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Constructive Simulation in Tactical Level Planning: Options for Optimizing Engineer Support

Konstruktivní simulace v rámci plánování na taktické úrovni: Možnosti optimalizace ženijní podpory

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Abstract: This article deals with the use of constructive simulation software in the planning process of military engineer staff personnel. The possibilities regarding the implementation of MASA SWORD simulation software are demonstrated on specific data from the Engineer Support Management Course, with overlapping applications to other specialized military troops. Three scenarios were used for the simulations, which were practiced and verified during the course's exercise. Each scenario was evaluated in silico within the simulation environment, incorporating analytical and graphical outputs. Utilizing the MASA SWORD analytical module, each scenario underwent comparative analysis using statistical tests to assess the fulfilment or failure of the assigned task. The findings emphasize the promising role of constructive simulation in enhancing military personnel training and planning process on tactical level.

Abstrakt: Článek se zabývá využitím softwaru konstruktivní simulace v plánovacím procesu příslušníků štábů ženijní odbornosti. Možnosti implementace simulačního softwaru MASA SWORD jsou prezentovány na konkrétních datech z kurzu řízení ženijní podpory s přesahem do dalších druhů vojsk. Pro simulace byly použity tři scénáře, které se ověřily během štábního cvičení v rámci kurzu. Každý scénář byl v rámci simulace ověřován in silico, včetně analytických a grafických výstupů. S využitím analytického modulu MASA SWORD byla u každého scénáře provedena srovnávací analýza pomocí statistických testů v kontextu splnění či nesplnění zadaného úkolu. Výsledky výzkumu zdůrazňují perspektivní úlohu konstruktivní simulace při zdokonalování výcviku vojenského personálu a procesu plánování na taktické úrovni.

Keywords: Command and Control; Education Process; Engineer Support; Modelling; MASA SWORD.

Klíčová slova: velení a řízení; proces vzdělávání; ženijní podpora; modelování; MASA SWORD.

INTRODUCTION

The training of military personnel, encompassing aspects beyond the military decision-making process, is taking a new dimension in the current international political environment. The threat of high-intensity conventional conflict is now at the highest level for the armies of the North Atlantic Treaty Organization (NATO) since the collapse of the Soviet Union (Hrnčiar and Kompan 2023). The trend of military personnel training in the Armed Forces of the Czech Republic (CAF) proved to be correct when, during the initial decade of the 21st century, after a period of training for foreign operations in the Middle East, the conduct of offensive and defensive operations began to be practised again to an increased extent. This resulted in a transition from training in tactical activities for peacekeeping operations to combat operations being initiated.

Defence expenditures by the armies of NATO member states has been on an upward trend since 2017 (Odehnal et al. 2021), i.e. not only within the context of the Russia-Ukraine conflict. This is usually due to the purchase of modern equipment and introduction of new technologies (Ivan et al. 2022). An essential part of such acquisitions is the necessity to train military (as well as non-military) personnel in the utilization of such equipment and technologies, which in many cases are more sophisticated and often accompanied by increased demands on service, not only in operational use, but also in maintenance and repair procedures. Therefore, it is logical to use new technologies and tools to train the military personnel. This often enables the required training to be achieved in a shorter time, while simultaneously mitigating risks and potentially reducing overall expenditure. Such promising technologies and approaches include, for example, modelling and simulation, virtual/augmented reality and artificial intelligence (Záleský and Palasiewicz 2019).

The training of military personnel of the CAF is a process that consists of accredited teaching (through the state university - University of Defence - in the relevant modules; for higher education institutions in the Czech Republic, the National Accreditation Office provides accreditation of fields of study and programmes (Reznakova et al. 2021) and non-accredited training (series of career and professional courses aimed at increasing the proficiency of officers).

The content of professional courses is determined by the command-level requirements across the CAF. For instance, the Engineer Support Management Course at the University of Defence is organized for officers of military engineering specialization, who are typically appointed as staff officers at the Brigade Combat Team level. The CAF sets standards for course content to ensure that it meets the needs of the organization. The course was designed to provide officers with the knowledge and skills necessary to plan and manage engineer support to military operations. In this course, students (military engineers) acquire theoretical foundations for providing engineer support for the performance of functions in units in command and staff positions (Rolenec et al. 2021).

