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COMPARATIVE STUDY OF COMMAND AND CONTROL STRUCTURE BETWEEN ROK AND US FIELD ARTILLERY BATTALION

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ABSTRACT

One of the main points of the Republic of Korea (ROK) military reformations is to reduce the number of personnel with the strengthened arsenal. However, the number of North Korean artillery forces far surpasses the ROK artillery forces, and the threat of mass destruction by these artillery remains in the Korean Peninsula. The aim of this study was to find the alternative field artillery operations and organization. This study presents a counterfire operation multi-agent model using LDEF formalism and its virtual experiments. The virtual experiments compared 1) the damage effectiveness between battalion and battery missions and 2) the effectiveness of command and control structures in the ROK and US artillery. Their results showed that splitting the units with strengthened guns and integrated C2 structure shows better performance in terms of damage effectiveness. We believe that this paper is basic research for the future ROK-US combined division, C2 network, and operations.

1 INTRODUCTION

The threats from North Korea are various in these days. North Korea currently focuses on asymmetric warfare capabilities. For example, it launched three times to test the intercontinental ballistic missile (ICBM) in 2013. They also developed new types of multiple launcher rockets and tested them by shooting projectiles into the near sea. They even carried out several nuclear tests in underground facilities in the Yeon-ben district. In addition, one of the biggest threats is field artillery forces,' conventional and massive weapons. The Korean Peninsula is the highest density area of field artillery forces in the world. Even though the North's field artillery forces are old-fashioned, these still exist, and the North's artillery is twice as large as the ROK's artillery. To respond to the North's threats, the ROK army plans reformation policies through various fields.

A major policy of the ROK army reformation is the reduction of military personnel with a strengthened arsenal. However, with the ever-growing threat from the North, we cannot simply reduce the number of units in the field without assurance that the better weapon will fill the gap. Furthermore, recent skirmishes on Yeonpeong Island (Richburg and Branigin 2010) between the North and ROK forces us to limit 1) the employment of high-technology strategic weaponry, e.g. fighter jets with guided missiles, and 2) the deployment of larger troops near the border, e.g. marine divisions, due to political, strategic, and operational reasons. Then, our question becomes how to strengthen and organize our future units, which will have less personnel and better tactical weapons, against the next skirmishes.

The objective of a counterfire operation is to defeat the enemy's indirect fire elements, including their target acquisition and C2 components. To suppress and destroy the long-range artilleries that are threats to the Seoul metropolitan region, the ROK-US combined counterfire headquarters (HQ) will be organized in the early stages and exercise together annually based on the joint operation plans. However, the simulation results using the ROK army's war-game model showed that the joint HQ couldn't accomplish their initial missions because of numerical inferiority. It is difficult to respond to large numbers of field artillery forces with only improved self-propelled howitzers. The alternative operation methods and C2 structure should be analyzed with the current situation and the operations.

Several recent studies illuminate the question of the counterfire operation based on the scenario North Korea skirmished by using modeling and simulation (M&S) methods (Lee 2011; Kim and Lee 2008; Kwon 2013; Yun et al. 2013). For instance, Lee (Lee 2011), identified the operations of target acquisition radar and the sequence of targeting order considering the North artillery's weak time. Lim (Lim 2012), ascertained the best combination of combat factors by case experiments with several variables. However, Lee (Lee 2011), focused on radar operations, and Lim's methodology, the finite-state machine (FSM), is not appropriate to describe the battle engagement correctly because of the internal state transition problem. Even though the ROK army HQ has extensively done research on the counterfire operation, there are too many conceptual and too few quantitative measurements to support the validity of tactical strategies.

