Algorithm Development of the Decision-Making Process of an Engineer Specialization Officer

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Abstract. Military operations represent a complex involvement of various types of forces, requiring as far as possible their flawless alignment during the maneuver to meet the objectives of the operation. In order to use the forces effectively, it is necessary to successfully carry out the planning process of the task force to create an operational order and to be able to effectively command and control subordinate units during the conduct of the operation based on the development of the situation in the combat zone. The article describes the algorithm development of individual steps of the decision-making process of the brigade combat team staff officer of the engineer specialization when designing the mobility and counter-mobility support of task force during the planning of the operation. The proposed individual steps of the decision-making process were designed based on the analysis of documents related to the engineer support of the troops and the authors' own experience from practical exercises and exercises on simulators. Each step of the algorithm requires input data from the user, based on which it adds values to the designed engineer modular elements. The output and the main benefit of the algorithm are the values of modular elements and engineer-based recommendations for their use. Based on the algorithm, software was programmed to support the decision-making process of the engineer officer, leading to a reduction in the probability of human error during the planning process given the different levels of knowledge.

Keywords: Algorithm · Counter-mobility support · Decision-making process · Military engineering · Mobility support

1 Introduction

Current and future armed conflicts will be characterized by a high degree of dynamics [1]. The gradual introduction of robotic assets [2] into the equipment of armed forces [3, 4] and the control of automated activities will place high demands on staff members in the planning and management of combat and combat support. Preparing staff members in the ability to correctly assess the battlefield situation and adapt to evolving situations is crucial to enable sound decision making and effective management of all subordinate units in an operation. To support decision making, it is necessary to have well-developed standard operating procedures and costings for unit-level activities at the staff and unit levels. Furthermore, it is advisable to have software tools that enable the unification of some parts of the decision making process [5].

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This approach also corresponds with Environment 4.0, elsewhere also Industry 4.0 or "Revolution 4.0", which is an environment whose characteristics seek to capture the various initiatives responding to what is called the fourth industrial revolution. Examples include the German initiative of 2013 called Industrie 4.0, the Industrial Internet Consortium or the Smart Manufacturing Leadership Coalition in the USA, or similar projects and programmes in Japan and China. All of them accentuate the "new" philosophy of systemic use, integration and interconnection of various technologies with the dominant role of information and communication technologies, considering their continuous and very rapid development. This "new" philosophy, in many of its supporting characteristics, corresponds to the issue of implementation of the NATO Network Enabled Capability (NNEC) concept, i.e. the concept of using modern information and communication technologies for effective performance [6, 7] of activities and functions in the security environment.

Although information on command and control systems is generally classified, there are articles on the general approach to this issue. In [8] is proposed a decision-making system to solve dynamic, multi-objective and unequal-area construction site layout planning problem to reduce construction costs. The system is using mathematical optimization models max-min ant system, modified Pareto-based ant colony optimization algorithm and the intuitionistic fuzzy TOPSIS method. Article [9] aims to elaborate an intelligent decision support system that provides relevant assistance to urban planners in urban projects by using machine learning classifiers, naive Bayes classifier and agglomerative clustering. The paper [10] presents a decision support system to help Command and Control operators to help the decision-making process in case of interdiction operations so that the success rate increases. Article [11] presents military tactical planning systems using computational system called fuzzy-genetic decision optimization which combines two soft computing methods, genetic optimization and fuzzy ordinal preference, and a traditional hard computing method, stochastic system simulation, to tackle the difficult task of generating battle plans for military tactical forces.

The shortcomings and deficiencies of the current command and control system modeling and proposed a command-and-control system modeling based on the entity-relationship is presented in [12]. Combined with the Lanchester model considering efficiency of command this paper takes command and control system models for scenario analysis. Paper [13] describes a new way to combine NATO partners' command and control systems and simulation systems into a system of systems, that can support military training, course of action analysis, and mission rehearsal for a coalition.

This article deals with the support of the decision making process of the engineer specialisation staff at the brigade and battalion level in the creation of engineer groups (modules) for engineer mobility support and counter-mobility support. When assessing the tasks performed in the above mentioned engineer roles, the survivability of the engineer role must also be taken into account, especially to assess protective structures [14] for their overcoming. The algorithm will allow the user to encompass all the factors needed to select appropriate engineer assets and units capable of effectively performing the required tasks. Thus, this article presents a different approach to developing a command and control system than that mentioned in the aforementioned papers, where the decision-making activities of members of a single specialty are optimized under predefined steps of a well-defined algorithm.

2 Algorithm Development

Determination of algorithm steps and ranges of values of individual coefficients is based on the study of national regulations and study texts of the University of Defence, calculation standards for individual military engineering works and tactical-technical data of engineering technology. The output of the algorithm are proposals of engineer modular elements related to the current structures of the engineer units of the Czech Army Corps of Engineers as well as to the engineer technology of the armies of NATO countries [15]. The algorithm described below is based on the previous version of the algorithm on the basis of which the APOSŽPP program was developed [16]. The new version of the algorithm includes:

- added steps in the mobility support part of the calculating engineer elements;
- modification of the original steps (changes in the descriptions of some steps) and modifications in the proposed number of engineering recommendations;
- extension of the whole section used for the creation of mine-laying means.