Constructive simulations offer numerous benefits in the educational process of military personnel. They provide practical training opportunities that complement theoretical education, allowing for the development of critical skills in a controlled environment (Talian and Moravčíková 2023); (Petz, Sobota, and Perhac 2009). The utilization of

constructive simulations in military education offers several advantages. These simulations facilitate the replication of realistic combat scenarios, provide immersive experiences, and enhance team interaction (Mazurenko 2024); (Drozd and Procházka 2022). Constructive simulations play a pivotal role in enhancing the cognitive readiness of military personnel. These simulations facilitate the development of essential knowledge, skills, and abilities requisite for critical thinking, problem-solving, and decision-making processes (Alim et al. 2024). Despite the acknowledged benefits of constructive simulation, there remains a lack of comprehensive studies on its effectiveness in improving decision-making skills among military engineer staff personnel in NATO armed forces. This paper focused on the use of constructive simulation tools in the planning process of military operations. The study was conducted within the tertiary education of military personnel, future commanders, and members of unit staff.

1 DATA AND METHODOLOGY

When planning a military operation, the decision-making process consists of seven steps, which is the established method of operation planning within the armies of NATO member states:

1. Receipt of the Mission;
2. Mission Analysis;
3. Course of Action (COA) Development;
4. COA Analysis;
5. COA Comparison;
6. Commander's Decision;
7. Orders Production, Dissemination and Transition (Terziev, Koleci, and Solovev 2020).

Briefings are held between each planning step to refine the activities for the next step, or to refine and redesign an existing step.

In accordance with the syllabus of the course, the practical application of acquired knowledge was limited to a two-day period. Owing to the time constraints of the exercise, the planning process was restricted to the initial four steps, whereas the distribution of engineer resources and units to complete the assigned task (the relevant COA) was ongoing. To expedite the process, the general and enemy situations remained unchanged from what the students had already discussed during the course. Conversely, the tactical situation and operational area of conduct for the operation varied (Rolenec, Vlkovsky, and Sedlacek 2023).

The MASA SWORD constructive simulation was used to evaluate the planned manoeuvre and its engineer support. This simulator enables the simulation of the combat course of a large number of units, which are independently controlled after entering commands (Korecki et al. 2024; Havlík et al. 2022). It is a sophisticated tool with the help of which a war game can be conducted. A war game is any simulation of a military operation involving two or more opposing armed forces. The war game implemented by

the MASA SWORD tool does not require a referee and it is not demanding in terms of materials or organisation.

MASA SWORD comprises an analytical tool embodied in a standalone software application designed for editing imported scenarios. The utility of this tool is most evident in the repetitive execution of simulations and assessment of predetermined criteria (De Mattia 2022; Pekař et al. 2022). The analytical tool typically provides average values and confidence intervals for $\pm\sigma$ (standard deviation) and upper and lower limits ($+\sigma$ and $-\sigma$) for monitored parameters, such as the combat power¹ of friendly units and enemy combat power. These values were used to evaluate the simulation results.

According to the outcomes of the initial two scenarios, the search for the optimal variant was initiated. Guided by the objective of the paper, a hypothesis was formulated: Employing constructive simulation, it is feasible to identify the optimal configuration of engineer units to achieve the goals of the military campaign.

2 MASA SWORD CONSTRUCTIVE SIMULATION TOOL

MASA SWORD constitutes a comprehensive software suite, which includes scenario creation applications and aggregated constructive simulation and analysis tools dedicated to staff training, education, classroom teaching, planning support, analysis, operational research, and Command & Control (C2) system simulation. In C2-level terms, it can simulate operations from battalion to division level and provides software for training tactical-level staff of land units. For evaluation purposes, it also enables the simulation of even lower levels of command (platoon, company). However, these usually do not act independently within the scope of the task forces. Above all, the planning process is limited to commanders of the lowest tactical units (Tolk 2012).

2.1 Advantages of the MASA SWORD Tool

The first advantage of MASA SWORD is that it enables the creation of scenarios according to different doctrinal conventions, depending on the technique and material; therefore, each country can access this software according to its needs or limitations. Because of this ability to adapt the software to national circumstances, the MASA SWORD has been used in more than 20 countries to evaluate asymmetric operations to support populations. In general, the advantages are as follows:

- staff training;
- after action review;
- reuse of an exercise at any time;

¹ Combat power represents the total force a military unit can bring to bear in a given situation, combining personnel, equipment, and training (HN and IM 2022).

- operational research to validate new doctrines or new equipment characteristics;
- wide choice of evaluation parameters, choice of evaluation objectives.

2.2 Disadvantages of the MASA SWORD Tool

Based on experiments conducted within the Faculty of Military Leadership, some limitations can be identified. These include:

- minefield breaching limitations (strict minefield parameters, impossibility to automatically clear passages when supporting units);
- the time-consuming nature of entering units into the tool;
- the inability to apply criteria following selected parameters to the objects created;
- the lack of consideration in the digital model of the territory and the digital model of the relief (Tichý et al. 2023) for the changing combat situation during the operation, the updates requires the intervention of the main programmer;
- some vector data of the map base are not considered. This leads to inaccurate analysis and evaluation (e.g., in watercourse sections);
- the inability to edit graphs and the complexity of extracting data from the analysis tool;
- regarding updates, loss of stored organizational structures or created resources.