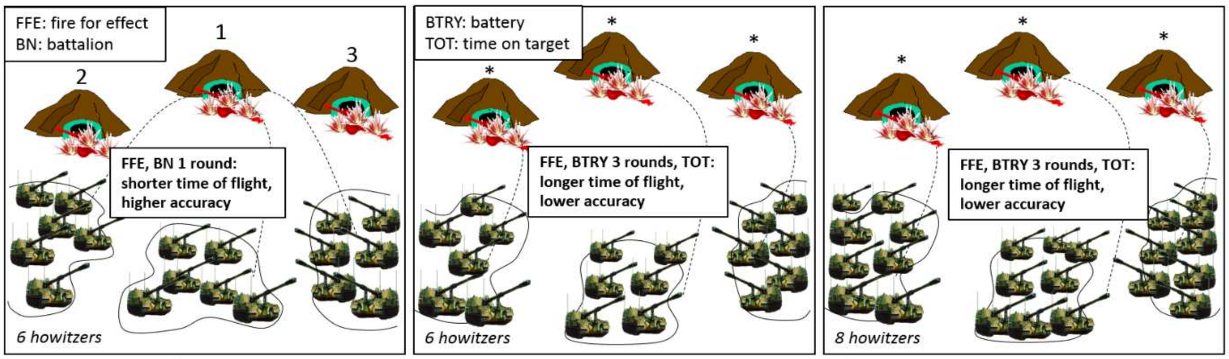
This study assessed the method of the counterfire operation and C2 structure between ROK and US artillery organization according to existing doctrine. We used the LDEF formalism (Bae et al. 2012), and developed a multi-agent model (Macal and North 2006) based on the Yeonpeong Island skirmish scenario. Using the model and scenarios, we have performed virtual experiments varying fire operation methods and C2 structure factors just like the previous researches in different military fields (Chung 2008; Jung et al. 2014; Kim et al. 2011). With the results from the virtual experiments, we performed various statistical analyses to figure out the relationships between the factors and performance measures.

Through the analysis, we found that the existing battalion mission could be substituted with the battery mission when many targets are acquired during artillery engagement. We also found that the strengthened battery mission is effectively superior to the battalion mission due to the reinforced gunfire and multiple responses to targets. From the results of these analyses, we expect that only the operational changes enable the ROK artillery to overcome the negative imbalance situation without force improvement investment cost. We expect this paper would be basic research for future ROK field artillery organization, C2 network, and operations (Alberts and Hayes 2003).

2 PROBLEM DEFINITION

2.1 Methods of Counterfire Operation

The ROK field artillery battalion consists of three batteries, each with 6 howitzers (ROK army 2006). The current ROK army field manual (ROK army [FM3-20] 2006; ROK army [FM32-1] 2008) dictates the counterfire operation method, saying that the battalion mission is more efficient than the battery mission. For example, assume that the fire direction officer (FDO) has decided that 18 rounds of high explosive projectiles are required to destroy the artillery target. In this case, the FDO might follow the field manual and choose the battalion (BN) one round method instead of the battery (BTRY) three rounds method for fire for effect (FFE) because the former method could accomplish the surprise attack and reduce the exposure risk from the enemy target acquisition assets. However, the problem is that it is difficult to respond to multiple targets with the battalion mission. Even though the K-9 self-propelled howitzer offers great performance in longer ranges and a higher rate of fire, the disparity of military strength between North and ROK artillery is huge. When we consider the additional artillery missions supporting the maneuver forces by fire, the current counterfire operation method should be reassessed for multiple missions. For example, we should consider for the battery mission the highly skilled time on target (TOT) method, e.g. multiple rounds simultaneous impact, and thereby, other batteries can strike multiple targets at the same time. If the battery mission is not enough to destroy and suppress the enemy artillery, we can consider the strengthened battery mission. The strengthened battery, like the US Paladin battery, has 8 howitzers, and it augments the fire by increasing the guns the battery operates (U.S. army [FM 6-40] 1999; U.S. army [ATP 3-09.24] 2012). Thus, we should consider the various operation methods and judge them by the current situations, not by their adherence to the field manuals. Figure 1 shows three examples of the counterfire operation methods.



	ROK current countfire method	Battery TOT mission	Strengthened battery TOT mission
Unit to fire	Battalion	Battery	Battery
Method of fire	Fire for effect	Time on target	Time on target
Number of guns	18 howitzers	18 howitzers	24 howitzers
Fire order	Sequential (1→2→3)	Simultaneous (*)	Simultaneous (*)
Time of flight	Shorter time of flight	Longer time of flight	Longer time of flight
Accuracy	Higher accuracy	Lower accuracy	Lower accuracy

Figure 1: The counterfire operation by (a) battalion (b) battery (c) strengthened battery.

