Supporting the decision-making process in the planning and controlling of engineer task teams to support mobility in a combat operation

Ota ROLENEC, Karel ŠILINGER, Tibor PALASIEWICZ, Pavel ŽIŽKA

***Abstract*—**The article deals with the possibilities of supporting the decision-making process of the engineer officer in a task force staff during planning the use and controlling of engineer task teams in a combat operation using designed software. Decision support is particularly important due to the increasing dynamics of the combat and the many factors that the engineer officer must assess during his/her activity in the staff of the unit. The application is designed to create engineer-modular elements suggestions to mobility support on a tactical level based on input data. Due to the simplicity of the algorithm and the speed of design creation, it can be used not only during the planning of the operation but also in the controlling of the engineer task teams in the change of the anticipated course of the operation, unexpected losses of engineer forces and resources, the necessity to perform new tasks of engineer support, etc. The analysis of national and foreign documents and the experience of authors from practical exercises was used to develop factors for assessing their influence on the composition of forces to support the mobility of troops. After the program was created, staff training (experiment) was carried out, which confirmed the research prerequisite and the correctness of the algorithm.

***Keywords*—** combat support, decision-making process, engineer mobility support, making models, staff training.

I. Introduction

THE current battle dynamics puts high demands on staff members to plan and manage combat and combat support [1],[2],[3]. There is no methodological procedure in the Armed Forces of the Czech Republic (ACR) defining individual steps in the decision-making process, which would allow the optimal structure of engineer teams not only to support mobility. It always depends on the particular designer of the engineer's proposal to support the activities of the troops, whether he will cover all the factors needed to select the appropriate engineer assets and units capable of effectively meeting the required tasks [4], [5]. The aim of the article is to describe the design of the universal process in the form of an algorithm that would serve to identify individual modular elements comprised of forces and devices of the engineer's army, allowing the creation of optimal teams to support mobility. The resulting designs of engineer modular elements are split to support light and heavy brigade task forces in accordance with the Bi-SC Capability Codes and Capability statements [6]. After the algorithm was created, it was transformed into a simple WPF application that uses the "Data" file containing the structures of the individual engineer modular elements. Such a processed application can be easily redrawn to any national context by translating the text of its user interface and taking into account the available technology and organizational structure of the state's army. The article also presents a version for the Army of the Czech Republic.

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II. Movement Assessment Factors for Planning and Controlling of Mobility Support

The determination of the following steps is based on the study of the national and North Atlantic Treaty Organization documents, study texts of the Czech military university (University of Defense) and on the experience in calculating the engineers' forces and devices during exercises of the ACR units [7]. When calculating the required engineer devices, the following factors should be considered in turn according to the individual tasks of engineer mobility support. **When creating passages in explosive and non-explosive barriers, account must be taken of:**

- assumed depth of anti-tank minefields - this parameter will determine the amount of self-propelled/towed explosive mine clearing devices, mechanical mine clearing devices, or the need of engineer squads for manual mine clearance;
- assumed depth of anti-personnel minefields – it will determine the amount of portable explosive mine clearing devices, or the need of engineer squads for manual mine clearance;
- assumed presence of surface mines on paved roads – it

will determine the need for surface clearance devices;
- assumed presence of non-explosive barriers and trenches - will determine the need for engineer earthmoving machines.

When bridging obstacles, it is necessary to consider:
- assumed width of overcome dry and water barriers in the operation area - which determines the number of assault or supporting bridges;
- assumed depth of dry and water barriers in the operation area - which determines usable assault or supporting bridges and the principles of their use;
- assumed water flow rate - which provides for restrictions on the use of bridge technology;
- assumed shore adjustments when overtaking an obstacle beyond contact with the enemy - which will determine the need for engineer earthmoving machines;
- assumed shore adjustments when crossing a water barrier under enemy fire, requiring an amphibious armored bulldozer.

When developing and improving roads it is necessary to consider:
- the number of main routes to monitor and maintenance (both cross and longitudinal brigade/battalion) - which affects the number of vehicles to reconnaissance, the number of earthmoving machines and land transport vehicles;
- sprawl of roads and areas due to rainfall - which has an impact on the increased need for earthmoving machines and land transport vehicles.