2.3 Combat Resources in the MASA SWORD Tool

This is the most widely used category of resources in the MASA SWORD tool. These resources (as well as others) are characterized by their specified parameters and behavioural models. During simulations, they are influenced by the specified tactical situation and the map base, which reflects elements of the natural and artificial environments and elevation.

The requirement for new combat resources (also based on combat experience from armed conflicts) is based on the need to address:

- automation;
- compatibility;
- ballistic protection (owing to the effect of UAVs in particular, but also mines on the whole vehicle profile – “smart” mines or booby traps);
- mobility of resources (gradient, angles of approach, obstacle crossing);
- firepower;
- camouflage options;
- protection from electronic warfare;
- possibility of using communication and information resources.

3 DESCRIPTION OF THE EXERCISE

The exercise consisted of three phases:

- execution – planning the engineer support of the operation based on the received combat order;
- presentation – clarification of the created variant of engineer support;
- evaluation – using constructive simulation to evaluate the selected solution options.

In total, six groups of two trainees were formed. Owing to the varying levels of experience of the course participants, they were divided such that the pair always contained a more experienced military engineer.

3.1 The Course of the Exercise

During the initial briefing, the order of the operation and the chosen COA were clearly outlined. Each participant was provided with a map detailing the locations of friendly and enemy units as well as the battle plan. The trainees' task was to allocate the available engineer resources and units to the 1st and 2nd echelons and assign them tasks to achieve the desired goal of the operation as quickly and efficiently as possible while minimizing the loss of manoeuvre units. The losses of engineer resources were only important to the extent that their numbers ensured the completion of the tasks because they fell into the category of forces, so-called "enablers". Calculations of individual engineering tasks were not required because they were not crucial to the tactical execution of the manoeuvre. The execution phase was planned to last a maximum of five hours, including the preparation of a presentation to defend the engineer support plan for the operation (Rolenec, Vlkovsky, and Sedlacek 2023).

During the presentation phase, the groups were responsible for clarifying the method of providing engineer support during the operation. Initially, they were provided with a sample presentation containing the necessary facts to be recorded. These included the timeline of their activities, such as the initiation of planning, completion of studying the operation order and its appendices, completion of planning for implementing engineer support, and completion of presentation preparation. Additionally, the factors assessed, engineer forces and resources at the Brigade Combat Team (BCT) level for individual phases of the operation, engineer forces and resources at the battalion level for individual phases of the operation, and engineer support tasks and recommendations for improving the exercise were also required to be recorded (Rolenec, Vlkovsky, and Sedlacek 2023).

3.2 Scenario Description

To conduct the exercise, an offensive operation was chosen as a type of basic tactical activity. In the simulated scenario, the attacking forces (friendly) must cross the wet gap defended by the enemy and seize the occupied territory. The attacking forces consist of three mechanized battalions, one tank battalion, and one engineer battalion. Further, the BCT includes an artillery battalion, an air-defence missile battalion, a logistics battalion, a radiological, chemical and biological protection unit, a signal platoon and additional components such as the civil-military cooperation, psychological operations, intelligence, surveillance and reconnaissance, forward air controller, and other relevant elements (Daniel and Wittichová 2020; Spitzer, Kappes, and Böker 2012).

The mechanized battalions consist of three mechanized companies and a mortar company. They also include a command company with an engineer platoon with earth-moving equipment, and a logistics company. The tank battalion consists of three tank companies and one mechanized company. The rest of the composition is similar to the mechanized battalion. The main combat force of the mechanized battalion is infantry fighting vehicles and 81 mm mortars, while the tank battalion relies on the main battle tanks.

The engineer battalion consists of a number of units with construction and mechanical equipment, bridging means, obstacle assets and obstacle-clearing equipment (Cibulova, Rolenc, and Zeleny 2021). Given the capability of the engineer resources in the CAF to support the manoeuvre of forward units over a wet gap that the enemy defends, the engineer battalion was augmented with the following assets:

- 10 × AACE armoured amphibious dozer;
- 3 × Alvis Moelv combat engineer vehicle;
- 3 × Python explosive minefield-breaching systems;
- pontoon platoon with the means to build a pontoon bridge.

The mechanized battalions would attack in the 1st echelon based on the established COA, and the tank battalion behind them, in the 2nd echelon. Tanks are not amphibious because of their weight; therefore, they move across the river using bridges or underwater crossing sites set up after both banks are occupied. Engineer units are intended to provide movement support for attacking units.