2.2 Command and Control Structure

The other problem is the ROK army reformation. Because of reduction in military personnel and combat troops, once the reformation is completed, the division will have twice as many responsibilities. Instead, better tactical weapons will be reinforced for the future division, and such weapons require higher combat capabilities than at present. However, the C2 structure under division artillery (DIVARTY) is not changed, and the mission procedure from acquisition to attack is still hierarchical. While the US artillery shows the integrated, networked forces at the battalion level, the ROK artillery shows the DIVARTY HQ has a central role. Considering the numerical inferiority and the enlarged responsible area, it is doubtful that the ROK artillery forces could counter the North's field artillery effectively with current operations and structures.

The purpose of this study is to 1) simulate the counterfire operation methods through virtual experiments, 2) evaluate the ROK's operations and C2 structures with the US army in the existing field manuals, and 3) analyze the results statistically to determine the effectiveness. For this purpose, we built the counterfire operation model using a multi-agent model including the command, detection, and fire elements. And we performed simulations with the model to see how its effectiveness was affected by 1) unit to fire and 2) C2 structure.

3 METHODOLOGY

We used the LDEF (Large-Scale Distributed Efficient Flexible) formal specification (Bae et al. 2012), which is extended from DEVS (Discrete Event Systems Specification) formalism (Zeigler et al. 2000). It describes the agent's state more specifically to reflect three statuses: perception, decision, and action. LDEF formalism is used to construct the hierarchical features of the models. This composed the multi-agent model and the multi-environment model. Using the DEVS models or its variant models have increased since 2000s (Kim and Moon 2012; Moon et al. 2013), and it has been known for its complete and clear specifications of models. This is a merit in the military modelling field because the modelled entities could be black-box to some of future users due to its domain specificity.

3.1 Overall Structure of the Counterfire Operation Model

Figure 2 illustrates the overall structure of the counterfire operation model. The model mainly comprises two models, the engagement model and the environment model. The engagement model consists of blue and red forces, and each force has models for detection, decision making, and delivering fire. For example, the blue forces have the radar model, the C2 model, and the field artillery battalion model. The red forces are made up of the same structures as the blue forces except for their model parameters. The environment model consists of target acquisition model and damage assessment model. The target acquisition model calculates the battery's center coordinate value to send the target information to the radar model. The damage assessment model gets a message from the gun's fire action model and determines whether the gun is damaged. Then, the damage assessment model sends a message, including the gun's status, to the gun damage action model.

