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MCDM model for the selection of network planning techniques in the army for the purposes of performing engineering works when overcoming water obstacles

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Abstract

Overcoming water obstacles is a demanding combat action that requires serious planning under conditions of uncertainty and risk. Choosing a planning method for the implementation of engineering works in the army, as well as how to choose them, has always been a challenge that engineering officers have faced. In this paper, for the selection of the network planning technique, the use of the multi-criteria decision-making (MCDM) model, which contains the methods Logarithm Methodology of Additive Weights (LMAW) and Grey Operational Competitiveness Rating (OCRA), as well as the Einstein weighted arithmetic average (EWAA) operator for aggregating expert opinions, is presented. The LMAW method was used to define the weights of the criteria, while the Grey OCRA method was used to select the optimal planning technique. The Event Chain Methodology (ECM) was identified as the most suitable method for planning the engineering works in question, while the Critical Path Method (CPM) and Precedence Diagramming Method (PDM) are also suitable. In order to check the consistency and validation of the obtained results, a sensitivity analysis to changes in criteria weights and a comparative analysis were performed, where the results were compared with four other MCDM methods in a grey environment. The results of the analyses indicate that the model provides consistent and valid results.

Keywords: LMAW, Grey OCRA, MCDM, military, overcoming water obstacles, network planning techniques

1. Introduction

Engineering units are an integral part of all modern armies of the world, and their tasks (works) were "preparing, securing and facilitating the operations of other branches" (Velojić, 2021). Their work includes various areas such as obstruction, overcoming obstacles, construction and repair of communications, construction of fortifications, water purification and camouflage. Through these activities, the army contributed to the modernization of society by building buildings and roads that later served civilian purposes. Their work was based on the latest scientific and technical achievements to efficiently perform work and reduce losses during military operations (Velojić, 2021). To carry out this technological process rationally with maximum efficiency, it is necessary to implement work organization. Based on the rules defined in the organization of work in civil society, the principles of organization of engineering works have also been developed. The organization of engineering works is defined as ‘‘a purposeful activity aimed at harmonizing the human and material potential of an engineering unit in terms of time, space and types of work, with the aim of high-quality and complete execution of engineering tasks, with the most rational use of time, manpower, resources and energy’’ (Hristov, 1978). The basic element of the process structure of engineering works organization is planning, or rather the development of certain plans. The above plans include activities that need to be implemented, mathematical calculations of the duration of activities, as well as their synchronization (Engineering Handbook 2, 1973), considering the circumstances in which the activities are carried out.

In general, plans can be divided into static and dynamic. Static plans show resource needs without considering the time dimension, while dynamic plans also consider the duration of activities. Dynamic plans can be numerical and graphical. The following dynamic graphical plans are most often used in engineering planning: parallel, orthogonal, cyclograms, histograms, and network (Hristov, 1978). Network plans represent modern planning techniques, dating back to the late 1950s, when the Critical Path Method (CPM) was introduced. This method was first applied between December 1956 and February 1959, on a maintenance and construction project for a chemical production plant at DuPont, USA (Kelley et al., 1989). From then until today, in addition to the CPM method, a large number of network planning techniques have been developed, and some of the most popular are: Program Evaluation and Review Technique (PERT) (Malcolm et al., 1959), Precedence Diagramming Method (PDM) (Fondahl, 1962), Graphical Evaluation and Review Technique (GERT) (Pritsker, 1966), Critical Chain Project Management (CCPM) (Goldratt, 1997). Event Chain Methodology (ECM) (Virine and Trumper, 2016), and others. Although these methods are different, they all have in common the goal of improving the planning, monitoring, and control of activities through project visualization, identification of critical activities, risk management, resource optimization, and improved communication among team members and stakeholders. By using graphical representations, these methods allow for a better understanding of the project flow and more efficient management of complex tasks.

The mentioned methods can be used in different areas for planning activities, while during the execution of engineering works, they can also be used for planning activities on the tasks of overcoming water obstacles. Overcoming water obstacles in the army means moving from one coast to another in order to complete the assigned task (Pifat, 1980). Overcoming is realized by the establishment of different crossing points (Božanić and Pamučar, 2010; Pamučar et al., 2011; Tešić et al., 2024). Overcoming water obstacles itself implies circumstances related to a limited time frame for implementation, uncertainty and risk, complexity, many interdependent activities, activities that are carried out in parallel, a large commitment of resources and the necessity of rapid adaptation to changes (Pifat, 1980). Based on the above, to successfully overcome water obstacles, it is necessary to carry out quality preparations and good planning and coordination of all activities and resources. Network planning techniques are suitable for solving such problems.

Choosing an adequate network planning method is a key challenge in this process. Multi-criteria decision making (MCDM) methods can be used for subject selection. There are different MCDM methods, some were created only for determining the weight of criteria, some only for choosing the optimal alternative, while some can successfully perform both tasks and are applied in different areas when making decisions (Taherdoost and Madanchian, 2023; Şimşek et al., 2025; Hesami, 2025; Mishra and Rani, 2025).

2. Materials and methods

In order to carry out the subject research, it is first necessary to identify the criteria that determine the choice of a suitable network planning method for planning engineering works to overcome water obstacles. Criteria are identified by experts. After defining the criteria, it is necessary to define a set of possible alternatives, i.e. planning techniques. When the input parameters are known, the weight coefficients of the criteria are determined using the Logarithm Methodology of Additive Weights (LMAW) method (Pamučar et al., 2021a), that is, the impact of each of the criteria on the final decision is defined. By obtaining the final values of the weights of the criteria, the determination of the optimal alternative is approached using the Grey Operational Competitiveness Rating (OCRA) method (Stanujkic et al., 2017a). For the purposes of aggregating expert opinions, the Einstein weighted arithmetic average (EWAA) operator (Deveci et al., 2023) was used. Finally, to determine the consistency and validity of the model, an analysis of the sensitivity of the output results of the method to changes in the weights of the criteria is carried out, as well as a comparison of the output results of the method with the results of other and similar methods, in a comparative analysis. The research algorithm is shown in Figure 1.