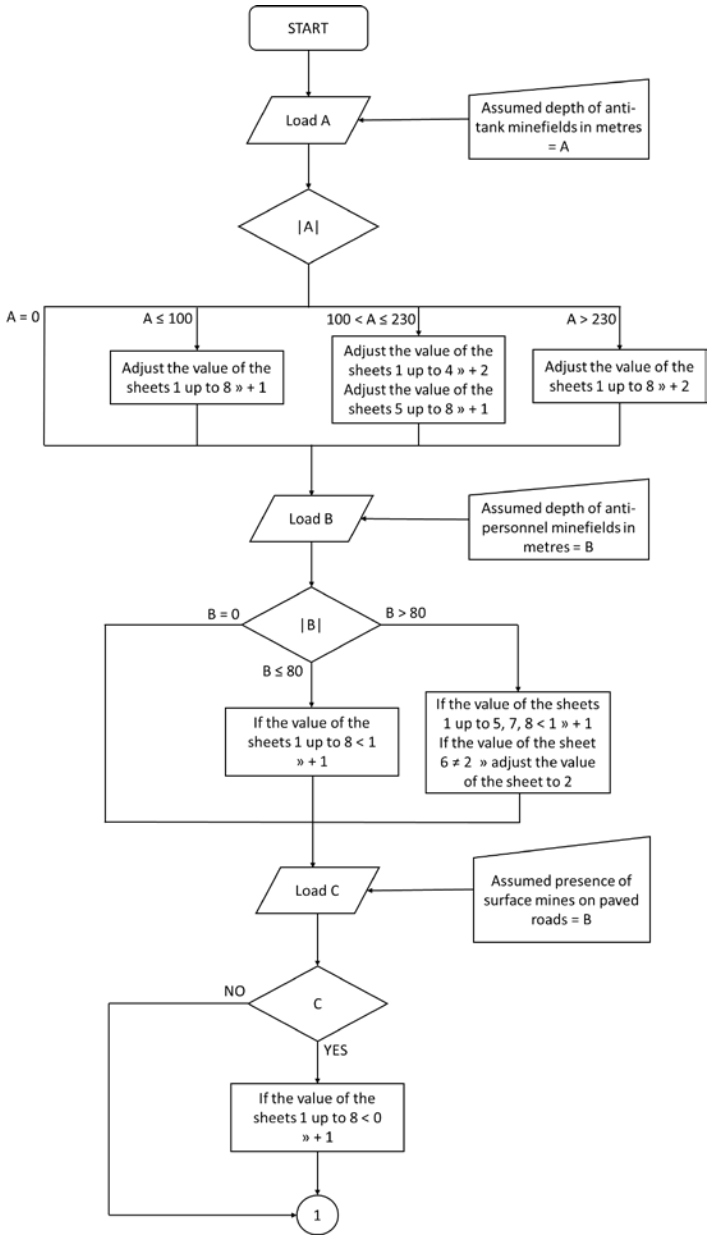
Anti-mine action should take into account the assumed occurrence of roadblocks in urbanized areas (larger agglomerations) to determine the need for a reconnaissance groups, armored bulldozers, engineer tanks, or an engineer squad with an increased supply of explosives.

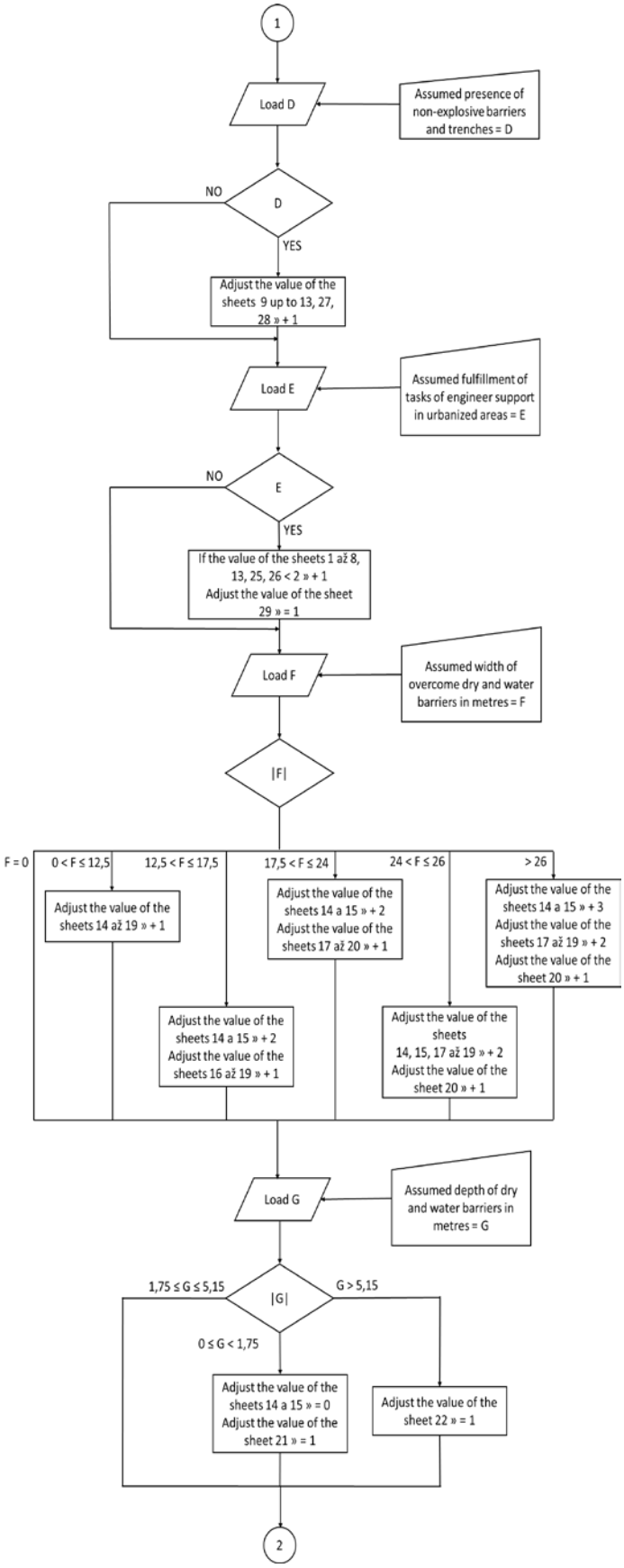
When constructing and maintaining of forward airstrips, consideration should be given to establishing additional requirements for engineer earthmoving machines.