The algorithm should be used with the accompanying excel file "DATA", which contains tabs with information about the individual designed engineer modular elements intended to support movement and to limit enemy movement. Each tab contains the name, organizational structure and capabilities of the modular element in the area of engineer support of troop movement or movement restriction. In addition, the "DATA" file contains engineer recommendations related to engineer equipment or conditions for accomplishing engineer support tasks.

The algorithm requires the input of specific values or information about the occurrence of certain obstacles or the performance of some task of engineering support of troops. The user usually obtains this information from the combat order related to the operation or from studying the map documentation of the area of operation, or from the conducted reconnaissance in the areas of interest.

The algorithm is divided into three basic parts. The first part concerns the design of modules for engineer mobility support. The second part deals with calculations to design suitable engineer modules for counter-mobility support. The last part of the algorithm is intended to allocate the design of modules for engineer support activities between the light and heavy brigade combat team type.

2.1 Mobility Support Part

Mobility support part of the algorithm can be divided into several sub-parts. The first one is dealing with the occurrence of explosive roadblocks and their possible overcoming (see Fig. 1). This part of the algorithm deals with tabs 1 to 8 containing engineer modular elements based on engineer teams and engineer demining teams containing transport vehicles (T-815 medium off-road vehicle, BVP-2 infantry fighting vehicle and Pandur wheeled armoured personnel carrier), explosive mine clearing devices (towed explosive ordnance deminer Python and portable explosive ordnance deminer SAPLIC), mechanical mine clearing devices (bulldozer and demining plough) and surface clearance devices (additional minesweeping device POOZ).

Step 'A' assesses the assumed depth of anti-tank minefields to be overcome, which the enemy will establish on threatened lines of advance of adversary forces, particularly in calculated mobility corridors. Depending on the evolution of the situation, anti-tank minefields may also be established by means for establishing minefields remotely. The ability to overcome anti-tank minefields is very important because they can cause casualties, disrupt the battle formation, divert the direction of advance of own forces to areas ready for destruction (Kill Zones) and negatively affect the psyche of soldiers.

Larger input values or the performance of a certain task usually means an increase in the number of individual tabs. In the next steps, however, this increase is linked to the previous possible value of the bookmarks, so that their value is not increased beyond an unrealistic limit.

Step "B" assesses the assumed depth of antipersonnel minefields that own troops will have to overcome. Anti-personnel mines may be part of anti-tank minefields or non-explosive barricades, or they may be established separately. The fastest way to overcome them is to use explosive demining devices. The intervals used for the algorithm steps are related to the tactical-technical capabilities of the proposed modules.

Step "C" assesses preparedness for the possible occurrence of surface mines on paved roads. This step of the algorithm primarily forces the user to assess possible enemy measures depending on the evolution of the situation on the battlefield. Especially in an offensive operation, it is necessary to calculate the possible deployment of means establishing minefields at a distance.

Another sub-part of the algorithm (see Fig. 2) is dealing with overcoming man-made objects or non-explosive roadblocks and landslides and performing tasks in urbanized areas, representing a very common task in current conflicts. In step "D" and "E", tabs 1 to 13, 26 to 29 are modified to include, in addition to the aforementioned engineer units and demining assets, engineer engineered modular elements equipped with engineer earthmoving machines (universal finishing machine UDS, tractor-trailer JCB 4CX, wheel loader KN-251, excavator-loader MPEV and armoured amphibious bulldozer AACE) which are very effective for clearing non-explosive roadblocks in urbanized environments. In addition, the tabs contain engineer reconnaissance and demarcation modular elements (light armoured reconnaissance vehicle) that are essential for early identification and assessment of adversary roadblocks. The last type of recommended engineer elements is transportation equipment that allows for the transport of soil to backfill roadway embankments or the transport of necessary engineer tools (T-815 S3 dump truck in both unarmored and armored versions). This part of the algorithm also includes recommendations for increased consumption of explosives when performing engineer tasks in urbanized areas [17]. This is because underground and aboveground spaces are also evaluated in urbanized spaces.

