Therefore, if the subject of the analysis is HPP, the time flow between failures can be said to follow the exponential distribution on average. The number of failure at that time follows the Poisson distribution. For this reason, the Markov process can be used for modeling and simulating by using states and information such as the failure rate at each unit, maintenance time, and time used for supports. A simulator built by applying the RAM system of Markov process has following advantages.

TABLE I:
CHARACTERISTICS OF A SIMULATOR USING THE MARKOV PROCESS

Classification	Features of Markov Process Application
Diversity of Analytical Unit	Easy to conduct analytical modeling of a unit composed of a system or multiple complex systems
State-based Modeling	Possible to model the actual state between systems or operations, more than analysis only considering the physical characteristics of a system
Diverse Analysis Results	Easy to understand and process information for analysis
Application of Temporal Analysis	Can use the advantages of temporal analysis (e.g., transient) for steady-state analysis

B. System Modeling

A mortar was selected as a weapon system for verification and the configuration of the system is as shown in Fig. 3. The total operating time and the total down time of the mortar were calculated by OMS/MP (Table 2). The lightweight mortar, digital stowage cradle, fire data computer, observation equipment, and observation equipment input/output unit are components of a mortar. Three types of down states (i.e., maintenance, administration and logistics delay, and failure) and three types of operating states (operation, alert, and standby) for each component were modeled (Fig. 3).

Fig. 3: Mortar Composition Diagram

TABLE II:
CLASSIFICATION OF THE MORTAR OPERATION TIME

Classification		Hour (H)
Total Operating Hours	OT	806
	ST	7099
	AT	154
Total Down Time	TPM	290.2
	TCM	20.8
	TALDT	390

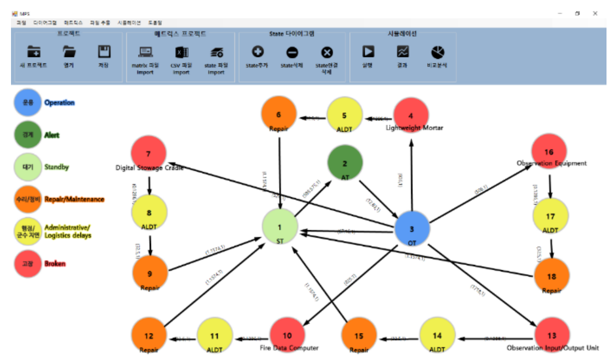


Fig. 4: MPS modeling

III. Mathematicla Verification

Mathematical verification, comparing the analysis results stated in the RAM analysis report and the results, was conducted as a method to verify basic features such as the coding and program system of MPS. Five elements (i.e., MTBF, MTTR, unique availability, achievement availability, and operation availability were calculated from the RAM analysis report. First, the reliability of MTBF was predicted by using the predicted value of a similar item at the beginning of development and the PCM method. It reflected the results of pre-CDR, post-CDR, LDC, and rest evaluation by using the PSA method for four times according to the design specification and the sub-item identification of the components. Based on the results, MTBF was determined as 95 hours and the system MTTR was estimated by using the lead time estimation. Moreover, the unique availability, achievement availability, and operational availability can be calculated as follows.

$$A_i = \frac{MTBF}{MTBF+MTTR} = \frac{95.000}{95.000+1.286} = 0.986644 \quad (1)$$

$$A_a = \frac{OT+ST+AT}{OT+ST+AT+TPM+TCM}$$
$$= \frac{806+7,212.7+154}{806+7,212.7+154+181.7+15.5} = 0.976437 \quad (2)$$

$$A_o = \frac{OT+ST+AT}{OT+ST+AT+TPM+TCM+TALDT}$$
$$= \frac{806+7,212.7+154}{806+7,212.7+154+181.7+15.5+390.1} = 0.932954 \quad (3)$$

IV. VERIFICATION BY USING OPUS 10

OPUS Suite (Systecon, Sweden) is a software program for RAM analysis and support analysis. It is used for the optimization of operation availability, LCC, and maintenance policy by using the system, maintenance, and support factors as input variables. OPUS Suite is composed of three modules (i.e., OPUS 10, SIMLOX, and CATLOC) and they can be interlocked with each other. Each module has following characteristics.

OPUS 10 provides an optimal access method for LSA by estimating repair parts and using RAM information as an LSA tool. It also supports the function of the optimal repair parts calculation for a unit cost structure, LORA analysis, supportability analysis, and logistics model during the operating period.

SIMLOX is a support simulator that uses the results of OPUS 10 to create an ILS scenario. It is also a software program applying the concept of Modeling & Simulation to LSA and ILS fields when it is hard to obtain operating data such as a newly developed weapon system. Moreover, it supports other functions such as time-based simulation for a virtual LSA model, cost-effectiveness analysis, and alternative analysis. .

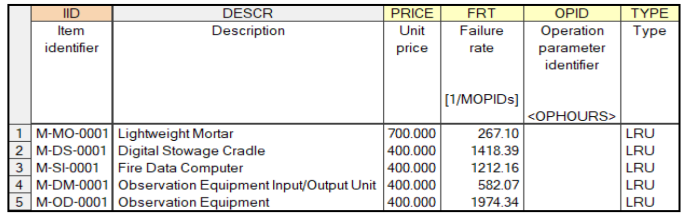
CATLOG consists of life-cycle cost and performance-based cost analysis with considering ILS elements such as LSA and the database type supporting format in the aspect of management and analysis through the data from scenario from SIMLOX and OMS/MP base. It is a tool for conducting cost structure analysis modeling in the aspect of TLCSM and supports functions such as life cycle cost & sensitivity analysis.

The subcomponents of the mortar were classified up to Level 3 and the predicted failure rate according to PSA was summarized to be used as system input variables (Table 3).