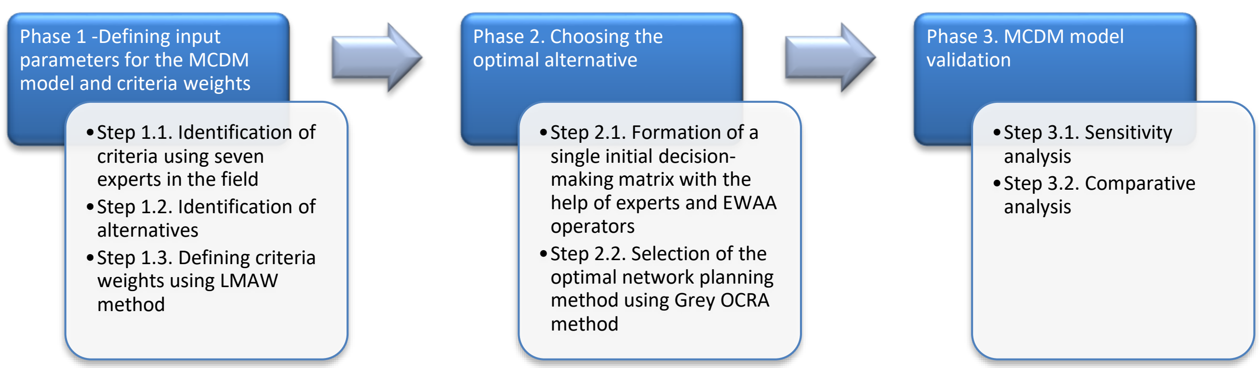

Figure 1. Research algorithm

Below, the methods used are described and a brief analysis of the literature regarding their application is performed.

2.1 LMAW method

The LMAW method (Pamučar et al., 2021a) is intended for determining the weight coefficients of criteria and ranking alternatives in MCDM. The main characteristics of the LMAW method are reflected in the simplicity of the mathematical apparatus, the high stability of the results, the fact that it does not suffer from the problem of ranking reversion, which indicates the consistency and reliability of the method. The method has been used so far in various areas where it was necessary to make decisions based on multiple criteria, in its classical form, as well as advanced by various theories that deal well with uncertainty and imprecision. The method was first presented in 2021 (Pamučar et al., 2021a) on the problem of logistics and supply chain management, i.e. in multimodal integrated logistics which involves the use of several types of transport to efficiently move goods. For the purposes of this research, the authors considered six criteria and six alternatives and concluded that the method provides consistent and stable results in MCDM, without ranking reversal problems, which is particularly useful for evaluating the operational efficiency of logistics providers. Lukić and Vojteški Kljenak (2024) analyze Serbia's external position using the LMAW- Double Normalization-based Multiple Aggregation (DNMA) MCDM model. The LMAW method was used to define the weights of the criteria. The results show that Serbia has a stable external position, but there are areas that require improvement, especially in economic indicators. Radovanović et al. (2024) employed the LMAW method to address military challenges, specifically for ranking assault rifles. Validation of the results and sensitivity analysis confirm the reliability and efficiency of the applied method. Like other MCDM methods, this method has been enhanced by theories such as fuzzy sets. The authors in Božanić et al. (2022) modify the LMAW method using triangular fuzzy numbers on the problem of location selection for a landing operation point (LOP). The modification significantly improves the method's ability to deal with decision-making uncertainties, especially when conducting military operations. Validation of the results through comparison with other methods and sensitivity analysis confirm the stability and quality of the ranking of alternatives. In the study Puška et al. (2022), the application of this method in a fuzzy environment is demonstrated on the problem of green supplier selection in agriculture using a hybrid MCDM model that combines Z-scores, fuzzy LMAW and fuzzy Compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS) methods. The results show that price and quality criteria are the most important in supplier selection, and validation of the results and sensitivity analysis confirm the stability of the model. Tešić et al. (2023) presented an MCDM model for the selection of dump trucks for the needs of military engineering units, using fuzzy LMAW to determine the weight coefficients of the criteria and the grey Measurement Alternatives and Ranking according to. Compromise Solution (MARCOS) method for selecting the optimal alternative. The results show that the characteristics of the construction of the truck, as well as the cost of acquisition and maintenance, are key criteria in the choice. The sensitivity analysis confirms the stability of the model but indicates the sensitivity to changes in the weight coefficients of the grey MARCOS method. Nayeb-Pashaei et al. (2025) explore the key criteria for sustainable urban transport using Fuzzy LMAW. The research results show that safety, health and greenhouse gas emissions are the most important sustainability factors, while the design of the transport system should prioritize human well-being and environmental protection. Analysis of the integration of professional surveys, available literature and obtained research results confirm the stability and reliability of the method.

The method has also been improved with fuzzy rough sets (Puška et al., 2023), neutrosophic sets (Salam and Mohamed, 2025), etc. The algorithm of the LMAW method is presented in Figure 2 according to Pamučar et al. (2021a).