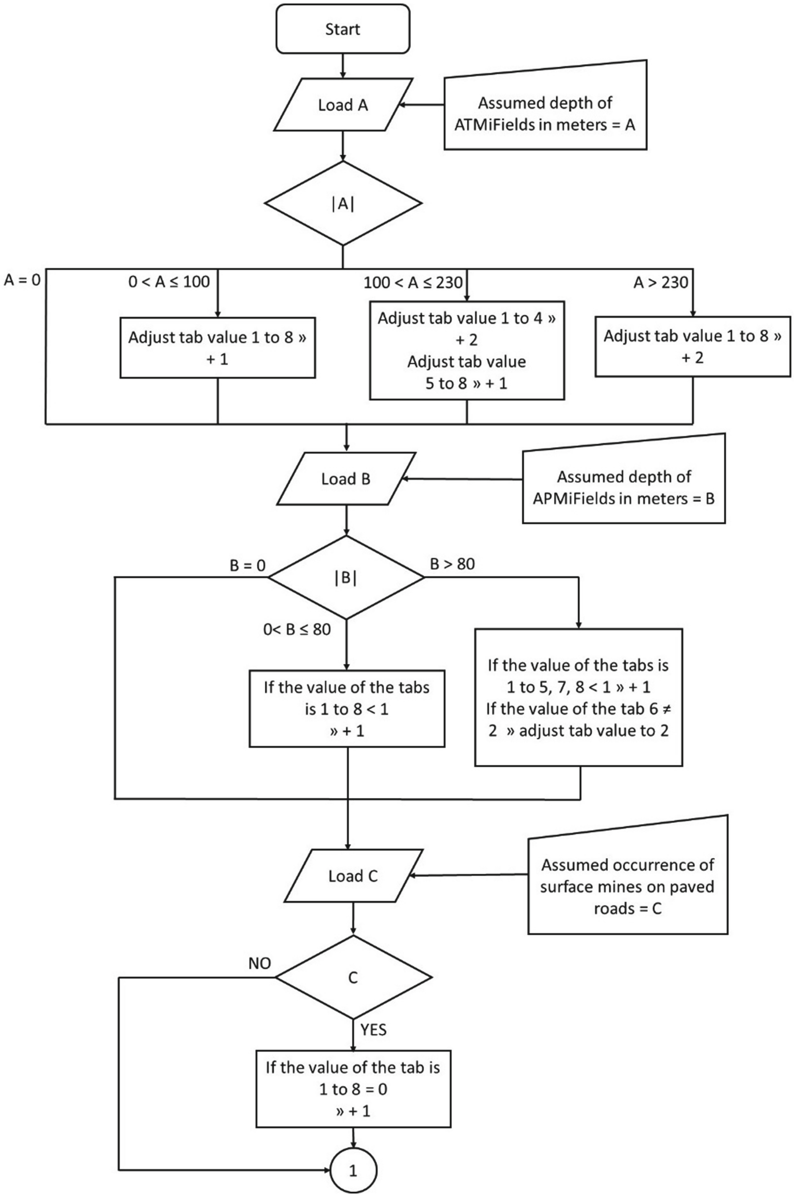

Fig. 1. Sub-part of the algorithm with steps “A”–“C”.

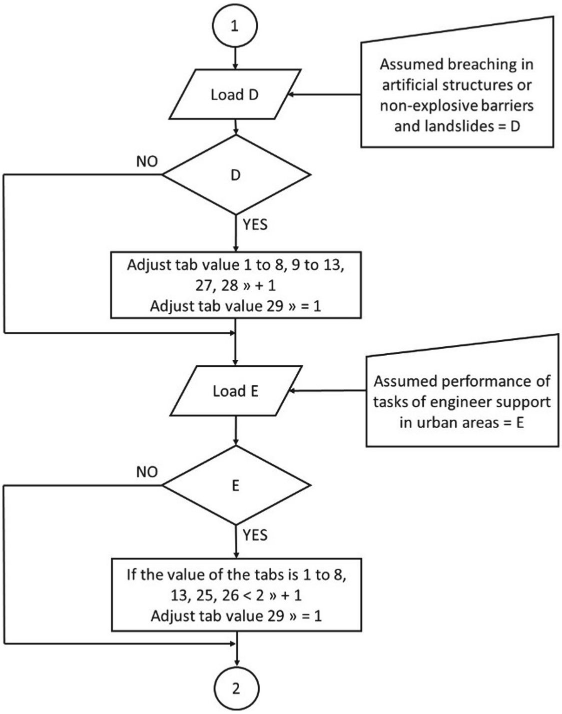

Fig. 2. Sub-part of the algorithm with steps "D"–"E".

The third sub-part of the algorithm (see Fig. 3) is dealing with the width and depth of dry and wet gap crossing. Step "F" calculates the engineered modular elements containing assault and accompanying bridges used in the armies of NATO countries (2nd echelon bridge layers AM-50/70, SISU Leguan, PAR-70, MS-20 and BR 90 ABLE; modular assault bridge PTA MAB; armoured vehicle launched bridge Mowag Piranha 3 and assault bridges Leopard 2 Leguan, Wolverine HAB and MT-55). The values of each tab are adjusted based on the ability of each asset to bridge a given gap width. Step 'G' assesses bridge assets whose design requires the placement of bridge piers in the gap.