The establishment and maintenance of most types of transport crossing sites will not be solved in this algorithm because the determination of the specific type of crossing site and the number of the required equipment and devices must be preceded by a detailed engineering survey enabling all the necessary data to be obtained, which cannot be gained from the study of the map data and the operation order. Consideration will be given to the proposed algorithm only to modify banks and bottom for the establishment of a ford crossing site and to determine the number of assault and support bridges for bridging obstacles.

III. Illustration of the Algorithm and Description of the Developed Application

Using modeling, the algorithm was developed in the form of a flowchart in accordance with the standard ISO 5807:1985 [8]. Based on the algorithm, the application was programmed for use in staff training (experiment). The algorithm was elaborated in accordance with the individual steps of the proposed procedure to determine the required engineer task teams to support mobility, and based on the engineer modular elements capabilities, mathematical conditions were determined to assess the required amount of engineering forces and resources relative to the expected amount of military engineering. The output of the algorithm are proposals relating to both the current structures of the ACR engineer units and to the engineer technology used in the NATO Army.




1
Load D
Assumed presence of non-explosive barriers and trenches = D
NO
D
YES
Adjust the value of the sheets 9 up to 13, 27, 28 » + 1
Load E
Assumed fulfillment of tasks of engineer support in urbanized areas = E
NO
E
YES
If the value of the sheets 1 až 8, 13, 25, 26 < 2 » + 1
Adjust the value of the sheet 29 » = 1
Load F
Assumed width of overcome dry and water barriers in metres = F
|F|
F = 0
0 < F ≤ 12,5
12,5 < F ≤ 17,5
17,5 < F ≤ 24
24 < F ≤ 26
> 26
Adjust the value of the sheets 14 až 19 » + 1
Adjust the value of the sheets 14 a 15 » + 2
Adjust the value of the sheets 16 až 19 » + 1
Adjust the value of the sheets 14 a 15 » + 2
Adjust the value of the sheets 17 až 20 » + 1
Adjust the value of the sheets 14, 15, 17 až 19 » + 2
Adjust the value of the sheet 20 » + 1
Adjust the value of the sheets 14 a 15 » + 3
Adjust the value of the sheets 17 až 19 » + 2
Adjust the value of the sheet 20 » + 1
Load G
Assumed depth of dry and water barriers in metres = G
1,75 ≤ G ≤ 5,15
|G|
G > 5,15
0 ≤ G < 1,75
Adjust the value of the sheets 14 a 15 » = 0
Adjust the value of the sheet 21 » = 1
Adjust the value of the sheet 22 » = 1
2
2
Load H
Assumed water flow rate of crossed watercourse in m/s = H
H ≤ 2,5
|H|
H > 2,5
Adjust the value of the sheet 23 » = 1
Load I
It is assumed that shore adjustments will be made to overcome the obstacle without presence of enemy = I
NO
I
YES
If the value of the sheets 9 až 13 < 1 » + 1
Load J
It is assumed that shore adjustments will be made to overcome the obstacle under enemy fire = J
NO
J
YES
If the value of the sheet 13 < 1 » + 1
Adjust the value of the sheet 24 » = 1
Load K
The number of main routes to monitor and maintenance = K
K = 0
|K|
K > 2
K ≤ 2
If the value of the sheet 11, 13, 30 až 33 < 1 » + 1
Adjust the value of the sheet 25, 26 » + 1
If the value of the sheet 11, 13, 30 až 33 < 1 » + 1
Adjust the value of the sheet 25, 26 » + 2
Load L
Assumed sprawl of roads and areas due to rainfall = L
NO
L
YES
Adjust the value of the sheet 9, 10, 12, 27, 28 » + 1
3