2.2 Grey OCRA method

The OCRA method (Parkan, 1994; Parkan and Wu, 1997; Parkan and Wu, 1999), intuitively incorporates decision-makers' preferences for the relative importance of criteria, allowing for different weight distributions for different alternatives. The main advantage of the OCRA method is its ability to deal with MCDM situations where the relative weights of the criteria are dependent on the alternatives, where different weight distributions are assigned to the criteria for different alternatives, while some criteria are not applicable to all alternatives. The main idea of the OCRA method is the independent evaluation of alternatives in relation to the Benefit and Cost criteria, thus obtaining competitiveness ratings that help in making quality decisions (Stanujkic et al., 2017a) The method in its classic form has been used in numerous studies so far. Lukić (2022) applies the OCRA method to analyze the productivity of distribution trade in certain countries of the European Union, Russia and Serbia. The results show that Germany ranks first in terms of productivity, as well as that the OCRA method enables precise measurement and comparison of productivity, which is crucial for identifying areas for improvement. The authors in Pandiangan et al. (2023) use the Rank Order Centroid (ROC) method to determine the weight values and the OCRA method to select the location of the minimarket. The system enables an objective and definitive determination of the location of the minimarket based on various criteria. They conclude that the OCRA method enables effective ranking and making accurate decisions. In the study Nurahmad et al. (2024), the authors use the OCRA method to assess employee performance based on seven criteria. Data on employee performance were collected and analysed using a quantitative approach. The results of the OCRA analysis enable the identification of employees with good performance who are offered the opportunity for permanent employment, thereby increasing transparency and accuracy in making decisions about human resource management.