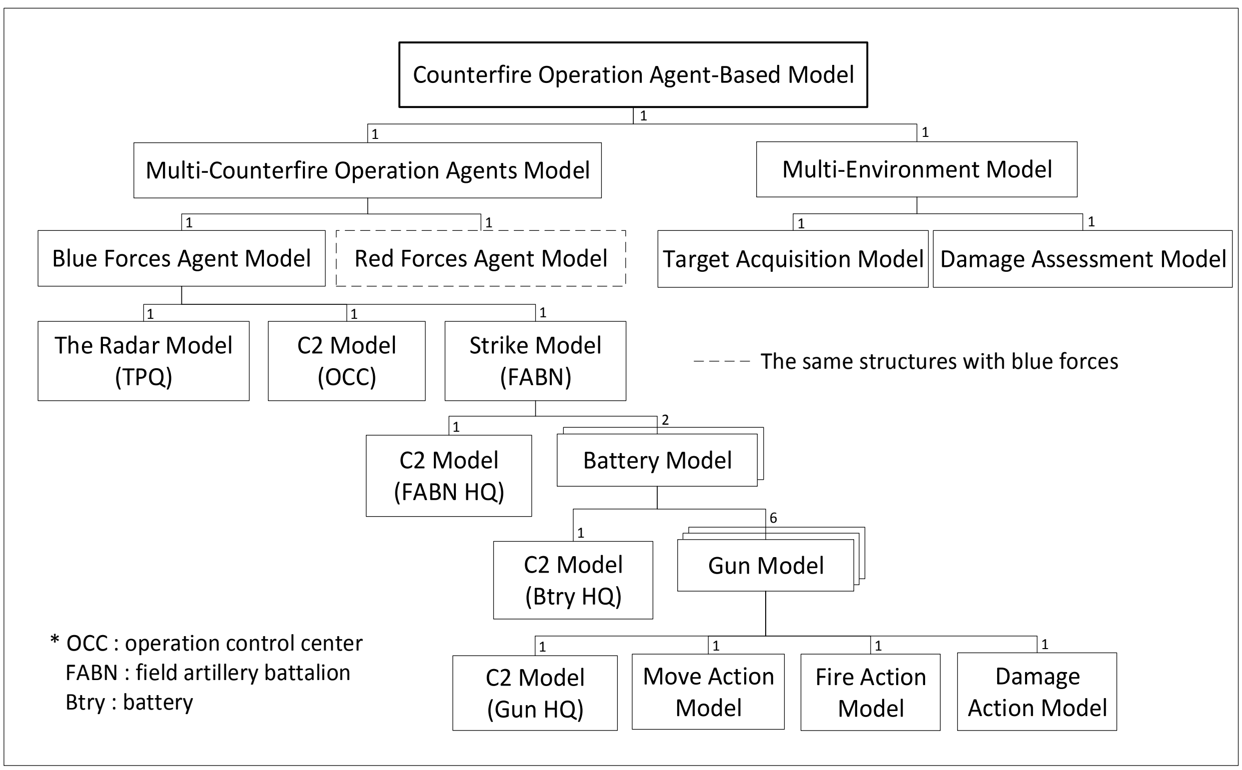


Figure 2: Hierarchical structure of the counterfire operation model.

3.2 The Gun Model

The gun model has four atomic models: 'headquarter,' 'move,' 'fire,' and 'damage.' The gun headquarter model receives the fire data and fire order from the battery headquarters and reports a 'Ready_ID' message after moving into artillery position and loading the projectile. Each gun moves along appointed routes and artillery positions, and the move action model reports the current gun location to the environment model at every simulation time tick. The fire action model sends a 'Fire_ID' message to the environment model to report each gun's impact point, so the environment model calculates the explosive radius with the probable error and judges the damage status of the gun model. The damage action model receives the gun's status message from the environment and reports a current status to headquarters model. Figure 3 is the example of the gun headquarters.

We developed the two types of gun models, the self-propelled howitzer and the multiple rocket launcher. Blue forces artillery include K-9s and up-to-date howitzers, and red forces artillery have the old self-propelled howitzers in the tunnel hardened position and multiple rocket launchers. The performance of the gun is based on real equipment, and we applied the K-9's TOT function when the battery mission was assigned to blue artillery forces.

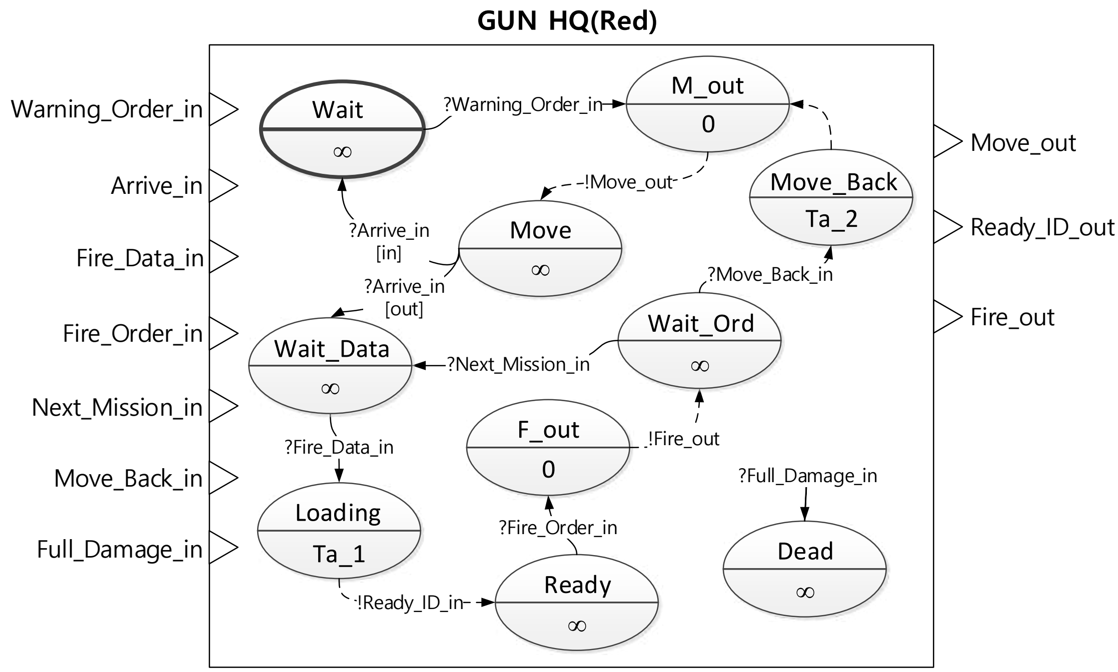


Figure 3: DEVS atomic model for the red gun headquarters.