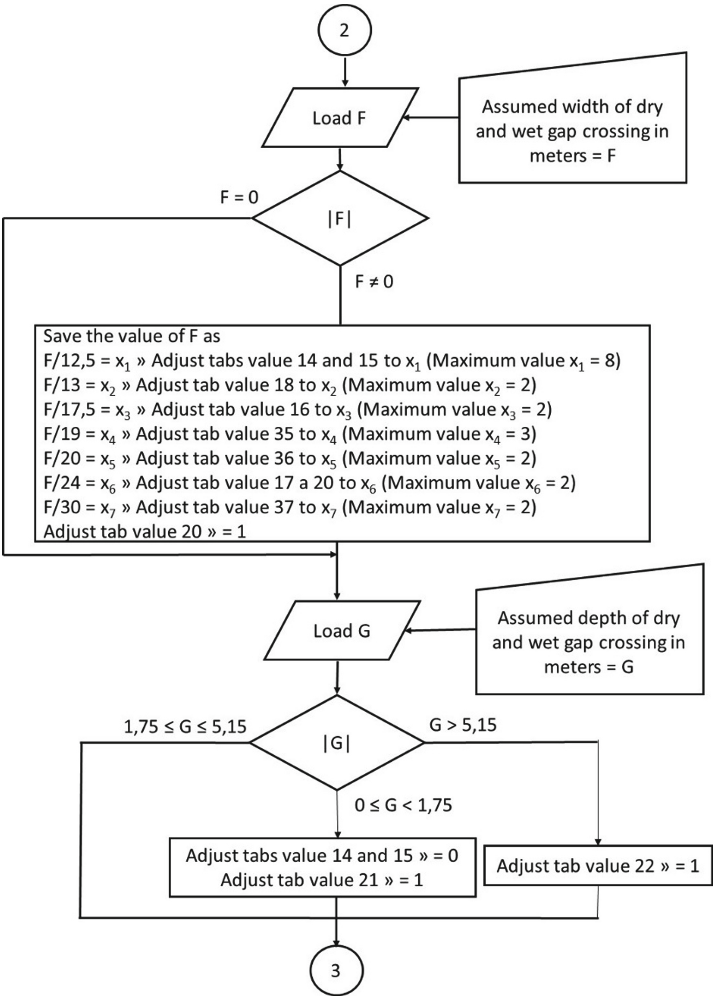

Fig. 3. Sub-part of the algorithm with steps “F”–“G”.

The next part of the algorithm deals with wet gap crossing and the earthworks in overcoming all types of obstacles (see Fig. 4). In step “H” it is necessary to assess whether the water velocity allows the construction of bridge crossing site requiring the use of bridge supports. If the watercourse velocity is too high, only single span bridges may be used and neither bridge ends nor bridge abutments may be placed in the watercourse.

Steps “I” and “J” assess the implementation of bank modifications when crossing an obstacle out of contact with the enemy or under enemy fire. This has implications for the selection of types of engineered earth moving equipment. While in the first case, ground vehicles with basic ballistic protection should be sufficient to accomplish this task, in the second case, it is necessary to use engineer amphibious ground vehicles with a high degree of protection against enemy fire. Amphibious armored bulldozers are suitable for this task.

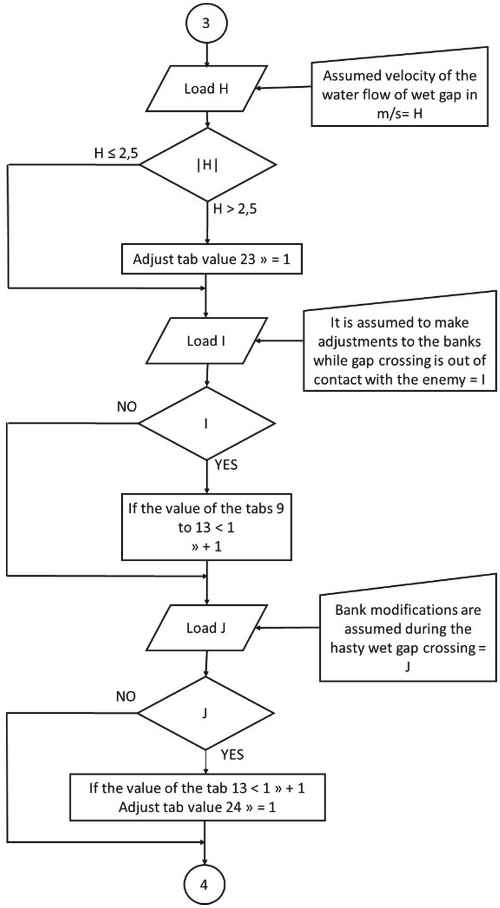

Fig. 4. Sub-part of the algorithm with steps "H"–"J".

The last part of the algorithm, which deals with engineer support for movement, is concerned with terrain modification to enable the movement of own forces (see Fig. 5). Step "K" specifies the number of longitudinal and tranverse paths to monitor and maintain in the area of operations. Their number affects the number of engineer earth moving equipment, engineer reconnaissance elements and technical modular elements representing a combination of transport equipment, displacement equipment and some types of engineer earth moving equipment. The selection in steps 'L' and 'M' allows increasing values for engineering modular elements and transport modular elements. These steps evaluate the possibility of muddying the roads due to meteorological conditions, overcoming natural obstacles and take into account the task of building and maintaining forward landing areas. In step 'N', the existence of explosive threats is assessed to calculate the clearance of paths and areas out of contact with the enemy. A positive selection under this step indicates a possible increase in the proposed number of engineer earth moving vehicles and mine clearance vehicles and a recommendation for deployment of EOD units.