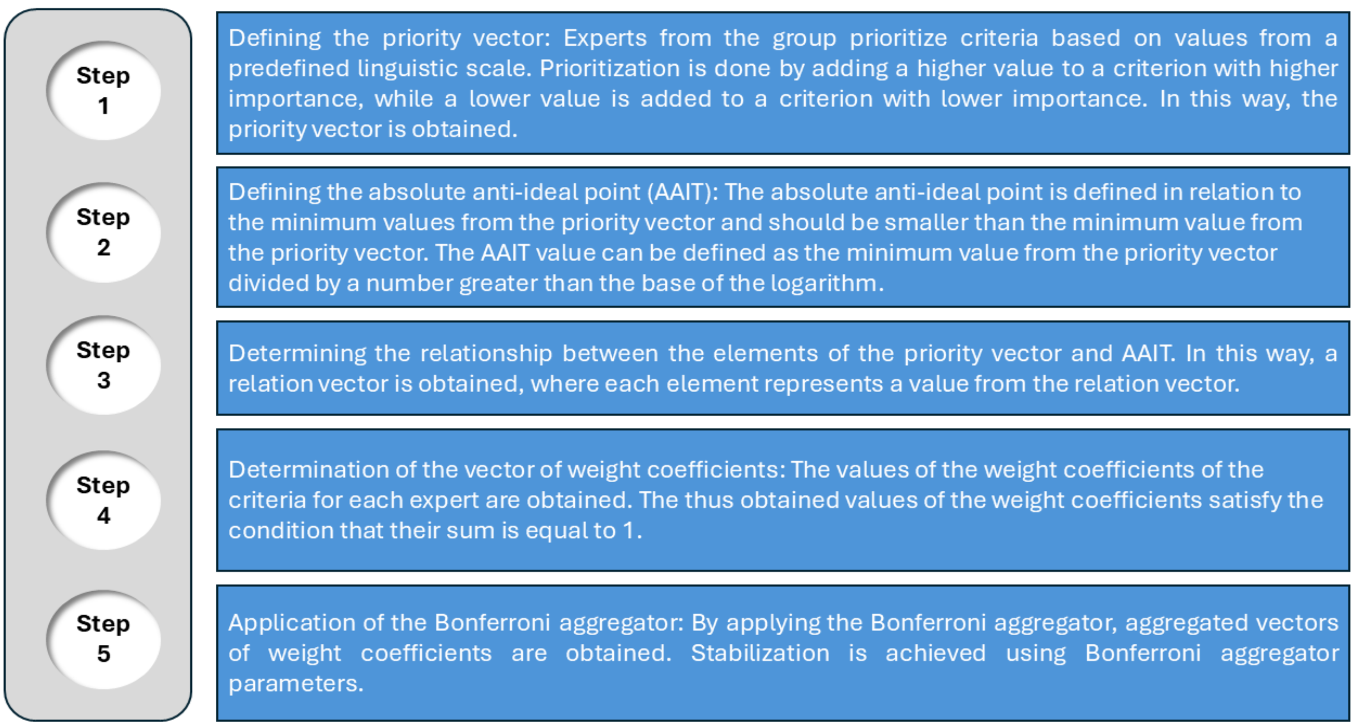

Figure 2. The algorithm of the LMAW method

In addition to the use of the original method, it has been applied in various fields and improved by various theories that treat uncertainty, vagueness and imprecision, such as Fuzzy theory (Ulutaş, 2019), Grey set theory (Stanujkic et al., 2017a), Rough theory (Zaher et al., 2018), etc. Considering that the Grey OCRA method was used in this research, the following part of the text shows a part of the investigation of various research problems related to the application of this method. This method improved with interval grey numbers was presented in 2017 (Stanujkic et al., 2017a). The authors propose this improved OCRA method for solving decision-making problems under conditions of uncertainty and partially known information. In the proposed approach, the original OCRA method is adapted to use grey numbers, thus enabling its application in solving problems with uncertain data. The efficiency and usability of the improved OCRA method are confirmed through numerical illustrations, including the selection of the best capital investment project. Ulutaş et al. (2020) propose a hybrid grey MCDM model for personnel selection, using the PIPRECIA-G method for determining the weights of criteria and the OCRA-G method for ranking alternatives (candidates). They conclude that the combination of these methods increases the reliability and security in the decision-making process and candidate selection. Madhavi et al. (2023) propose a hybrid dynamic MCDM model based on grey Pivot Pairwise Relative Criteria Importance Assessment (PIPRECIA) and grey OCRA methods for preventing malicious and selfish nodes in wireless sensor networks. The PIPRECIA-G method is used to determine the weight coefficients of the criteria, while the OCRA-G method is used to determine the rank of sensor nodes, with the aim of dynamically isolating the worst nodes. Simulation results show improved packet delivery rate, increased throughput, reduced energy consumption, and reduced end-to-end delay, confirming the effectiveness of the MCDM model in fast and accurate detection and isolation of malicious and selfish nodes. Kara et al. (2023) uses the Fuzzy Stepwise Weight Assessment Ratio Analysis (SWARA) method to determine the weight values of the criteria and the grey OCRA method to select the most suitable candidate for a project manager in the supply chain according to their operational competitiveness. The results of the research show that experience is the most important criterion, and the second candidate is rated as the most suitable for the position of project manager, and the above methods can successfully solve such problems. In addition to the above, there are numerous other researches in different areas with different decision-making problems.

All these papers indicate the wide application of the OCRA method in various fields and its importance in decision-making. The classical OCRA method allows solving various MCDM problems. In addition, based on the previously mentioned research, in which the OCRA method was improved with various theories that treat uncertainty, vagueness and imprecision, it is concluded that these improvements increase the reliability and security in the decision-making process, enabling efficient ranking and accurate decision-making under conditions of uncertainty. The mathematical apparatus of the Grey OCRA method consists of six steps and is described below, according to (Stanujkic et al., 2017a).

Step 1: Calculation of the grey aggregate performance score ($\otimes APC$) for the Cost criteria, using Eq. (1)

$$\otimes APC_i = \sum_{j=Co_{\min}} \omega_j \frac{\left(\max_j \underline{g}_{ij} - \overline{g}_{ij}, \max_j \overline{g}_{ij} - \underline{g}_{ij}\right)}{\left(\max_j \underline{g}_{ij} - \min_j \overline{g}_{ij}, \max_j \overline{g}_{ij} - \min_j \underline{g}_{ij}\right)} \tag{1}$$

where is $\otimes g = \left(\underline{g}, \overline{g}\right)$ interval grey number, ω_j criteria weights, Co set of Cost criteria.

Step 2: Calculation of the grey linear performance score ($\otimes LPC$) for the Cost criteria, using Eq. (2)

$$\otimes LPC_i = \otimes APC_i - \min_i \otimes APC_i \tag{2}$$

Step 3: Calculation of the grey aggregate performance score ($\otimes APB$) for the Benefit criteria, using Eq. (3)

$$\otimes APB_i = \sum_{j=Be} \omega_j \frac{\left(\underline{g}_{ij} - \min_j \overline{g}_{ij}, \overline{g}_{ij} - \min_j \underline{g}_{ij}\right)}{\left(\max_j \underline{g}_{ij} - \min_j \overline{g}_{ij}, \max_j \overline{g}_{ij} - \min_j \underline{g}_{ij}\right)} \tag{3}$$

where is Be set of Benefit criteria.

Step 4: Calculation of the grey linear performance score ($\otimes LPB$) for the Benefit criteria, using Eq. (4)

$$\otimes LPB_i = \otimes APB_i - \min_i \otimes APB_i \tag{4}$$

Step 5: Calculation of the overall grey performance score ($\otimes OP$), using Eq. (5)

$$\otimes OP_i = \otimes LPC_i + \otimes LPB_i - \min\left(\otimes LPB_i - \otimes LPB_i\right) \tag{5}$$

Step 6: Ranking of alternatives. The alternative with a higher overall performance score takes a better place in the ranking. Before the final ranking of the alternatives, it is necessary to convert grey values to crisp, using Eq. (6)

$$g_{\varpi} = (1-\varpi)\underline{g} + \varpi\overline{g} \tag{6}$$

where is ϖ the whitening coefficient which most often has a value of 0.5.

3. Results

Following the phases of the algorithm from Figure 1, the input parameters of the MCDM model are defined.

3.1 Identification of criteria

By engaging seven experts (*E_e=E1,E2,…,E7)*) with expert competences $E^{\varpi} = (0.14, 0.135, 0.145, 0.143, 0.144, 0.143, 0.15)$) in the field of overcoming water obstacles six criteria $C_j = (C1, C2, ..., C6)$ that determine the subject selection were defined (Table 1).

Table 1. Criteria for selecting the optimal network planning method for engineering works when overcoming water obstacles

Criterion name	Criteria description	Character of criteria
C1 - Accuracy of time planning	Describes and presents the accuracy of the method to predict and track the duration of a task and individual activities.	Benefit
C2 - Ability to manage uncertainty and risk	It represents an estimate of how well a method can deal with unknown factors and risks, as uncertainty is common in military operations.	Benefit
C3 - Activity dependency display	It represents the ability of the method to show interdependence and the sequence of activities (which activity depends on which, which activities can be performed in parallel), which is crucial for complex tasks such as engineering works.	Benefit
C4 - Simplicity of application	Represents the assessment of the simplicity of the method's use in real conditions, i.e. in a military environment where a method that can be quickly explained, understood and applied even under great pressure on people is valued.	Benefit
C5 - Resource management capabilities	It represents an assessment of how well the method helps in planning and distributing resources (people, equipment, pontoons, vehicles, weapons, etc.), given that when overcoming water obstacles, resources are limited and time-critical, so it is necessary that the method enables high-quality optimization and distribution of resources.	Benefit
C6 - Flexibility during changes	It represents an assessment of the method's ability to adjust the plan in real time (in situations when an activity is postponed, if a new task appears or an individual activity must be skipped, etc.), i.e. the ability to dynamically update and quickly respond to changes.	Benefit

3.2 Identification of alternatives

For the purposes of this research, six alternatives were identified $A_i = (A1, A2, ..., A6)$, shown in Table 2.