3.3 The Damage Assessment Model

The damage assessment process is almost the same with the ROK army fire operation analysis model applied. We apply the cookie-cutter algorithm, one of the artillery ammunition damage logics, because it assumes there is no fragment damage. We set the lethality radius (LR) as 25 m. From the mean point of impact, targets within LR get the probability of kill, p(kill)=1. Then, we subdivide the damaged targets by maneuver damage and fire damage.

Specifically, we developed two types of damage assessment, the howitzer and the rocket launcher, to reflect the real situation. In the howitzer's damage assessment, we apply the distribution and two different probable errors, range and deflection, to describe the limited explosive area. We apply the circular error probability (CEP) to the rocket launcher's damage assessment. The CEP is defined as the radius of a circle, centered about the mean, whose boundary is expected to include the landing points of 50% of the rounds. With the CEP, we can describe the rocket launcher more precisely and give the damage to multiple unspecified areas and targets within the CEP.

3.4 Model Parameters and Performance Measures

To describe the numerical gap in artillery forces, blue artillery forces consist of two batteries and red artillery forces consist of two self-propelled battalions and one rocket launcher battalion in the scenario parameters. We arrange the rocket launchers in the artillery position where the North actually skirmished during 2010. Other artillery forces are positioned virtually on Google Maps. Model parameters mainly consist of the arsenal features, the accuracy of attack, the detection rate, and the time to move and communicate. The blue forces' parameters such as the probable error, the radius of explosion, and the time of flight, are measured as real data, which are the results of operation tests and evaluation. Analogous data were applied for the red forces because little is known about the North's data. Instead, we assumed the red artillery's probable error based on the shelling point of the Yeonpeong skirmish.

We measured two types of performance measures, the number of red forces and the time of mission completion for blue gun during simulation, and we compared two input variables, unit to fire and C2 structure. Table 1 shows the details of our simulation model.

Table 1: List of parameters and the performance measures.

Type	**Name**	**Description**
Scenario Parameters	The number of blue forces	2 batteries (K-9 self-propelled howitzer)
	The number of red forces	3(-1) battalions (2 field artillery battalions and 2 rocket launcher batteries)
Model Parameters	Damage rate	Cookie-cutter algorithm
	Distribution	Lateral spread distribution (250m x 50m)
	Circular error probability	The radius of a circle whose boundary is expected to include the landing points of 50% of the rounds
	Probable error (range and deflection)	An error that is exceeded as often as it is not exceeded. (unit: meter)
	Time of flight	Time for a round to travel from the muzzle to the target point (unit: seconds)
	Probability of detection	The detection rate of radar while a round travels to the target point (unit: percentage)
Performance Measures	The number of red guns (red forces)	The number of alive red forces at every 500 simulation ticks
	Mission completion time (blue forces)	The average of the completion time of simulation executions (unit: simulation tick)

4 EXPERIMENTAL DESIGN

We conducted experiments to analyze how to strengthen the units, which will have less personnel and better tactical weapons. We evaluated the ROK army, comparing with the US army from the following perspectives. Firstly, we categorized unit to fire as the battalion, the battery, and the strengthened battery to compare the effectiveness between the strengthened fires and flexibility to react to multiple targets. In addition, we analyzed whether the strengthened battery, the US Paladin battery, could substitute the battalion mission. Secondly, C2 structure between ROK and US artillery organization are analyzed to confirm how the reinforced command and fire support elements affect the combat capability.

Table 2 shows the experimental design for our simulation. We established 6 cases for the experiment, and the experiment was replicated 30 times for each case. The experiment was finished when the survivability of blue artillery forces was below 20 percent.

Table 2: Experiment design of the counterfire operation model.