The enemy forces are represented by a mechanized battalion that has secured its position on its own bank. It has the same units and resources at its disposal as a mechanized battalion of friendly forces. The overall ratio of manoeuvre forces is therefore 4:1 in favour of the attacking units, which represents a tentative value for planning offensive operations (Pikner and Galatik 2015).

The operation is located in Central Europe, where the most important terrain object is a river with an average width of 45 m. As its banks are defended by the enemy, crossing them is difficult. Armoured equipment capable of floating, engineer units and obstacle-clearing engineer means must therefore be included in the 1st echelon. In addition, there are forests in the area that provide cover, but make movement difficult; there are also open spaces that make it possible to observe at a greater distance and to move faster,

but without the possibility of cover from direct and indirect fire. Support in the form of a bridge-crossing site is feasible during the advance of units only after the 1st echelon of the task force troops.

3.3 Modelled and Simulated Variants

All six groups presented distinct proposals for the allocation of engineer support to the established COA. As some of the proposals had similar numbers of engineer resources and units allocated, it was determined that the average values would be utilized for simulation purposes. Consequently, the proposals of three groups that designated the least engineer forces for the first echelon battalions and three groups that assigned the greatest number of engineer forces were selected for further consideration (Rolenec, Vlakovsky, and Sedlacek 2023). By doing so, course participants could become familiar with two variants (LOS and WIN) of engineer support that differ significantly in the number of assigned engineer resources.

Because the simulation of all units of the Brigade Combat Team and the enemy battalion would be very time-consuming and because three identical mechanized battalion attacks in the 1st echelon, a smaller part of the whole operation was simulated, namely the attack of the mechanized battalion on the mechanized company, whereby reconnaissance elements reinforced both formations.

To simulate two variants with lower and higher levels of engineer support for troop activities, the number of engineer resources and units had to be averaged and assigned to the 1st echelon companies. For the variant with less engineer support, the following engineer forces and resources were assigned to the manoeuvre battalion:

- 1 × AACE assigned to the upper mechanized company;
- 1 × AACE assigned to the central mechanized company;
- 1 × engineer platoon consisting of two engineer squads equipped with infantry fighting vehicles, excavators and trucks providing support and 1 × AACE, 1 × Python and 1 × Alvis Moelv to the lower mechanized company, as the direction of attack features the most roadblocks and is an open terrain that will be covered by an enemy fire;
- there were a total of 35 soldiers and 15 vehicles.

For the variant with more engineer support, the following resources were additionally assigned:

- 1 × Python and 1 × Alvis Moelv assigned to the upper mechanized company;
- 1 × mine clearance team equivalent in size to an engineer platoon consisting of two engineer squads equipped with infantry fighting vehicles, trucks and passenger vehicles and 1 × Python and 1 × Alvis Moelv providing support to the central mechanized company;
- in total, there were 63 soldiers with 25 vehicles (quantitatively, the number increased by 28 soldiers and 10 vehicles).

Figure 1 shows the initial deployment of units for the variant with more engineer support (blue units represent the attacking forces and red units represent the defending enemy).



Figure 1: Display of the simulation progress

4 RESULTS AND DISCUSSION

Utilizing the data from Part III, simulations were executed in MASA SWORD software, employing the specified simulation model assumptions:

- area in the combat zone has not experienced previous combat activity and remains undamaged (waterworks, roads, settlements, etc., are not destroyed);
- optimal weather conditions (without rain, snow, fog, smoke, or strong winds);
- lack of civilian presence and traffic that would limit the movement of combat units;
- same level of combat readiness of units on both sides;
- military engineer terrain modification – establishment of minefields limiting the movement of units. In the simulation, the enemy refers to the actions of their engineering units, which are not part of their existing military composition (they were involved in the construction of the defence) and have no bearing on the outcome of the simulation in the scenarios discussed;
- same type of manoeuvre unit in friendly and enemy forces;
- owing to the intricate nature of the simulation, it was not possible to incorporate an air support on either side;

- performance with 10 and 100 repetitions for both variants (Rolenec, Vlkovsky, and Sedlacek 2023).

In the first scenario, it was assumed that owing to the combat power of friendly forces, it would be possible to accomplish the task. However, the simulation results (10 repetitions), as shown in Figure 2, show that the enemy maintained its position despite incurring relatively heavy losses (over 36% of the forces).