Table 2. Criteria for selecting the optimal network planning method for engineering works when overcoming water obstacles

Criterion name	Alternative description
A1 - PERT	PERT is a network planning technique developed to manage projects with a high degree of uncertainty. To calculate the expected duration of activity I of the project, it uses the approach of determining the duration of activities using three estimates: optimistic, most likely and pessimistic. The focus of the PERT method is on time analysis and the probability of completing the project within a certain period (Malcolm et al., 1959).
A2 - CPM	CPM is a planning method used for projects with known activity durations. Its main role is to identify the critical path - the parts of the activity that directly affect the overall duration of the project. The method enables completely clear management of time and resource allocation (Kelley et al., 1989).
A3 - PDM	PDM is a network planning method that uses nodes to represent activities and connects them using logical links. It is also known as the Activity-on-Node (AON) method. Four types of connections are used in PDM: FS (Finish-to-Start), SS (Start-to-Start), FF (Finish-to-Finish), SF (Start-to-Finish). These connections allow for more flexible planning. It is often used in project management software tools such as MS Project (Fondahl, 1962).
A4 - GERT	The GERT method enables advanced modeling of complex systems with elements of uncertainty, repetition and decisions. Unlike other methods, it allows conditional paths, loops, and various activity outcomes (Pritsker, 1966).
A5 - CCPM	CCPM contains the concept of resources as key constraints in planning. The critical chain in this method considers both the sequence of activities and the availability of resources. Protective "buffers" are used to protect against delays. This method focuses on faster project delivery, reducing multitasking and minimizing interruptions (Goldratt, 1997).
A6 - ECM	ECM is a methodology that focuses on dynamic events and their consequences on activities. A key concept is the "chain reactions" of events that can cause shifts in the timeline. It is used in combination with Monte Carlo analysis to better manage risks and uncertainties in complex projects, Event Chain Methodology (ECM) (Virine and Trumper, 2016).

The next step of the research algorithm, in the first phase, is the determination of criteria weights using the LMAW method. For the purposes of this part of the research, the same seven experts were hired, as during the identification of the criteria, who defined the priority vector using the linguistic scale [Absolutely Low (AL=1), Very Low (VL=1.5), Low (L=2), Medium (M=2.5), Equal (E=3), Medium High (MH=3.5), High (H=4), Very High (VH=4.5), Absolutely High (AH=5)] presented in (Pamučar et al., 2021a) and who agreed that the significance of the criteria was presented as $C6 > C3 > C2 > C5 > C1 > C4$. The results of the relationship between the criteria, determined by the experts, are given in Table 3.

Table 3. Criteria priority vectors defined by experts

	C1	C2	C3	C4	C5	C6
E1	AH	H	MH	E	M	L
E2	VH	H	MH	E	M	M
E3	H	E	MH	M	M	L
E4	AH	E	M	E	E	M
E5	H	VH	E	E	E	M
E6	H	E	MH	E	M	M
E7	VH	E	MH	M	M	M

Using the mathematical apparatus of the LMAW method, the following weight coefficients of the criteria were obtained (Figure 3):

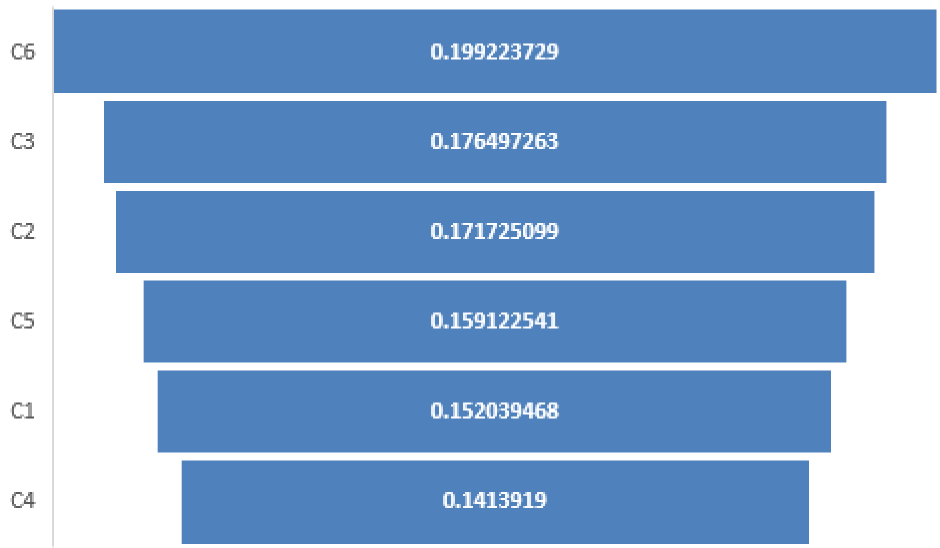

Figure 3. Criterion weights obtained using the LMAW method

After the weights of the criteria have been obtained, the evaluation of the defined alternatives according to each criterion is started by engaged experts, using the following grey linguistic scale (Table 4):

Table 4. Grey linguistic scale

Linguistic descriptor	Grey value
Absolutely satisfying	(4,5)
Satisfies	(3,4)
Partially satisfying	(2,3)
Partially unsatisfactory	(1,2)

The expert evaluations of the alternatives according to the criteria, immediately translated into interval grey numbers, are presented in Table 5.