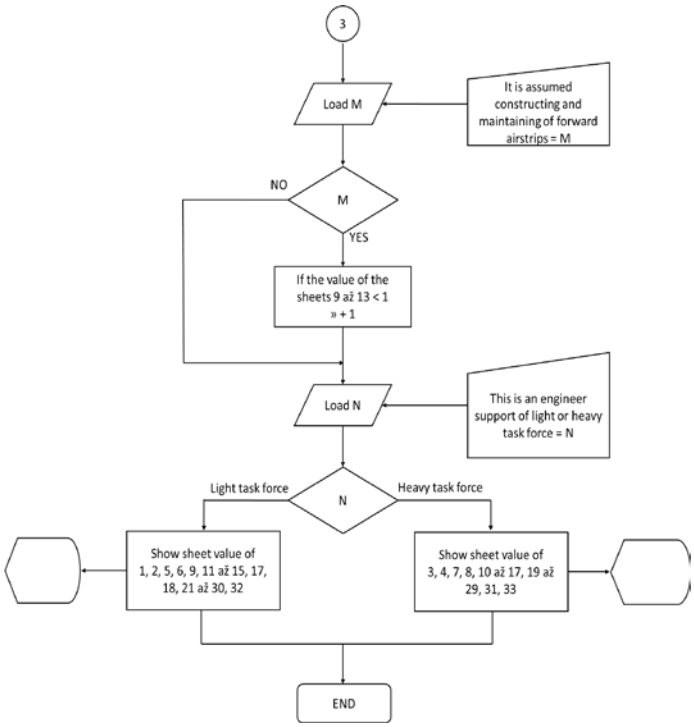


Fig. 1 Algorithm

To enable the creation of engineer task teams to support mobility, engineer modular elements were designed to form the basic "building blocks" of the proposed engineer forces for mobility support. The DATA file contains the following information about engineer modular elements:

1) modular element – engineer squad (for support of light task force – part of mobility support detachment of brigade level): 1 x truck tatra T-815/810;
2) modular element – engineer squad (for support of light task force – part of mobility support group of battalion level): 1 x wheeled armored vehicle in engineer version KOT-Ž Pandur, 1 x T-815/810;
3) modular element – engineer squad (for support of heavy task force – part of mobility support detachment): 1 x infantry fighting vehicle BMP-2;
4) modular element – engineer squad (for support of heavy task force – part of mobility support group): 1 x BMP-2, 1 x T-815/810;
5) engineer counter-obstacle modular element (for support of light task force – part of mobility support detachment): 1 x KOT-Ž Pandur, 1 x T-815 with armored cabin and hydraulic arm, 1 x mechanical mine clearing device, 1 x minefield breaching system Python;
6) engineer counter-obstacle modular element (for support of light task force – part of mobility support group): 1 x KOT-Ž Pandur, 1 x mechanical mine clearing device, 1 x bulldozer equipment, 1 x small projected line charge SAPLIC;
7) engineer counter-obstacle modular element (for support of heavy task force – part of mobility support detachment): 1 x BMP-2, 1 x T-815 with armored cabin and hydraulic arm, 1 x mechanical mine clearing device, 1 x bulldozer equipment, 1 x minefield breaching system Python;
8) engineer counter-obstacle modular element (for support of heavy task force – part of mobility support group): 1 x BMP-2, 1 x T-815 with armored cabin and hydraulic arm, 1 x mechanical mine clearing device, 1 x bulldozer equipment, 1 x minefield breaching system Python;
9) engineer machinal modular element (for support of light task force – part of mobility support detachment): 1 x excavator UDS 114 (214), 1 x excavator-loader JCB 4CX;
10) engineer machinal modular element (for support of heavy task force – part of mobility support detachment): 1 x excavator UDS 114 (214), 1 x excavator-loader JCB 4CX;
11) engineer machinal modular element (for support of light or heavy task force – part of mobility support group): 1 x excavator UDS 114 (214), 2 x loader KN-251;
12) engineer machinal modular element weakened (for support of light or heavy task force – part of mobility support detachment): 2 x armored excavator-loader MPEV;
13) engineer machinal modular element (for support of light or heavy task force – part of mobility support group): 2 x armored excavator-loader MPEV, 2 x armored bulldozer AACE;
14) modular element – automobile bridge (for support of light or heavy task force – part of mobility support detachment): 1 x automobile bridge AM-50;
15) modular element – automobile bridge (for support of light or heavy task force – part of mobility support group): 1 x automobile bridge AM-50;
16) modular element – bridge tank (for support of tank battalion – part of mobility support group): 1 x bridge tank MT-55;
17) modular element – support bridge (for support of light or heavy task force – part of mobility support detachment): 1 x support bridge SISU Leguan;
18) modular element – assault bridge (for support of light task force – part of mobility support group): 1 x assault bridge MOWAG Piranha 3;
19) modular element – assault bridge (for support of heavy task force – part of mobility support group): 1 x assault bridge Leopard 2 Leguan;
20) modular bridge element (for support of tank battalion – part of mobility support group): 1 x MT-55, 1 x bridge transporter PM-55;
21) recommendations to AM-50: Because of the low depth of the obstacles, the AM-50 can not be used when using more than one bridge span;
22) recommendations to AM-50: Because of the too deep obstacles, the AM-50 can only be used with one bridge span;