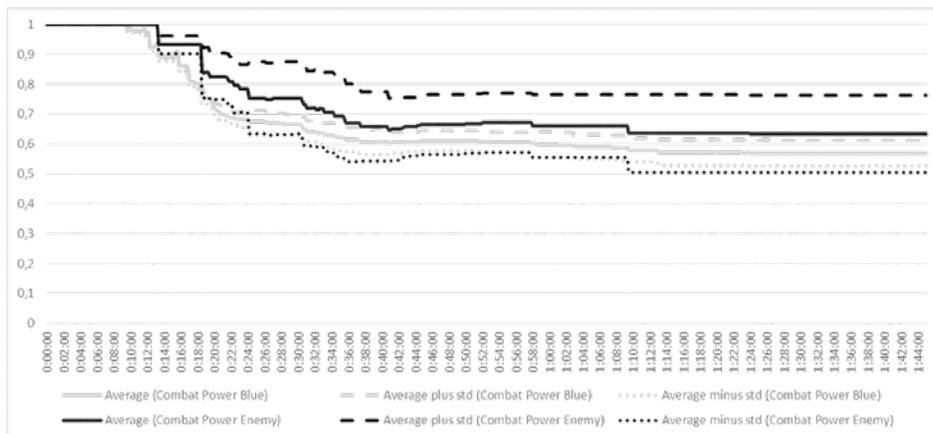


Figure 2: Combat power – average values, incl. confidence intervals (10)

For completeness, a graph of the development of friendly forces for 100 repetitions (see Figure 3) is presented, which does not show significant differences for the needs of this study compared with 10 repetitions performed for the same scenario. The loss of friendly forces was slightly greater than 43%, which was only 1% lower than that for ten repetitions.

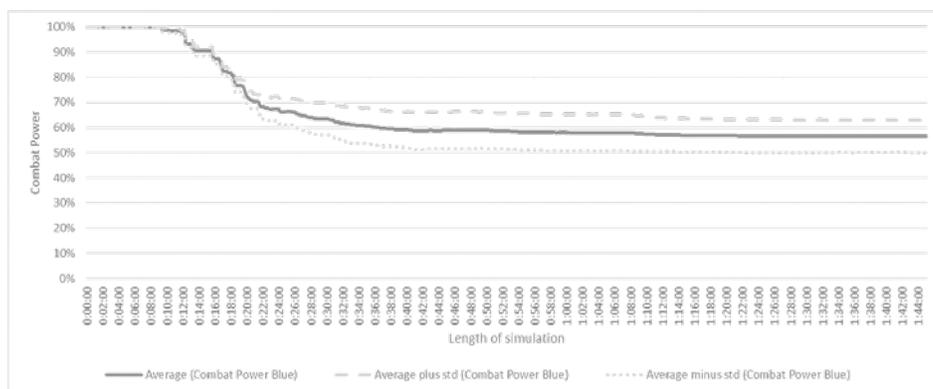


Figure 3: Combat power of friendly forces (100)

In the second scenario, the situation was different (see Figure 4). Owing to the strengthening of friendly forces, the task was accomplished even if losses were incurred (18% of friendly forces) for 10 repetitions.

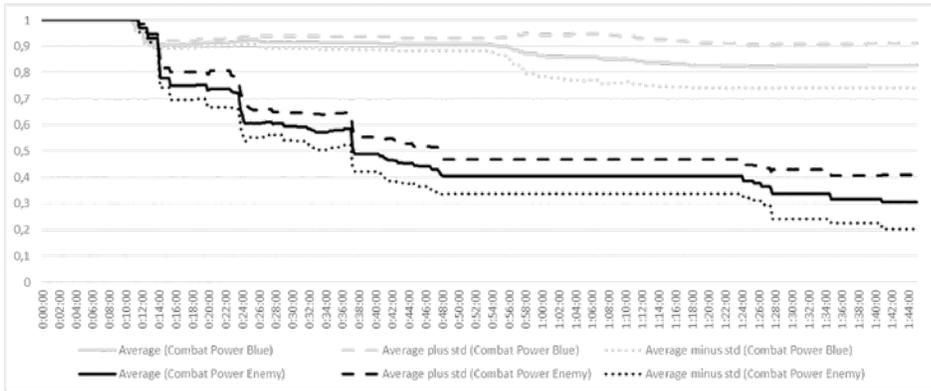


Figure 4: Combat power (10)

Analogue to the previous scenario, the deviation for the needs of this study at 100 repetitions was insignificant (see Figure 5). The losses of friendly forces at approximately 17% were slightly higher than those of the 10 repetitions.