Table 5. Expert opinions for each alternative according to each criterion

	C1	C2	C3	C4	C5	C6
			E1			
A1	(2,3)	(3,4)	(3,4)	(2,3)	(1,2)	(3,4)
A2	(4,5)	(3,4)	(4,5)	(3,4)	(3,4)	(2,3)
A3	(4,5)	(2,3)	(4,5)	(2,3)	(3,4)	(4,5)
A4	(2,3)	(2,3)	(3,4)	(1,2)	(2,3)	(3,4)
A5	(4,5)	(3,4)	(2,3)	(2,3)	(4,5)	(2,3)
A6	(4,5)	(4,5)	(3,4)	(4,5)	(3,4)	(4,5)
			E2			
A1	(2,3)	(2,3)	(2,3)	(2,3)	(1,2)	(2,3)
A2	(3,4)	(2,3)	(3,4)	(3,4)	(3,4)	(3,4)
A3	(4,5)	(3,4)	(4,5)	(3,4)	(4,5)	(3,4)
A4	(3,4)	(2,3)	(2,3)	(2,3)	(2,3)	(2,3)
A5	(4,5)	(4,5)	(1,2)	(3,4)	(3,4)	(3,4)
A6	(3,4)	(4,5)	(4,5)	(2,3)	(3,4)	(3,4)
			E3			
A1	(3,4)	(3,4)	(4,5)	(2,3)	(2,3)	(2,3)
A2	(3,4)	(3,4)	(3,4)	(3,4)	(2,3)	(4,5)
A3	(4,5)	(2,3)	(4,5)	(2,3)	(3,4)	(3,4)
A4	(2,3)	(3,4)	(3,4)	(2,3)	(2,3)	(2,3)
A5	(2,3)	(4,5)	(1,2)	(2,3)	(2,3)	(3,4)
A6	(3,4)	(4,5)	(3,4)	(3,4)	(3,4)	(4,5)
			E4			
A1	(2,3)	(3,4)	(3,4)	(2,3)	(1,2)	(3,4)
A2	(3,4)	(3,4)	(4,5)	(2,3)	(3,4)	(3,4)
A3	(4,5)	(3,4)	(3,4)	(3,4)	(2,3)	(4,5)
A4	(2,3)	(3,4)	(2,3)	(2,3)	(2,3)	(2,3)
A5	(2,3)	(3,4)	(1,2)	(1,2)	(2,3)	(3,4)
A6	(4,5)	(4,5)	(2,3)	(4,5)	(3,4)	(4,5)
			E5			
A1	(3,4)	(2,3)	(3,4)	(2,3)	(1,2)	(2,3)
A2	(3,4)	(3,4)	(3,4)	(2,3)	(3,4)	(3,4)
A3	(4,5)	(3,4)	(3,4)	(2,3)	(2,3)	(4,5)
A4	(2,3)	(2,3)	(2,3)	(1,2)	(3,4)	(1,2)
A5	(2,3)	(3,4)	(2,3)	(2,3)	(2,3)	(2,3)
A6	(4,5)	(4,5)	(3,4)	(4,5)	(3,4)	(3,4)
			E6			
A1	(2,3)	(2,3)	(3,4)	(3,4)	(2,3)	(3,4)
A2	(3,4)	(2,3)	(3,4)	(3,4)	(3,4)	(3,4)
A3	(4,5)	(3,4)	(4,5)	(3,4)	(3,4)	(4,5)
A4	(2,3)	(4,5)	(1,2)	(2,3)	(3,4)	(1,2)
A5	(2,3)	(3,4)	(2,3)	(1,2)	(2,3)	(3,4)
A6	(3,4)	(4,5)	(4,5)	(4,5)	(4,5)	(4,5)

	C1	C2	C3	C4	C5	C6
			E7			
A1	(3,4)	(2,3)	(3,4)	(2,3)	(1,2)	(2,3)
A2	(4,5)	(3,4)	(3,4)	(3,4)	(3,4)	(3,4)
A3	(3,4)	(2,3)	(4,5)	(3,4)	(4,5)	(4,5)
A4	(1,2)	(3,4)	(1,2)	(2,3)	(2,3)	(1,2)
A5	(3,4)	(2,3)	(2,3)	(1,2)	(2,3)	(3,4)
A6	(4,5)	(4,5)	(4,5)	(3,4)	(4,5)	(4,5)

The evaluations given by the experts for each of the alternatives must be aggregated into one initial decision-making matrix, with which to enter the method. The above was performed using EWAA operator (Deveci et al., 2023). The unique aggregated initial decision grey matrix is presented in Table 6.

Table 6. Initial decision grey matrix

	C1	C2	C3	C4	C5	C6
A1	(2.44,3.44)	(2.43,3.43)	(3.01,4.01)	(2.14,3.14)	(1.29,2.29)	(2.43,3.43)
A2	(3.29,4.29)	(2.72,3.72)	(3.28,4.28)	(2.71,3.71)	(2.86,3.86)	(3.01,4.01)
A3	(3.85,4.85)	(2.57,3.57)	(3.71,4.71)	(2.57,3.57)	(3.00,4.00)	(3.72,4.72)
A4	(1.99,2.99)	(2.73,3.73)	(2.00,3.00)	(1.72,2.72)	(2.29,3.29)	(1.71,2.71)
A5	(2.71,3.70)	(3.13,4.13)	(1.58,2.58)	(1.71,2.70)	(2.42,3.42)	(2.72,3.72)
A6	(3.58,4.58)	(4.00,5.00)	(3.29,4.29)	(3.44,4.44)	(3.29,4.29)	(3.72,4.72)

By applying the steps of the Grey OCRA method, Eqs. (1)-(6) the overall performance score and the final rank of alternatives are obtained, shown in Table 7.