TABLE III:
SUMMARY DATA OF THE MORTAR RELIABILITY ANALYSIS RESULTS

Reference Designator	Level	Name of Item	Classification	Quantity	RAM Result Value		
					Failure Rate		MTBF (Total)
					Unit	Total	
KLM0001	1	Mortar	Assembly	1	10507.77	10507.77	95
KLM0002	2	Mortar sub-system	Assembly	1	10507.77	10507.77	95
KLM-MO-0001	3	Lightweight Mortar	Assembly	4	267.10	1068.39	936
KLM-DS-0001	3	Digital Stowage Cradle Set	Assembly	4	1418.39	5673.58	176
KLM-SI-0001	3	Fire Data Computer	Assembly	1	1212.16	1212.16	825
KLM-DM-0001	3	Observation Equipment Input/Output Set	Assembly	1	582.07	582.07	1718
KLM-OD-0001	3	Observation Equipment Set	Assembly	1	1974.34	1974.34	506

The input parameters of OPUS 10 are shown in Fig. 5 and the model view of OPUS 10 including the maintenance strategy is the same as Fig. 6.



	IID Item identifier	DESCR Description	PRICE Unit price	FRT Failure rate [1/MOPIDs]	OPID Operation parameter identifier <OPHOURS>	TYPE Type
1	M-MO-0001	Lightweight Mortar	700.000	267.10		LRU
2	M-DS-0001	Digital Stowage Cradle	400.000	1418.39		LRU
3	M-SI-0001	Fire Data Computer	400.000	1212.16		LRU
4	M-DM-0001	Observation Equipment Input/Output Unit	400.000	582.07		LRU
5	M-OD-0001	Observation Equipment	400.000	1974.34		LRU

Fig. 5: OPUS 10 input parameters for the mortar

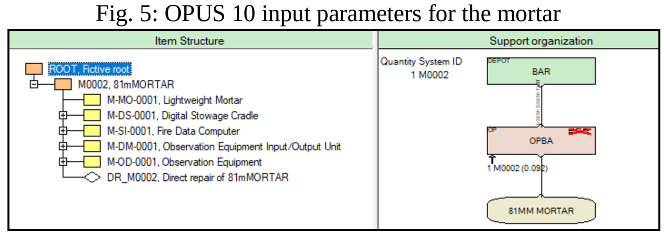


Fig. 6:OPUS 10 model view of the mortar

The results of the simulation using the OPUS 10 input parameters and modeling are shown in Fig. 7, showing the 93.9% usage of the operating availability.

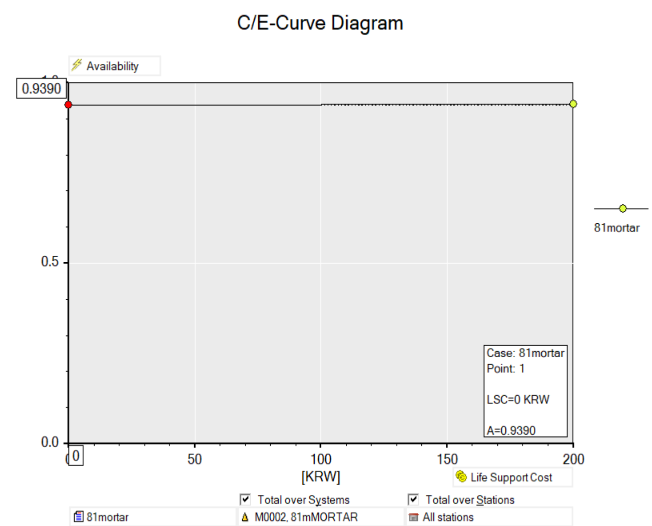


Fig. 7: Ao of the mortar estimated from OPUS 10

V. MPS RESULTS AND DISCUSSION

The simulation was conducted for 5-year duration (43,800H) with 200 reiterations in order to have sufficient operating time, probability result, and stable mean value. The simulation results were found as 98.18H of MTBF, 1.28H of MTTR, 98.6% of unique availability, 97.5% of achievement availability, and 95.6% of operating availability (Fig. 8).

Summary of Result

	series
Simulation Period	43800
Replication	200
MTBF	98.17818
MTTR	1.280654
Failure Rate (100만시간 당 고장률)	10676.792074
Repair Rate	0.812777
Inherent Availability	0.986485
Operational Availability	0.95615
Achieved Availability	0.975283

Fig. 8: Results of MPS simulation

The MPS of RAM analysis was verified by using a mathematical method and an advanced software OPUS Suite for the mortar. The verification results are shown in Table 4. The results of MPS showed an error below 3% in the mathematical verification and 1.8% in the OPUS 10. It was concluded that MPS was valid from the low error from the mathematical verification and the verification using an advanced software program. The future study will estimate the projected cost by using the using the cumulative number of visits during the simulation period after adding a cost analysis function and verify it by using the CATLOG of OPUS Suite.

TABLE IV:
MPS VERIFICATION RESULTS

Classification	MPS(a)	Mathematical Verification (b)	OPUS 10(c)	Deviation	
				a-b	a-c
A_i	98.7	98.7	-	0	-
A_a	97.6	97.6	-	0	-
A_o	95.6	93.3	93.9	2.3	1.7

VI. CONCLUSION

This study verified the validity of RAM analysis model for the Markov Process Simulator (MPS) developed by using Markov process. This study carried out the verification by comparing and analyzing the results with using a mathematical method and OPUS Suite, an advanced software program, for the mortar. The results of MPS showed up to 3% of error in the mathematical verification and 1.8% in the OPUS 10. It was found that it was valid since the mathematical verification and an advanced software program verification revealed small errors.

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