23) recommendations to modular bridge elements: Due to the high velocity of the watercourse, it is possible to use bridges with only one bridge (the ends of the bridges or bridge supports are not allowed into the water);
24) general warnings for mobility support: There are no devices in the ACR report for engineer support of the attack in case of crossing of the water barrier under enemy fire;
25) engineer reconnaissance and staking off modular element (for support of light or heavy task force – part of mobility support detachment or group): 1 x personal off-road car;
26) engineer reconnaissance and staking off modular element (for support of light or heavy task force – part of mobility support detachment or group): 1 x light armored vehicle;
27) transportation modular element (for support of light or heavy task force – part of mobility support detachment or group): 2 x tipper truck tatra T-815 S3;
28) transportation modular element (for support of light or heavy task force – part of mobility support detachment or group): 2 x T-815 S3 with armored cabin;
29) recommendations on the use of explosives: There will be an increased need for explosives in an urbanized area during mobility support for removing barriers;
30) technical modular element (for support of light task force – part of mobility support detachment): 1 x T-815/T-810, 1 x UDS 114 (214), 1 x KN 251, 1 x JCB 4CX, 1 x T-815 S3;
31) technical modular element (for support of heavy task force – part of mobility support detachment): 1 x BMP-2/T-815/T-810, 1 x UDS 114 (214), 1 x KN 251, 1 x JCB 4CX, 1 x T-815 S3;
32) technical modular element (for support of light task force – part of mobility support detachment): 1 x KOT-Ž Pandur, 1 x mechanical mine clearing device, 1 x bulldozer equipment, 2 x MPEV;
33) technical modular element (for support of heavy task force – part of mobility support detachment): 1 x BMP-2, 1 x mechanical mine clearing device, 1 x bulldozer equipment, 2 x MPEV;

The application was developed in the Microsoft Visual Studio Community 2015 development environment using the C # programming language. For the design of the application the .NET Framework 4.5.2 platform was used. The program is handled as a Windows Presentation Foundation application and requires about 70 MB of free operating memory. It was named "Application to Optimize Engineer Structures for Mobility Support" - shortly APOSŽPP. The shortcut name APOSŽPP consists of the initial letters of the program name (in Czech language) and is also used for individual application files (including the created shortcut on the Windows operating system desktop after installation). The program's initial application window provides basic information about the program, and after pressing START, the user is prompted to enter the required values (Figure 2).

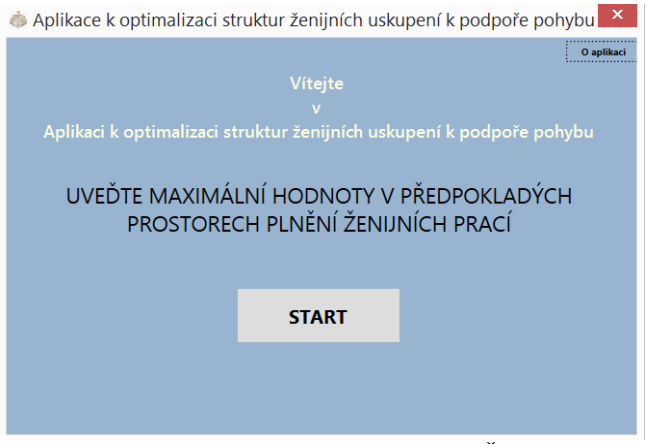


Fig. 2 Initial application screen of APOSŽPP

The last window of the application displays the values of the sheets of the "Data" file (Figure 3). The engineer officer, depending on his level (battalion, brigade), will choose which pane will draw the required information to support him in building the optimal structure of engineer task teams to support mobility, depending on available devices. The right part of window contains sheet´s values to build up the structure of teams if it has the necessary (proposed) vehicles and devices available.