Table 7. The overall grey performance score and the final rank of alternatives

	$\otimes OP_i$	Crisp OP_i	Rank
A1	(-4.26,4.50)	0.120	5
A2	(-3.69,5.22)	0.764	3
A3	(-3.67,5.42)	0.878	2
A4	(-4.36,4.36)	0.000	6
A5	(-3.98,4.76)	0.387	4
A6	(-3.32,5.98)	1.329	1

As can be seen from Table 7, the most suitable alternative, i.e. the network planning method for carrying out engineering works when overcoming water obstacles is ECM, but both PDM and CPM can be used successfully, while the least suitable method is GERT, which stands out significantly with its overall performance score, i.e. has a value of 0. To check the stability and validity of the output results of the model, sensitivity analysis and comparative analysis will be performed in the following text.

4. MCDM model validation

4.1 Sensitivity analysis

In order to examine how changes in the weights of the criteria affect the final decision results, we will perform a Sensitivity Analysis, with the aim of checking the stability of the decision, identifying critical criteria, and increasing confidence in the decision (Biswas et al., 2024; Jameel et al., 2025). This analysis is crucial for ensuring that decisions are of high quality and robust (Kamarul Zaman et al., 2025; Baydaş et al., 2024), i.e. that the results of the method remain stable and reliable even when faced with changes or uncertainties in the input data or conditions (Li and Rong, 2025; Sarfraz and Gul, 2025). To carry out this analysis, 22 scenarios of changes in criteria weights were created (Figure 4).

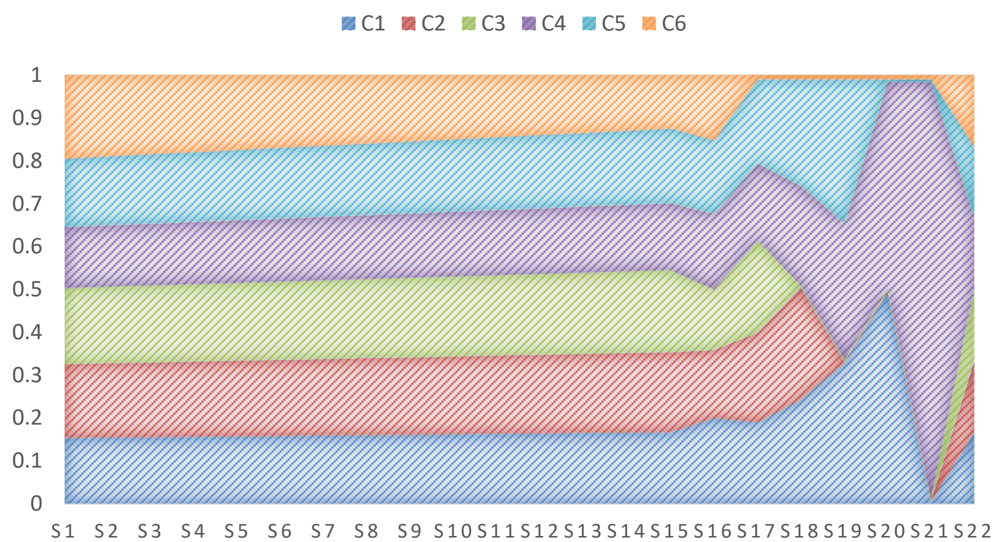

Figure 4. Sensitivity analysis scenarios

By implementing the scenario of changing the weight coefficients of the criteria (Figure 4) in the Grey OCRA method, the following ranks of alternatives are obtained (Figure 5):

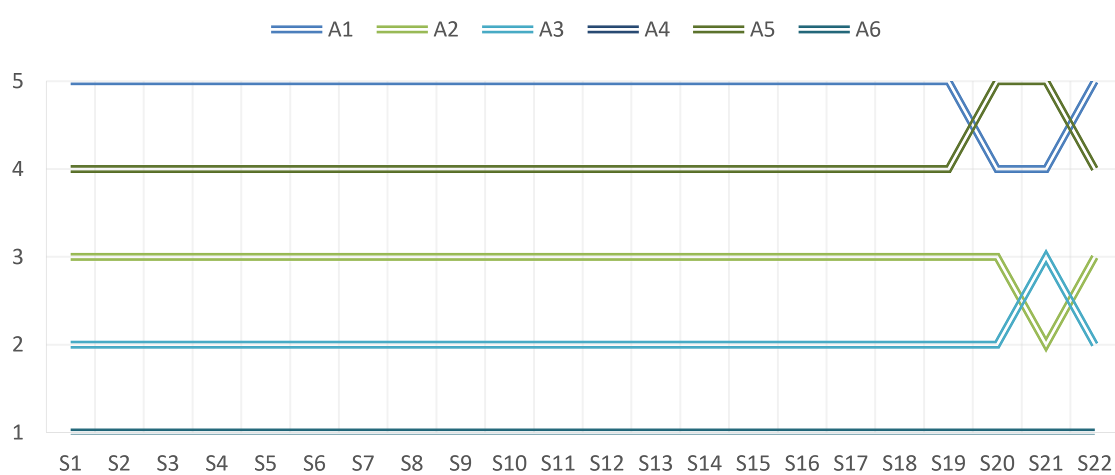

Figure 5. Results of the Sensitivity analysis

The results of the Sensitivity analysis (Figure 5) indicate that the Grey OCRA method is not sensitive to minor changes in the weights of the criteria, i.e. that changes in the ranking of alternatives occur only with larger changes in the weights of the criteria, as well as that the method gives consistent results.