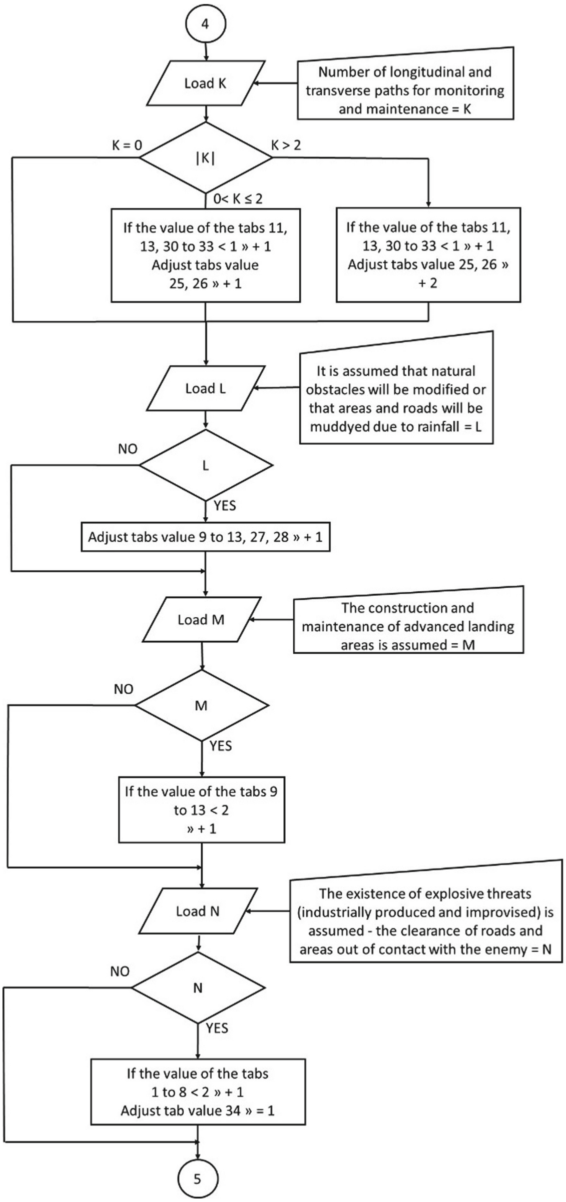

Fig. 5. Sub-part of the algorithm with steps "K"–"N".

2.2 Counter - Mobility Support Part

The second main part of the algorithm deals with the design of engineer mine-laying means. The algorithm's designs are particularly useful for obstacle detachments performing the task of establishing anti-tank minefields during a manoeuvre. As a first step in the first sub-part is the selection of available mine-laying means used in the armies of NATO countries (trucks with mines and slides, MV-3 mine thrower, minesweepers Minotaur, Skorpion, SUM Kalina and Volcano). This information is important for the calculations in the next steps of the algorithm.

In step "P" there is the possibility to define a custom minelayer. For further needs of the algorithm the name of the means, the amount of mines carried, the range value and the number of means are stored. Step "Q" allows to repeat this option based on the user's need (see Fig. 6).

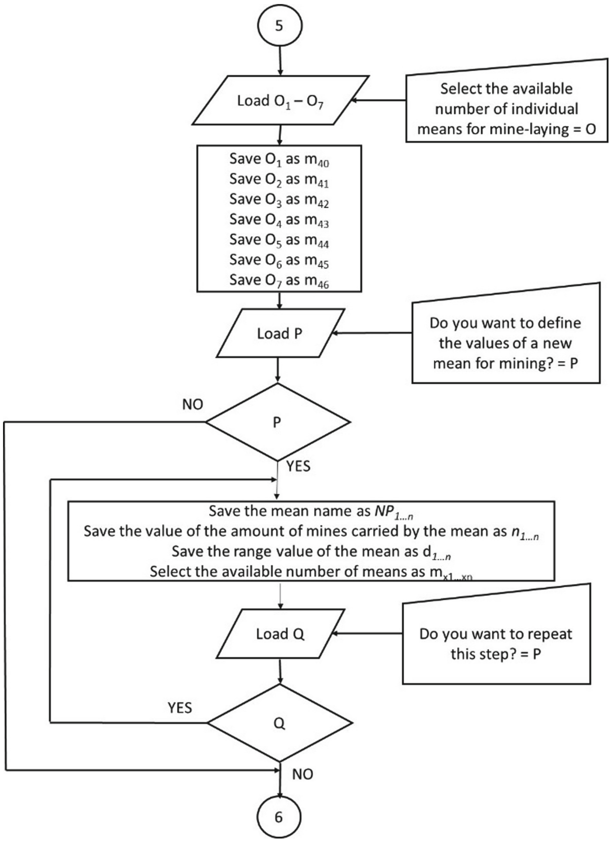

Fig. 6. Sub-part of the algorithm with steps "O"–"Q".

In the next sub-part of the algorithm (see Fig. 7), the quantity values for each obstacle are calculated based on the input data. In step "R", the expected maximum number of mines in the minefields to be established during the conduct of the operation is entered. This data is used to determine the maximum number of individual mine-laying devices with respect to their available quantity and their capabilities regarding the quantity of mines carried. In the 'S' and 'T' steps, the expected maximum length of the anti-tank minefields to be established and their calculated density are entered, considering for all proposed assets the use of only anti-tank mine types acting on the entire vehicle profile.