Variables	Values
Operation Methods	Type 1 = battalion mission, Type 2 = battery mission, Type 3 = strengthened battery mission
C2 Structures	Case 1 = The ROK artillery, Case 2 = The US artillery
Total number of cells	3 x 2 = 6 cases (30 replications for each case)

5 SIMULATION RESULTS

Figure 4 shows several captured pictures from the LDEF visualized tools during a specific period of simulation. The screenshots show the red force's artillery position in the North's Gaemeri area. The red circles represent each gun, and the green circles represent the explosive radius of projectiles. When guns are within lethality radius and suffer the full damage, they are removed from the screen to represent the dead state.

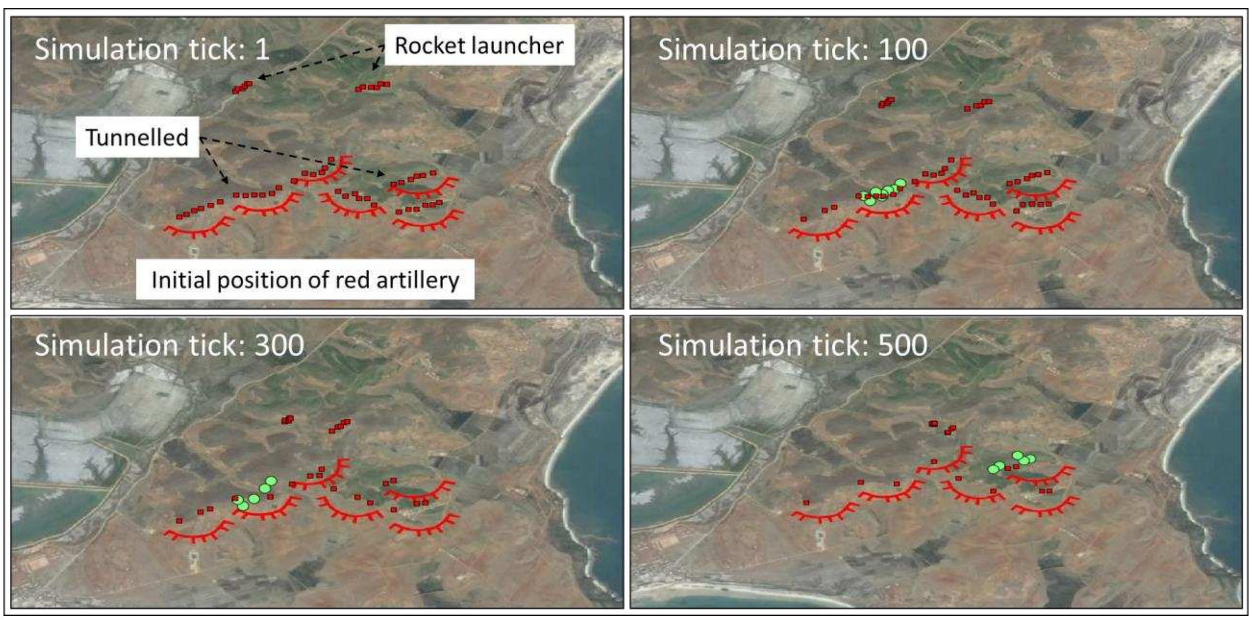


Figure 4: The screenshots of the virtual experiment: Red circles represents each gun, and green circles represent the explosive radius of projectiles.

Figure 5 demonstrates that the battery mission is equivalent to or has even more effectiveness than the battalion mission. Because of high angle fire during the TOT mission, we gave penalty factors in the case of the battery mission, with five times the projectile flight time and two times the probable error against the battalion mission. At an early simulation time, the effectiveness in the case of the battalion mission is better than in the battery mission. However, as the simulation time goes, targets acquired from the radar are increasing, and the effectiveness is reversed. Furthermore, the strengthened battery mission showed better results than the battalion mission. In the case of C2 structure, networked US artillery organizations are superior for fire missions.