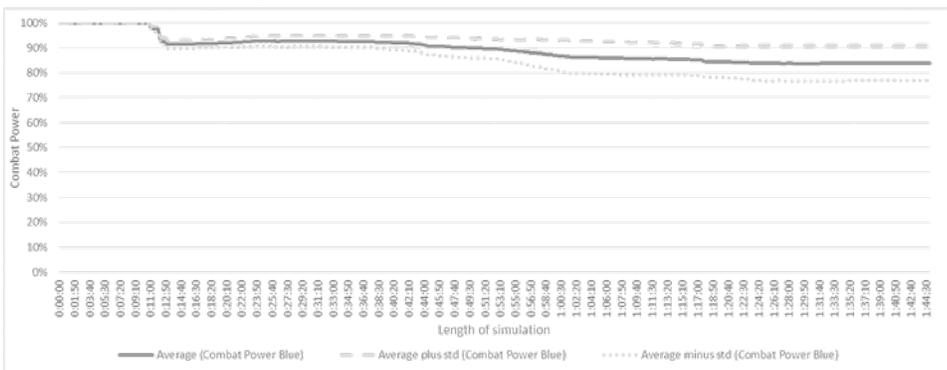


Figure 5: Combat power of friendly forces (100) for the WIN variant

4.1 Simulating an Optimal Variant of Engineer Support

These results demonstrate the importance of engineer support for troop movement during offensive operations. The differences in losses incurred by the attacking forces, as demonstrated in Figures 3 to 6, confirm the doctrinal tactical principle that effective engineer support of troop movements indirectly increases the protection of their own forces. This thesis is based on the logical assumption that when obstacles are set up, these objects are covered by fire, maintaining the mobility of one's own troops, thereby creating a difficult target for the enemy. Barriers always slows down or stops units, requiring the partial regrouping of forces to overcome it.

Another interesting aspect is the increase in enemy losses when reinforcing one's own forces with explosive mine-clearance systems, armoured bulldozers, and other resources. Engineer vehicles for mobility support are not intended for direct combat and are not equipped with weapons systems to conduct fire; therefore, they indirectly participate in the elimination of enemy forces, that is, their capabilities enable them to perform a specific manoeuvre. By outnumbering the defending forces, the attacking forces, after crossing the river and minefields, can open a concentrated fire from their primary weapons systems to destroy them.

The current conflict in Ukraine confirms another lesson learned, namely that there will always be a shortage of engineer resources. The required number of demining and other engineer resources will always exceed their available numbers. In the simulations for the second variant, although the objective of minimizing friendly force casualties and inflicting significant damage on enemy forces was achieved, concerns arose regarding the inefficient utilization of engineer forces and resources. This prompted the need to identify a more effective approach to engineer support for mission accomplishment. It can be assumed that we are looking for an optimal variant characterized by the lowest number of engineer assets (in comparison to the second variant), but still enabling the task to be completed. Prior to initiating the reduction of engineer resources of the second variant, it was necessary to determine values of the monitored criteria for the optimal variant:

- losses of the attacking forces will not exceed 33% (with tolerance $\pm 5\%$) of their combat power;
- enemy force combat power will not exceed 50% (with tolerance $\pm 5\%$).

If we assume that the losses of the attacking forces are higher, it is possible that in some simulated cases, they would occupy the area across the river and push the enemy out in all locations. However, from a tactical point of view, it is necessary to reckon with a counterattack by the enemy, who will try to regain control of the seized territory. Therefore, attacking forces must retain sufficient fighting power to hold the area.

If the losses of the units in the defence exceed a specific limit, they cannot withstand the pressure exerted, and they begin to retreat to other lines of defence. Losses of approximately 50% are already considerably high, forcing commanders to withdraw from the fight and take a more advantageous position.

Engineer vehicles and units were reduced three times, and individual simulations were performed under the same conditions. In the first reduction, the following were eliminated:

- the upper mechanized company – 1 × Alvis Moelv;
- the central mechanized company – 1 × Alvis Moelv and 1 × mine clearance team from the demining team;
- the lower mechanized company – 1 × AACE

The Python explosive deminer was removed from the central company as part of the second variant to reduce the engineer force. The lower company was further stripped of the Alvis Moelv engineer tank in the final, third variant of the reduced engineer support. For improved comprehension, the reduction of engineer support is summarized in Table 1.