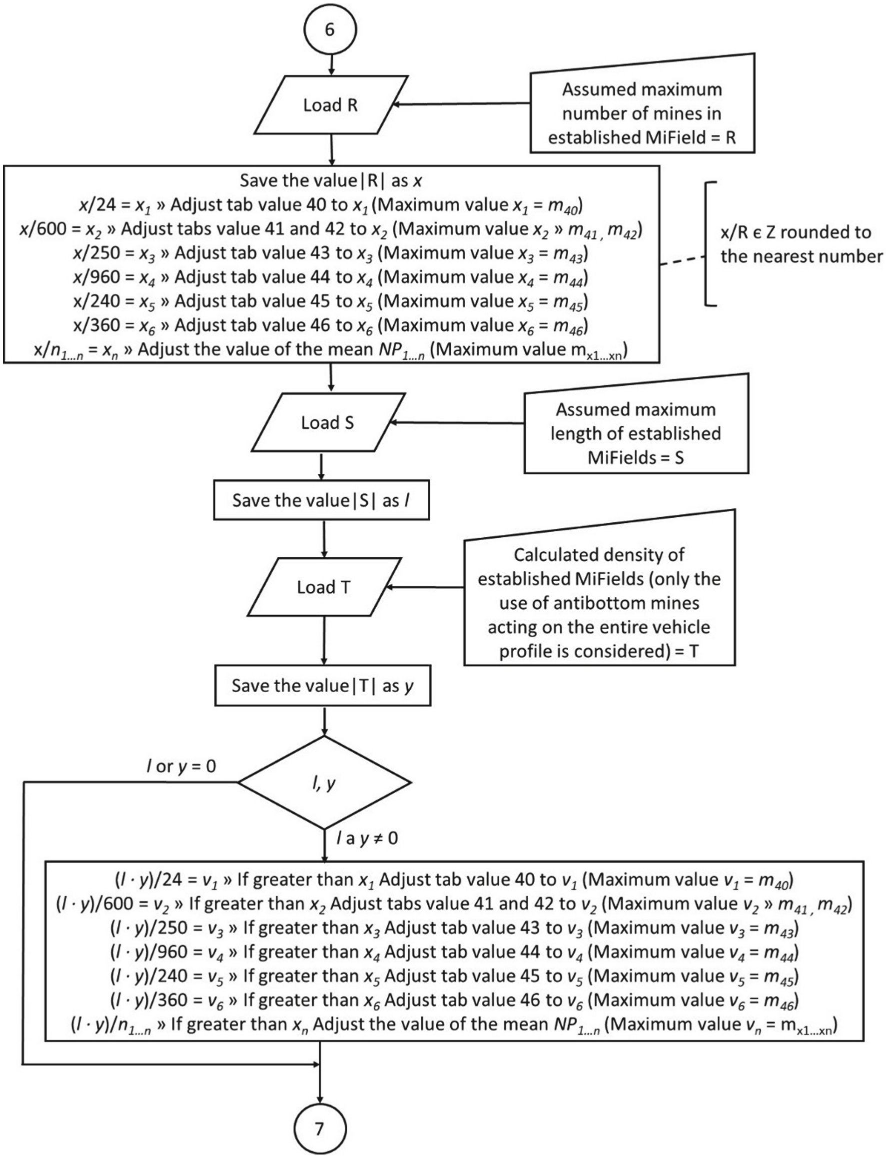

Fig. 7. Sub-part of the algorithm with steps "R"–"T".

These data are used to determine the number of individual mine clearance devices based on the calculation of the quantity of mines to be laid in each minefield. If the determined values are higher than in the previous step, the total number of devices is increased.

The last part of the algorithm concerning the design of mine countermeasures deals with the possible supply of ammunition to the formed blocking units during combat and the range of the mine countermeasures. In step "U" the user enters the total number of mines calculated for a given phase of the operation. If this value is higher than the amount of mines carried by each type of calculated minelayer, a warning is displayed regarding cooperation with logistics units in the area of resupplying units with ammunition vehicles or possible mine supply during the conduct of combat.

In step 'V', the requirement for a minimum spacing to lay a minefield is assessed. This step of the algorithm relates to the tactical situation and the range of the minelayer. A longer distance from the edge of the minefield when establishing a passage means more protection for the asset, as it must be considered that in combat operations, obstacles will

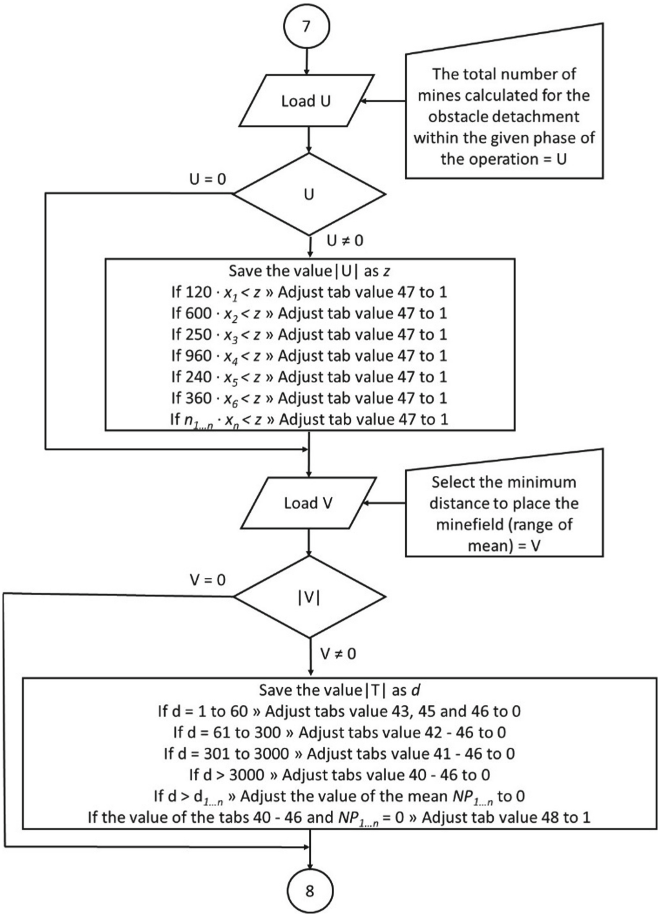

Fig. 8. Sub-part of the algorithm with steps "U"–"V".

always be under enemy fire to increase their effectiveness (see Fig. 8). If the required range exceeds the range of the calculated resource, the value of 0 is set for that resource and it will not be present in the proposed resources.