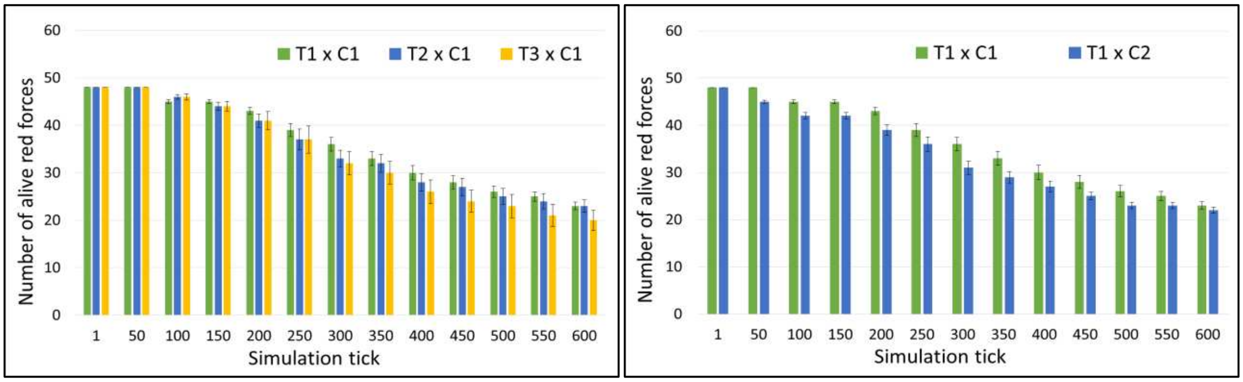


Figure 5: The number of alive red forces by unit to fire (Left) and by C2 structure (Right).

To analyze which factors contributed to the performance measures, we used regression analysis in metamodeling. Table 3 shows the metamodel of our simulation model. The table entries indicate standardized coefficient values of corresponding experimental variables and show how much impact the variables have on the performance measures. The metamodel shows that two independent variables, strengthened battery mission (0.5603) and the US C2 structure (0.1565), influence the red forces' damage during simulation. We confirmed that the strengthened battery significantly affects the results. It represents that even though the high angle fire mission has some faults, the battery TOT mission with strengthened guns substitutes the existing battalion mission when there are many targets to fire upon.

Table 3: Meta-model analysis on red gun's damage rate results. Standardized coefficient for sensitivity of factors, and P-value for robustness of factors (**: $p < 0.01$, *: $p < 0.05$).

Experiment variable name	**Standardized coefficient**
Battery mission	0.0046
Strengthened battery mission	0.5603 **
The US artillery(C2)	0.1565 *
Adj. R-square	0.3246

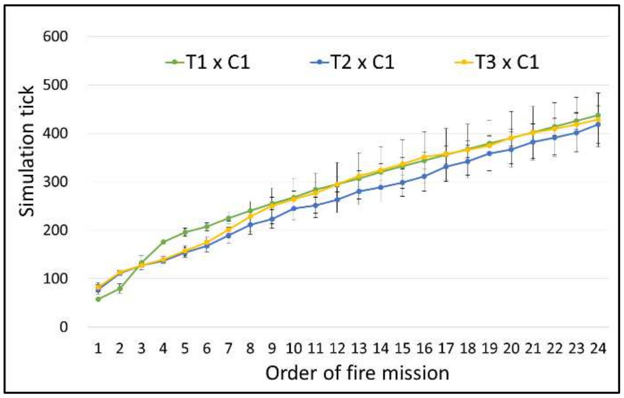
We performed the ANOVA, and the ANOVA results (Table 4) confirm the metamodeling results. The strengthened battery mission ($F = 62.0143$) is more important than the C2 structure ($F = 6.4525$). However, we cannot find the interaction effects of the experimental factors. From the results of this analysis, we confirm that battery-based missions with the US C2 structure significantly influence the performance measures.

Figure 6 shows that the blue gun's mission completion time is shortened with the battery mission and the US C2 structure. At an early simulation time, we also confirmed that the performances are reversed between battalion and battery missions. Once the time is reversed, the battery mission's completion time is shorter than the battalion mission's time during simulation. However, no significant results are shown with confidence intervals. The strengthened battery mission shows better performance than the battalion mission, even though the mission completion time is similar or inferior. Overall, we can demonstrate that the blue gun reduces the mission completion time with the battery mission. In the case of C2 structure, the

US artillery organization significantly influences the performance measure in comparison to the ROK artillery organization.

Table 4: ANOVA for significance analysis of experiment factors and their compounding factors(**: $p < 0.01$, *: $p < 0.05$).