Table 1: Summary of the reduction of engineer support

Reduction of engineer support	Mechanised companies	Complete reduction of engineer forces in comparison to the second variant
1 st reduction	Upper company	1 x Alvis Moelv
	Central company	1 x Alvis Moelv 1 x engineer squad
	Lower company	1 x AACE
2 nd reduction	Upper company	1 x Alvis Moelv
	Central company	1 x Alvis Moelv 1 x mine clearance team 1 x Python
	Lower company	1 x AACE
3 rd reduction	Upper company	1 x Alvis Moelv
	Central company	1 x Alvis Moelv 1 x engineer squad 1 x Python
	Lower company	1 x Alvis Moelv 1 x AACE

A gradual approximation of the curves expressing the losses of friendly and enemy forces was evident when considering the results of the simulations for variants of the reduced engineer support. For the second variant, the simulation results were very close to the desired state. Subsequently, the amount of engineer support for the lower company was further reduced, even compared to the condition where the simulation results confirmed the defeat of the attacking forces, because the total amount of support for the lower company appeared oversized compared to the other two. Nevertheless, the aggregate size of the engineer force and allocated resources was larger, comprising a total of 46 personnel and 18 vehicles. The following represents the optimal configuration of engineering support for the simulated scenario.:

- 1 × AACE and 1 × Python assigned to the upper mechanized company;
- 1 × AACE assigned to the central mechanized company;

- 1 × engineer platoon consisting of two engineer squads equipped with infantry fighting vehicles, excavators and trucks providing support and 1 × Python to the lower mechanized company;

Figure 6 shows the course of the loss of fighting forces over time when the task of attacking forces, supported by an optimal variant of engineer forces, is fulfilled. The task was completed with losses (34% of friendly forces).

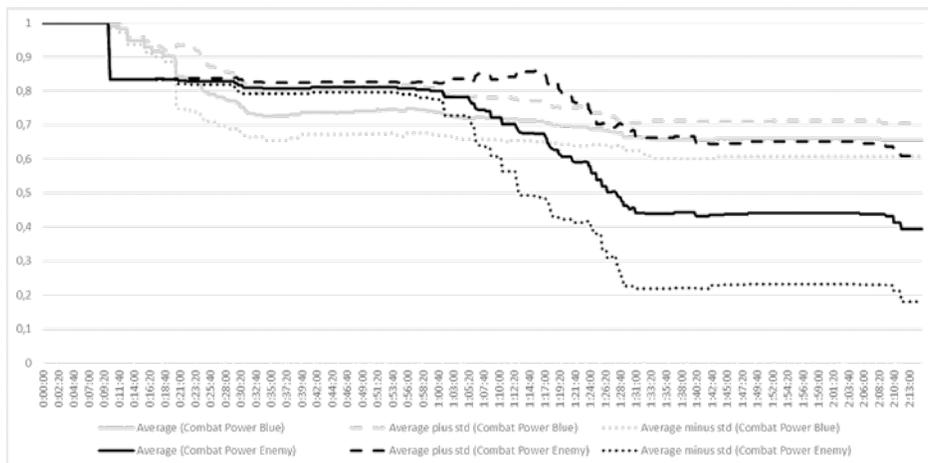


Figure 6: Combat power (10) – optimal engineer support

Analogous to the previous scenario, the deviation was insignificant for the needs of this study at 100 repetitions (see Figure 7). The losses of friendly forces were higher for the comparison involving 10 repetitions (35 %).

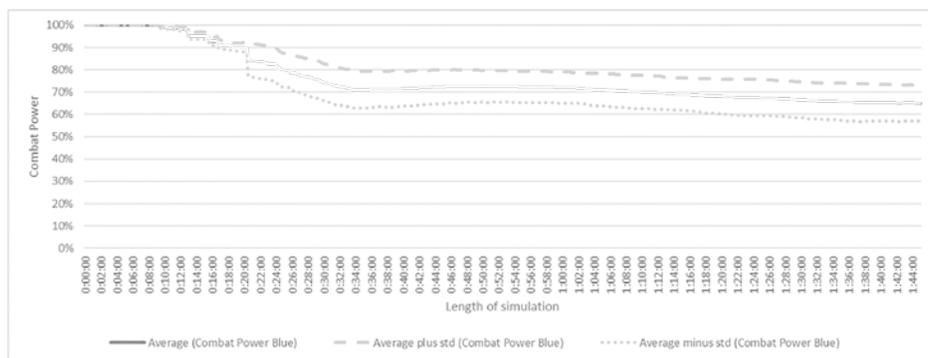


Figure 7: Combat power (10) – optimal engineer support

4.2 Statistical Evaluation

For the purposes of statistical evaluation, two-sided and one-sided parametric statistical hypotheses tests were applied, namely the test of the agreement of mean values (Student's t-distribution). For these purposes, the normality of the data was verified using Q-Q plots, including the determination of skewness and kurtosis coefficients. Small deviations from normality were found especially when testing the kurtosis of the distribution; nevertheless, graphic analysis did not show significant deviations from normality, the theoretical quantiles and the corresponding empirical quantiles lay approximately on the same straight line (Vlkovský et al. 2021). The mean values (μ) of Combat Power Blue (friendly forces) for 10 and 100 repetitions, and analogously for the Combat Power Enemy (enemy forces), were tested.