2.3 Resulting Part

The last main part of the algorithm (see Fig. 9) is used to display the resulting values of the engineering modular elements and engineering recommendations. In the last step, the user chooses whether to display values for the engineer support of a light task force (in the conditions of the Czech Armed Forces, this is a task force based on the 4th Rapid Deployment Brigade) or for the engineer support of a heavy task force (in the conditions of the Czech Armed Forces, this is a task force based on the 7th Mechanised Brigade) in the area of engineer support of movement. Engineer mine-laying assets are displayed identically for both types of task groups.

A member of the engineer specialisation staff chooses, according to his level (battalion, brigade), which information is relevant for him in establishing the optimal structure of engineer groups to support troop activities depending on the available resources.

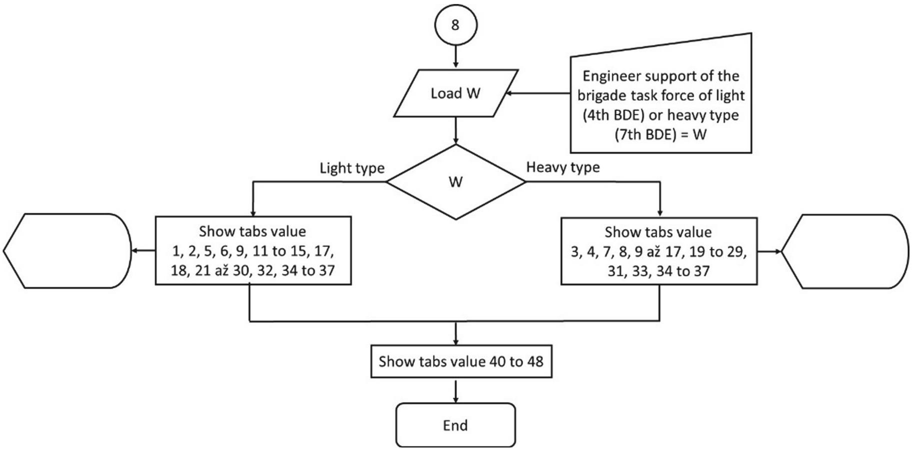

Fig. 9. The final part of the algorithm.

3 Software Development

Based on the algorithm, the APOSŽMC software was created. The application to optimize engineer group structures to support mobility and counter-mobility is a Windows Presentation Foundation program based on NET Framework 4.5.2 architecture. The source code of the implemented calculation model is separated within a self-contained class named StructureCalculation.cs. After internal checks of the input data, data variables (inputs, parameters) are passed to it from the graphical user interface for further processing.

The software has been improved over the previous version to provide a more user-friendly environment. The findings were based on experimental validation conducted with members of the Engineer Specialization Staff. The operation of the application is intuitive and ToolTip help is available if needed (by hovering the mouse cursor over the appropriate application control). The individual controls are hidden from the user until they can be used. The gradual uncovering of the application controls allows the user to be clearly directed to the next steps. The number of inputs required from the user is eliminated as much as possible in the program. When the application is started, the user is presented with an introductory window (see Fig. 10).

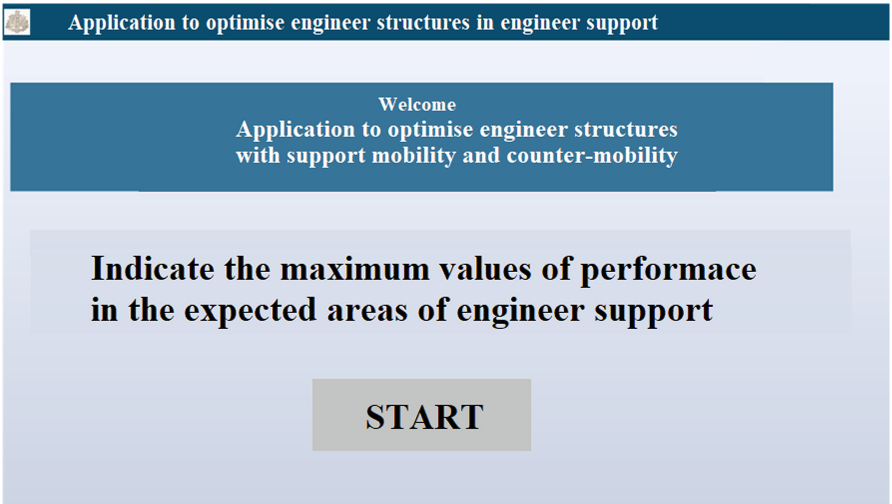

Fig. 10. Home window of APOSŽMC application in Czech language.

In the initial window, the user can get acquainted with the basic characteristics of the program by clicking on the option "About the application". Pressing the START button will start a series of steps that require the user to enter the necessary values to determine the corresponding engineered modular elements (see Fig. 11).