Source	DF	SS	MS	F	Pr > F
Battery mission	1	0.0688	0.0688	19.9965	< 0.01**
Strengthened battery mission	1	0.2135	0.2135	62.0143	< 0.01**
The US artillery(C2)	1	0.0222	0.0222	6.4525	0.0119*
Battery mission and The US artillery(C2)	1	0.0000	0.0000	0.0032	0.9553
Strengthened battery mission and The US artillery(C2)	1	0.0030	0.0030	0.8832	0.3486
Error	174	0.5992	0.0034		
Total	179	0.9069			



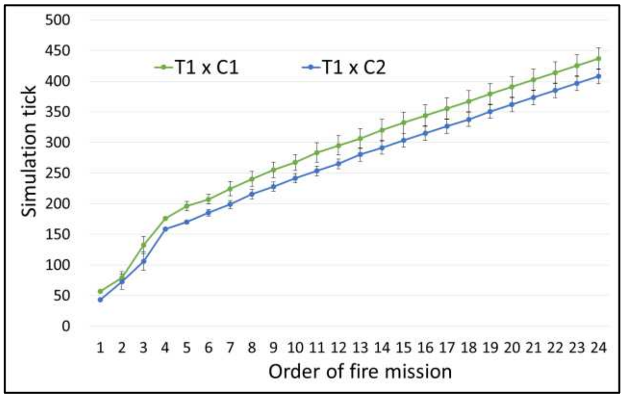


Figure 6: The mission completion time by unit to fire (Left) and by C2 structure (Right).

We performed the metamodeling using linear regression. The results (Table 5) show that two battery-based mission variables influence the mission completion time compared with battalion mission. The battery mission variable (-0.4961) significantly affects the performance measure. However, unlike the metamodeling results we performed in Table 3, the US artillery C2 structure doesn't significantly influence the performance measure. It represents that having a lot of units to fire is more effective than integrating C2 structure to reduce mission completion time.

Table 5: Meta-model analysis on simulation results. Standardized coefficient for sensitivity of factors, and P-value for robustness of factors (**: $p < 0.01$, *: $p < 0.05$).

Experiment variable name	Standardized coefficient
Battery mission	-0.4961 **
Strengthened battery mission	-0.1903 *
The US artillery(C2)	-0.0631
Adj. R-square	0.1782

In general, the ANOVA results in Table 6 confirm the metamodeling results. The battery mission (F = 37.3708) is more important than the C2 structure (F = 0.9282) with respect to the variation in the performance. Another finding is obtained from the interaction effects of the experimental factors. The significant compounding effects of battery mission and the US C2 structure (F = 13.1671) indicate that these two variables should be simultaneously considered during the counterfire operation.

Table 6: ANOVA for significance analysis of experiment factors and their compounding factors (**: $p < 0.01$, *: $p < 0.05$).

Source	DF	SS	MS	F	Pr > F
Battery mission	1	54366	54366	37.3708	< 0.01**
Strengthened battery mission	1	9188	9188	6.3154	< 0.05*
The US artillery(C2)	1	1350	1350	0.9282	0.3366
Battery mission and The US artillery(C2)	1	19155	19155	13.1671	< 0.01**
Strengthened battery mission and The US artillery(C2)	1	963	963	0.6622	0.4169
Error	174	253131	1455		
Total	179	338153			

6 CONCLUSIONS

The current ROK army forms a hierarchical artillery structure and operates battalion level missions against counterfire operations. To improve the current tactical strategies, we studied several counterfire operation methods at the tactical level and made a comparative study on C2 structure between ROK and US artillery organization. We used LDEF formalism to develop the counterfire operation model and performed virtual experiments via LDEF.

Statistical analyses on the experimental results provide two insights about combat effectiveness and mission completion time: 1) From the combat effectiveness perspective, the strengthened battery mission and the networked C2 structure with more capabilities show better performance, and 2) from the mission completion time perspective, the normal battery and the strengthened battery are more efficient. From these insights, adopting various operations methods and C2 structures to counterfire operations with respect to combat objectives would be worthy of consideration. Moreover, such considerations would contribute to constructing agile and interoperable forces.

In our future work, we plan to construct the meta network by 6 experimental cases, and to analyze the virtual simulation results and network metrics results simultaneously to find the key network metrics. Moreover, we plan to analyze the interaction effects of the experimental factors to confirm which factor is more influential in results.

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