4.2 Comparative analysis

In order to check the validity of the proposed MCDM model, a comparative analysis was performed. Comparative analysis has become an essential component in validating MCDM models (Karel and Plašil, 2024; Radovanović et al., 2025). The output results of the Gray OCRA method are compared with the four other methods: Grey EDAS (Stanujkic et al., 2017b), Grey COPRAS (Zavadskas et al., 2009), Grey TOPSIS (Wang, 2009), Grey MARCOS (Pamucar et al., 2021b). The results of the Comparative analysis are presented in Figure 6.

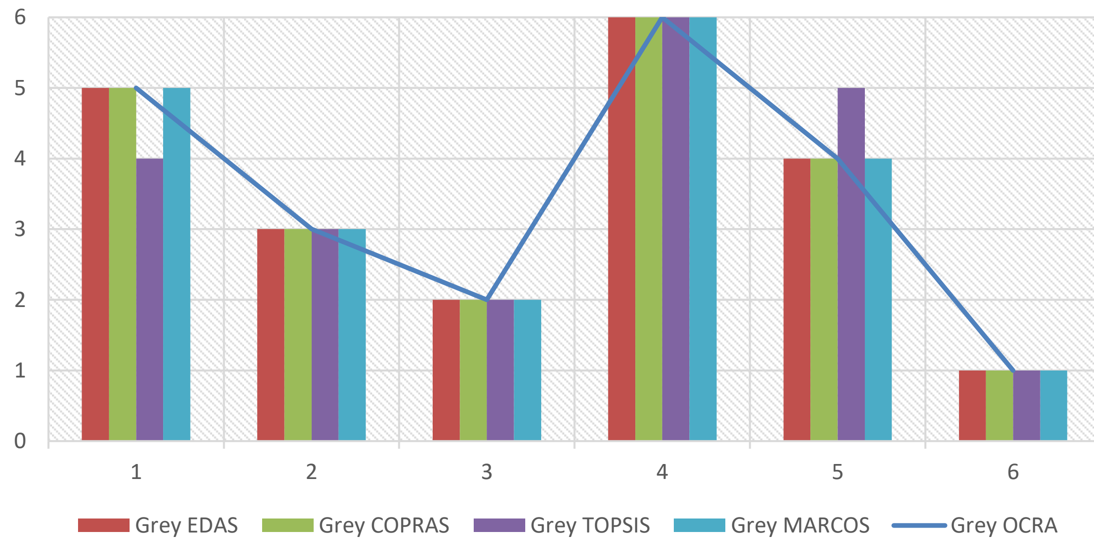

Figure 6. Results of the Comparative analysis

The results of the comparative analysis indicate a valid model, that is, the two first-ranked alternatives in all methods remain in the first two places in the ranking, while the last-ranked alternative is always in the last place in the ranking, in all methods.

5. Conclusion

Engineer units are a key part of modern armies, responsible for preparing, securing and facilitating the operations of other branches of the military. Their work includes areas such as overcoming obstacles, building and repairing communications, fortification, water purification and camouflage. In order to successfully implement these tasks, a high-quality organization of work is necessary. The organization of engineering work is based on the latest scientific and technical achievements in order to efficiently perform tasks and reduce losses during military operations.

The basic element of the organization of engineering works is planning, which includes the development of certain plans, mathematical calculations of the duration of activities and their synchronization. Plans can be divided into static, which show resource needs without a time dimension, and dynamic, which take into account the duration of activities. Dynamic plans can be numerical and graphic, and the most commonly used graphic plans in engineering planning are parallel, orthogonal, cyclograms, histograms and network plans. Network plans, such as CPM, PERT, PDM, GERT, CCPM, ECM, and others, improve planning, monitoring, and control of activities through project visualization, identification of critical activities, risk management, resource optimization, and improved communication among team members and stakeholders. The selection of the appropriate technique in this paper was made using the MCDM model.

To conduct the research, it was first necessary to identify the criteria that determine the choice of the appropriate method of network planning for engineering works when overcoming water obstacles, which was done by experts. After defining the criteria, possible alternatives, i.e. planning techniques, were determined, and the weight coefficients of the criteria were calculated using the LMAW method. The optimal alternative was then determined by the Grey OCRA method, with the aggregation of expert opinions using the EWAA operator. This MCDM model enables the precise determination of criteria weights and the selection of the best alternative, taking into account the opinions of experts

The ECM method was identified as the most suitable for planning the engineering works in question, while the CPM and PDM methods were also identified as appropriate. Sensitivity analysis to changes in criterion weights showed that the Grey OCRA method provides consistent results and is not sensitive to minor changes in criterion weights. Comparative analysis confirmed the validity of the model, as the two best ranked alternatives in all methods remained in the first two places, while the last ranked alternative was always in the last place. The results of the analysis indicate that the model provides consistent and valid results.

Limitations of this study include the limited sample of experts and potential bias in their assessments, as well as the limited application of the model to specific engineering works. Future research could focus on expanding the number of experts, applying the model to other engineering works, and integrating new and other planning techniques. Also, research can explore additional MCDM methods for determining criterion weights and for selecting the optimal planning technique.

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