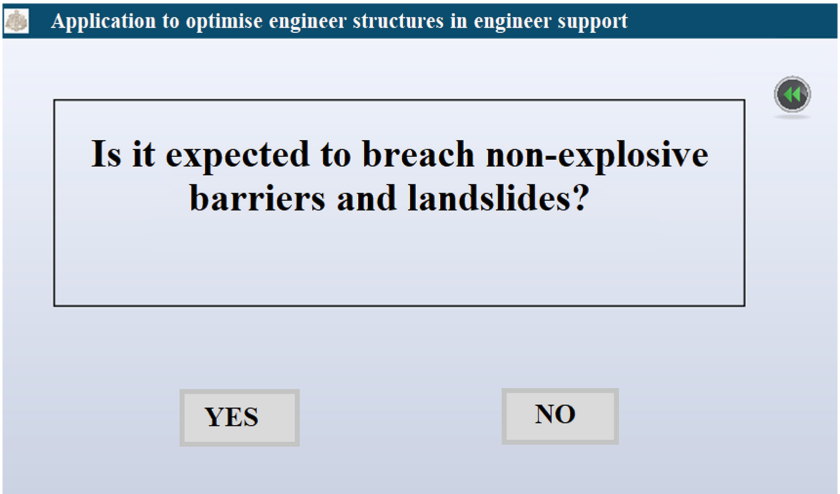

Fig. 11. One of the steps of the APOSŽMC application in Czech language.

The application allows the display of engineer modular elements for light and heavy group types (see Fig. 12). At the top of the displayed results are listed the engineer elements for forming a mobility support detachment generated at the brigade level. Also shown are the elements for the formation of mobility support group and accompanying groups formed at the battalion and company level. At the bottom, the blocking groups are shown. For further work with the resulting data, the values obtained can be saved in a text file, where the names of the modular elements and their composition are also shown.

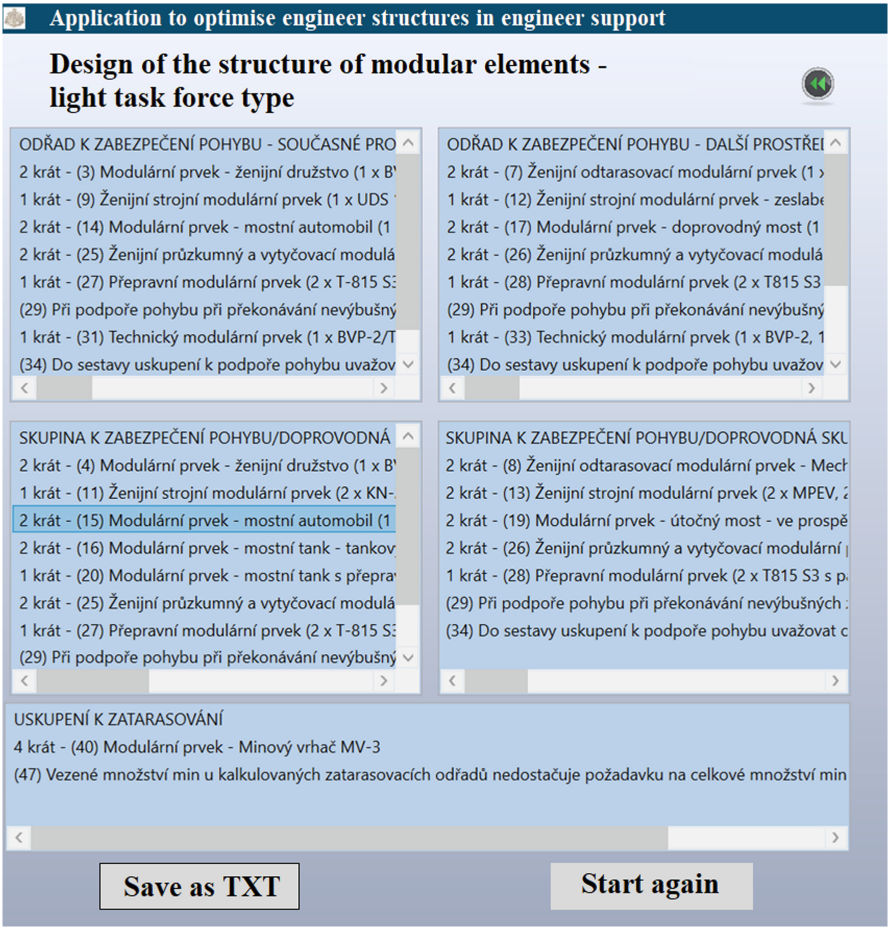

Fig. 12. Results of APOSŽMC application in Czech language.

4 Conclusion

The developed algorithm allowed us to program a software tool that is intuitive and requires minimal user training. However, when using this and similar programs, the user must be aware that he/she must always be able to perform the specified tasks without using them. When assessing the results of a program based on the above algorithm, one must think critically about the values obtained. The displayed values of the engineering modular elements are of a recommendatory nature and serve to support the decision-making of the officer of engineering expertise. The decision support can have benefits in reducing the time consuming nature of the planning process, but also in the effectiveness of the designs for individual engineer support tasks. This is a benefit that is not only required within the Czech Army Corps of Engineers.

In the next part of the research it is planned to conduct staff drills at engineer units. The aim of the staff exercises will be to perform calculations of the deployment of engineer forces and assets in combat operations. The staff members will be divided into groups, with one part performing the calculations without the use of software and the other part using the software. The proposed engineer support options will then be compared using the MASA Sword constructive simulation, assessing established criteria related to the conduct of combat operations and the provision of engineer support.

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