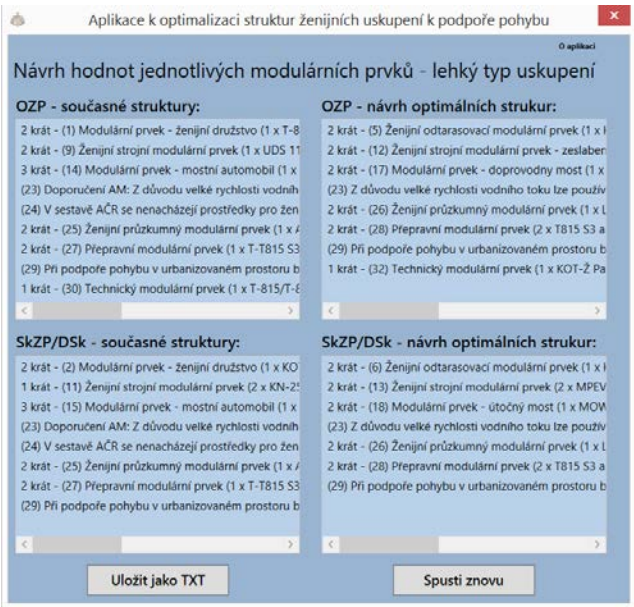


Fig. 3 Application results of APOSŽPP

The program also offers the ability to save structure designs to any * .txt file or to run the application again (Figure 4).

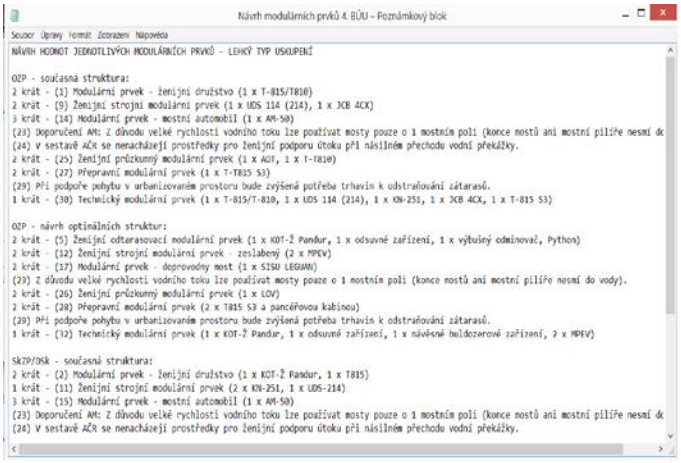


Fig. 4 Application results of APOSŽPP shown in a text file

IV. 3 Execution and Evaluation of Staff Training

On 15 May 2018, a staff training was carried out at the crew of the engineer battalion, the task of which was to create elements of the combat composition (mobility support detachment, block detachment, engineer reserve and others) and to assess the allocation of the engineers' forces of battalions of the brigade combat team on the basis of an operational order related to the offensive operation. From the point of view of the planning process of the engineer support of the operation, it was the stage of elaboration the concept and plan based on the decision of the commander to select a certain variant of the troops' activities. The purpose of the staff training was to train staff members in the decision-making process when planning engineer support and to confirm the research prerequisite: "The use of software will support the decision making of engineer officers and will allow the creation of an optimal organizational structure of the engineer unit for mobility support from available resources, from an engineering point of view. " Another goal was to confirm that the algorithm meets all the relevant criteria, including:

- universality – the algorithm leads to the solution of a general class of tasks in the field of engineer forces calculation for mobility support;
- unambiguous – at any step of the algorithm, it is clear how to proceed;
- resultant – after the final number of steps has been completed, the algorithm has resulted in the final result;
- correctness – after completing the final number of elementary operations over a meaningful set of input data, the algorithm has reached the correct result;
- efficiency – time effectiveness of the algorithm.

During excercise were participants of the staff training found in the brigade combat team staff. They created 3 separate working groups of 2 members, which corresponds to the inclusion of engineer officers in the Group of combat planning of the Operation center. Their sorting was based on the assessment of the data from the structured CVs of the participants in the exercise so that the individual groups are balanced due to experience with planning and controlling of the engineer support. Everyone had to meet the entry criterion of an Master of science degree obtained at the Department of Engineer Support of the University of Defense or attending the "Engineer support management" course at the Department of Engineer Support.