The results of the statistical analysis are presented in Table 2. Index 1 indicates Combat Power Blue (friendly forces), and index 2 indicates Combat Power Red (enemy forces). Each test was performed for simulations with 10 and 100 repetitions, respectively. The AH abbreviation denotes the alternative hypothesis for the F and t parameters (the values of the statistics for the tests of hypotheses concerning the homogeneity of variances σ^2 or, more precisely, the mean values μ for all three scenarios (LOS, MIN, WIN). These tests were performed based on the assumption of heteroscedasticity.

Table 2: Results of statistical tests

Dataset	AH _F	F	AH _t	t
LOS10	$\sigma_1^2 \neq \sigma_2^2$	1.539	$\mu_1 \neq \mu_2$	-11.870
MIN10	$\sigma_1^2 \neq \sigma_2^2$	0.266	$\mu_1 \neq \mu_2$	12.549
WIN10	$\sigma_1^2 \neq \sigma_2^2$	0.063	$\mu_1 \neq \mu_2$	56.524
LOS100	$\sigma_1^2 \neq \sigma_2^2$	1.166	$\mu_1 \neq \mu_2$	-4.987
MIN100	$\sigma_1^2 \neq \sigma_2^2$	0.379	$\mu_1 \neq \mu_2$	8.257
WIN100	$\sigma_1^2 \neq \sigma_2^2$	0.055	$\mu_1 \neq \mu_2$	58.742

Statistical tests were performed at a significance level of $\alpha = 0.01$. Statistically significant differences between the observed parameters (μ and σ^2) were observed for the LOS10 and LOS100 variants. A one-sided test was then applied to test the validity of the alternative hypothesis, where the mean values of Combat Power were statistically significantly lower for Blue (friendly) than for Red (enemy), hence $\mu_1 < \mu_2$. The number of repetitions of the simulation did not play a significant role in this case, although the value of the t-parameter was different from that of the WIN variant. The WIN variant also showed a statistically significant difference between the examined parameters, and the one-sided test subsequently showed the opposite conclusion than the previous variant, namely that the median Combat Power values were statistically significantly higher for Blue (friendly) than for Red (enemy), thereby ($\mu_1 > \mu_2$).

Statistical analysis was further performed for the MIN variant, which represents the minimum required military engineer forces to achieve the task that was simulated and was meaningful from the perspective of the CAF structures. Although the values were

marginal, there was a statistically significant difference in the variances and medians for both the 10 and 100 repetitions, as in the previous variants. A one-sided test was then performed to verify the validity of the sought inequality, and it was verified that the median values of Combat Power were statistically significantly higher for Blue (friendly) than for Red (enemy), and the same was valid for the WIN variant $\mu_1 > \mu_2$. However, from the previous graphs (Figure 6 and 8), it is apparent that the losses are significantly higher (20%).

The results of the statistical evaluation showed that there were significant differences between the different variants performed, although the difference between the minimum and optimal variants was only 11 soldiers and 3 vehicles. From the simulation results, it can be concluded that the hypothesis has been confirmed.

CONCLUSION

It is suggested that the constructive simulation tool is highly beneficial for military planning purposes, as it allows for the swift and accurate assessment of chosen scenarios. Constructive simulation is applicable across all stages of staff planning, but is particularly useful during the COA Development, COA Analysis, and COA Comparison phases. However, one potential drawback of using this tool in scientific research is the challenging verification of outcomes, particularly in larger military units, where conducting such exercises would be prohibitively expensive if not entirely impractical.

Owing to the possibility of replaying selected simulations, the course participants could see the course of the manoeuvres of the attacking forces and the reaction of the units in defence of the development of the situation. On this basis, a stimulating discussion was held between the various processing groups in which they exchanged views and opinions on the results of the individual simulations. This allowed the participants to think about the issue from a new perspective, whereby they strengthened their knowledge concerning the effect of the robustness of engineer support on the losses of friendly and enemy forces, the importance of reconnaissance in military operations, the effect of losses on unit behaviour, the effect of artillery fires on the partial clearance of minefields, and the importance of protecting engineer units from enemy fires.

Even so, it must be remembered that the results of a simulation may not always correspond to the real situation because a very large number of factors enter into a military operation and influence it, but the results obtained, and the course of the simulations can serve as an important guide for making decisions about limited resources in combat. The subject of further research will be the wider application of the constructive simulation tool in CAF. It could be very beneficial to implement constructive simulation in the educational process of not only engineer officers to evaluate the effect of the planned measures.

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