Staff training participants were divided into groups so that the differences between them in knowledge and experience in planning engineer support were minimal. Multiple groups have ensured more incentives and the opportunity to compare and evaluate more data. During the first part, the individual groups had to separately and independently of each other divide engineer forces to perform military engineering in engineer roles of mobility, counter-mobility and survivability. In the second part of the training was an application presented and then a re-planning of the engineer support was performed, now only within the role of the mobility support. This ensured that the participants in the first part did not concentrate solely on mobility support and had to comprehensively plan the engineer support of the task force. The training was commenced at 7:30 am with a briefing of the general situation, the task and intent of the supervisor and commander of the brigade combat team, the organizational structure of own forces (including the assigned engineer's and superiors' units), enemy forces structure, intelligence and phase of the operation. For the field analysis, they used a 1:50000 scale mapping background. To divide the engineer units into engineer task teams was calculated with the engineering battalion designated for the benefit of the brigade combat team, assigned counter-obstacle detachment and the engineer forces of the maneuver battalions of the mechanized brigade. All groups were given a two-hour timeframe to complete the task and create a document justifying the intention of engineer support of the variant of the troops' activities. By presentation of the proposed intention to perform the tasks of engineer support of individual groups was completed the first part of staff training (Figure 5).

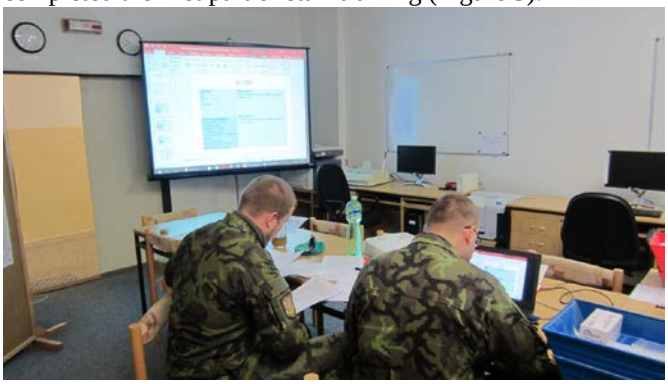


Fig. 5 First part of staff training

The second part consisted in the re-distribution of engineering forces for mobility support using the APOSŽPP application (Figure 6). At the beginning of the exerciser was explained how to enter values into the application and meaning of the resulting data and work with them. It was emphasized

that the engineer modular elements depicted are suggestions that engineer officers can use in planning of engineer support. Therefore, they do not represent values that they must use strictly. The remaining conditions were the same as in the first part. One hour was set to complete the task. The output was a presentation justifying the intention of engineer support and the differences between the calculations in the first and second part of the staff training.

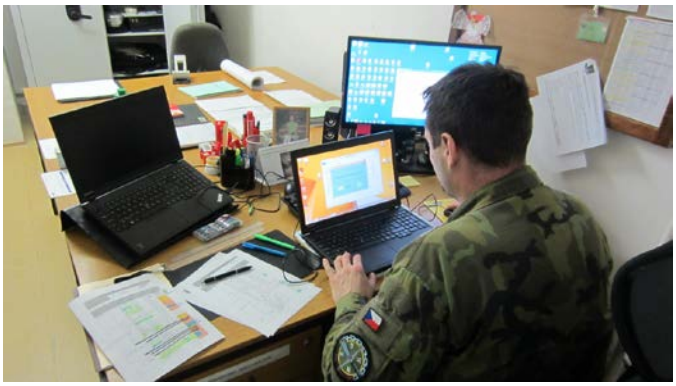


Fig. 6 First part of staff training

Each group prepared its own draft of brigade combat team engineer support, which differed from each other in the number and types engineer task teams and their structure. In the first part of the training the following suggestions were prepared:

1) counter-obstacle detachment (to support mobility of mechanized battalions and light motorized battalion), 2 x mobility support detachments (obstacle breaching, developing and improving brigade longitudinal routes for tactical movement), block detachment, counter-obstacle group (reinforcement of mechanized battalion), mobility support group (reinforcement of light motorized battalion), engineer reserve;
2) 2 x counter-obstacle detachments (to support mobility of mechanized battalions and tank battalion), 3 x mobility support detachments (obstacle breaching, developing and improving brigade longitudinal and cross routes for tactical movement), block detachment and engineer reserve;
3) 2 x mobility support detachments (obstacle breaching, developing and improving brigade longitudinal routes for tactical movement), block detachment, 3 x counter-obstacle group (reinforcement of two mechanized battalions and tank battalion) and engineer reserve.

When using APOSŽPP, each type and number of engineer task teams for mobility support in two groups did not differ from the original design. But their structures have always been modified on the basis of designs of engineer modular elements. For example, the removal of an automobile bridge (AM-50) due to the low depth of overcome obstacles in the area of operation, the assignment of engineer squads to the mobility support detachment for using of explosives and engineer kits in the execution of military engineering, the removal of BOŽENA de-mining complex from the counter-obstacle detachment for minefield breaching and the strengthening of counter-obstacle detachments in III. phase of the operation for the implementation of engineer support in an urbanized area. For the rest of the group, a complete reorganization of the engineer units was carried out due to the software, and instead of the counter-obstacle detachments and the two mobility support detachments, it was proposed to create one mobility support detachments by merging the aforementioned detachments. In addition, it was proposed to include other engineer machinery to engineer units to enhance mechanized battalions and light motorized battalion.

During the second part of the staff training, the participants were asked to give the assets and the recommendations for use of the application. These assets are as follows:

- the ability to compare engineer task units structure without and with the application;
- obtaining and deepening the general overview of the use of engineer machinery;
- enabling minimization of failure to include engineer forces in task units;
- the speed of the initial suggestion of engineer modular elements;
- take into account the degree of battalion.

Suggestions have been made to improve the application's user interface and to add some features and extend its capabilities:

- option to generate input values for the application for feedback control;
- subtracting unit numbers and techniques from the engineer battalion structure, then displaying the remaining battalion forces;
- elaboration and extension of the algorithm for input of multiple input values - to incorporate the possible effects of enemy artillery, to develop the possibilities of fulfilling the engineer support in dry and rainy conditions, etc.

All training groups agreed to the research prerequisite, which they had to express at the end of the staff training. One group, however, said that the next step should be followed by evaluation of individual proposals using selected criteria in the war games, which would verify the relevance of the proposals with the application. This recommendation can be only partially agreed, because the resulting proposals of engineers are always the product of an engineer officer and the proposed engineer modular elements may or may not use. This testing would be possible if the algorithm were extensively extended and allowed to generate the organizational structures of engineer task teams.

V. Conclusion

Each group elaborated their own variant of engineer support, differing in numbers and types of engineer task teams. The used machinery in the task teams was very similar in all

groups. After using the APOŠŽPP application, all task teams have been able to adjust the numbers and types of engineer devices and engineer squads within mobility support tasks. In one case, the engineer support version was even completely redesigned.

The recommendations from the participants of the staff training were stimulating and inspirational. Most of them concerned application features that can be integrated without modifications in the flowchart and are about facilitating and extending workflow capabilities. The last two points of the application recommendation describe the next possible phase of the algorithm development, which would put his every step to develop longer and more complex algorithm. To do this, it can be used the formula to solve optimization tasks and graphical tools to display the resulting engineer task teams' designs. These suggestions would then be linked to the organizational structure of the engineer battalion and would be subtracted from mutual values. The resulting flowchart and linking to source files, containing organizational structures of modular elements and engineer structures, would be considerably more robust. It is one of the other possible directions of scientific research in the field of engineer mobility support.

After the end of the staff training, it was stated in the subsequent discussion that the use of the APOSŽP application could lead to a reduction of the view and consideration of the overall concept of the operation of an engineer officer because of over-confidence in the software. This problem, however, concerns all the modern functionalities that use the operational-tactical command and control system. The user of this and similar programs must always be able to perform the assigned tasks even without their use and must critically consider the acquired values.

Staff training on the basis of the expressions of the participants and proposed engineer task teams confirmed the research prerequisite: "The use of software will support the decision making of engineer officers and will allow the creation of an optimal organizational structure of the engineer unit for mobility support from available resources, from an engineering point of view." The remaining objective for algorithm criteria has been reached. The groups evaluated the data as generic enough to support the creation of task teams, the program led to a clear result, which with its parameters approached the values calculated in the first part of the training, and therefore they represented the correct output. The time effectiveness (speed) of the data obtained was positively evaluated by all groups.

A solution for the ACR was presented, but it is simply editable to another army, as the processed algorithm is usable by anyone. In the next phase of the research, it would be appropriate to elaborate the individual steps of the algorithm using a set of equations solving the optimization tasks to more detailed determination of the required engineering technique and to extend the application to the possibility of generating variants of the organizational structures of the engineer units based on the rules and principles stated in the national regulations.

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