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D NUMBERS – FUCOM – FUZZY RAFSI MODEL FOR SELECTING THE GROUP OF CONSTRUCTION MACHINES FOR ENABLING MOBILITY

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Abstract. *The paper presents a hybrid model for decision-making support based on D numbers, the FUCOM method and fuzzified RAFSI method, used for solving the selection of the group of construction machines for enabling mobility. By applying D numbers, the input parameters for the calculation of the weight coefficients of the criteria were provided. The calculation of the weight coefficients of the criteria was performed using the FUCOM method. The best alternative was selected using the fuzzified method, which was conditioned by the specificity of the issue so that in this case, the selection of the best alternative was made using the fuzzified RAFSI method.*

Key Words: *D Numbers, FUCOM, Fuzzy Numbers, RAFSI, Construction Machines*

1. INTRODUCTION

The dynamics of living in a modern environment imposes plenty of demands. One of the determining demands is most often expressed through the need for faster transport of goods and services. The way of fulfilling the set of demands is represented by the development of communication - transport capacities and possibilities (*e.g.* quality and branching of roads expressed by meeting certain standards, possibilities of certain means of transport, etc.).

The most significant percentage of roads are civil engineering structures - roads of high quality and high throughput. Enabling mobility on such roads is based on repairing possible damage to certain road sections and reconstructing certain sections to improve

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their features. The construction machines are the main working means in these tasks. Therefore, it can be pointed out with certainty that these are the factors on which the quality, scope, and costs of production, respectively, of construction, depend on. Having in mind that different construction machines perform numerous works, the requirements are set such as: complete consideration of the scope and type of assignments, precise determination of the required machines and their number (with knowledge of their characteristics and reliability), an appropriate grouping of the machines, consideration of their interdependence and determination of the critical machine.

The above-mentioned facts provide the condition for a large share in the total facilities' repair and reconstruction costs. Simultaneously with the stated costs, one of the requirements for reducing the operating costs of the vehicle fleet and savings in construction costs stands out [1]. Solving resource savings is one of the defining directions of industry and modern economy [2, 3]. One of the cost reduction approaches in the construction sector is presented through: assessment of the performance of different types and subcategories of construction machines in different conditions [4-6], consideration of critical machine performance (engine speed, engine type, operating hours, torque or engine power, weight of machines, type of fuel, service life of equipment) [7-11], the definition of the maximum allowed idling time, the definition of critical machine, change of type of fuel and mixture, use of machines equipped with newer technology and transition to electrical circuit systems [10, 12- 15].

In addition to the above mentioned, there are other, so-called external parameters affecting the consumption of resources and are related to the performance of construction machinery, such as climatic and soil conditions, driver/operator experience, terrain slope, soil type, density, and volume of sediment being worked on, etc. [12].

Many requests for reducing the costs of road repair and reconstruction have resulted in the imposition of different approaches to resolving the set requests. Some approaches are based on: precise definition of the set task, clear sizing of the group of machines composition, complete knowledge of the machines' performances (under the stated conditions), the definition of critical machine, or understanding the conditionality of the work process by a machine. All the approaches have their advantages and disadvantages.

The engineering units of the Serbian Army possess construction machines in their service, and these machines are intended for the construction, repair, and reconstruction of temporary military roads. In that regard, engineering units are designed to enable the mobility of other units. It is essential to facilitate mobility during the implementation of combat operations, where possible omissions (or untimely execution of tasks) can have significant consequences.

Considering that there are many construction machines in the Serbian Army with the same or similar purpose, the decision-makers are often faced with reaching the optimal composition of the group of devices that will perform a particular task. In this context, a model was developed to select the group of construction machines for enabling mobility, which is primarily based on the structural characteristics of the devices, respectively, the criteria based on these characteristics. Other external influences are also combined through the evaluations of the values of alternative solutions by every criterion.

Selecting the optimal group of machines for earthworks is not a typical research subject in scientific papers. Jovanović [16] considered selecting the optimal group of devices for earthworks on a residential and office building by applying compromise programming and multi-criteria ranking of alternative solutions. Similar to the presented problem, the selection of other different working groups using multi-criteria decision-making in the literature has not been, for the most part, considered. Karabašević et al. [17] select staff in the company's team, using the SWARA and ARAS methods. Alencar and de Almeida [18] apply the PROMETHEE method and group decision-making to select project team members. Shipley et al. [19] show the selection of team members during the project using fuzzy logic and the Dempster-Shafer theory of evidence. Zolfani and Antucheviciene [20] use the AHP and TOPSIS methods to select team members. Bazsova [21] selects members of the project management team using the AHP method. Božanić and Pamučar [22] select a military unit to remove explosive barriers using a fuzzy logic system. To form an elite security team, Dadelo et al [23] use the TOPSIS and SAW methods.

2. Description of the Methods Used

The specificity of the research issue conditioned the use of methods which take into consideration uncertainty, both for the calculation of the weight coefficients of the criteria, and for the selection of the best alternative. Having in mind the simplicity of the mathematical apparatus, on the one hand, as well as the possibilities of the methods on the other hand, the authors decided to use models based on D numbers, the FUCOM method and fuzzified RAFSI method. Fig. 1 presents general overview of the model.

Through the first phase of the model, the criteria influencing the selection are identified, using expert evaluation while the calculation of weight coefficients is made using expert evaluation, D numbers and the FUCOM method. In the second phase, the identification of alternatives and the selection of the best alternative are performed. In the third phase of model development, the sensitivity analysis is performed by changing the weight coefficients of the criteria. The following text of this unit provides theoretical basis of the applied methods (D numbers, the FUCOM method and fuzzified RAFSI method).

2.1. D numbers

The *Dempster-Shafer's theory* of evidence is used to process uncertain information [24, 25]. This theory has wide application because it allows direct expression of uncertainty by assigning probability to the elements organized into subsets within a set, rather than to individual objects within a set. Although it has been applied in a large number of papers for processing uncertain information, the classic *Dempster-Shafer's* theory of evidence has certain limitations as well. One of the well-known problems is the management of contradictions in the case of very conflicting evidence. Additionally, the *Dempster-Shafer's* theory of evidence implies the exclusivity of elements in discernment, which has greatly limited the practical application of this theory [26, 27].

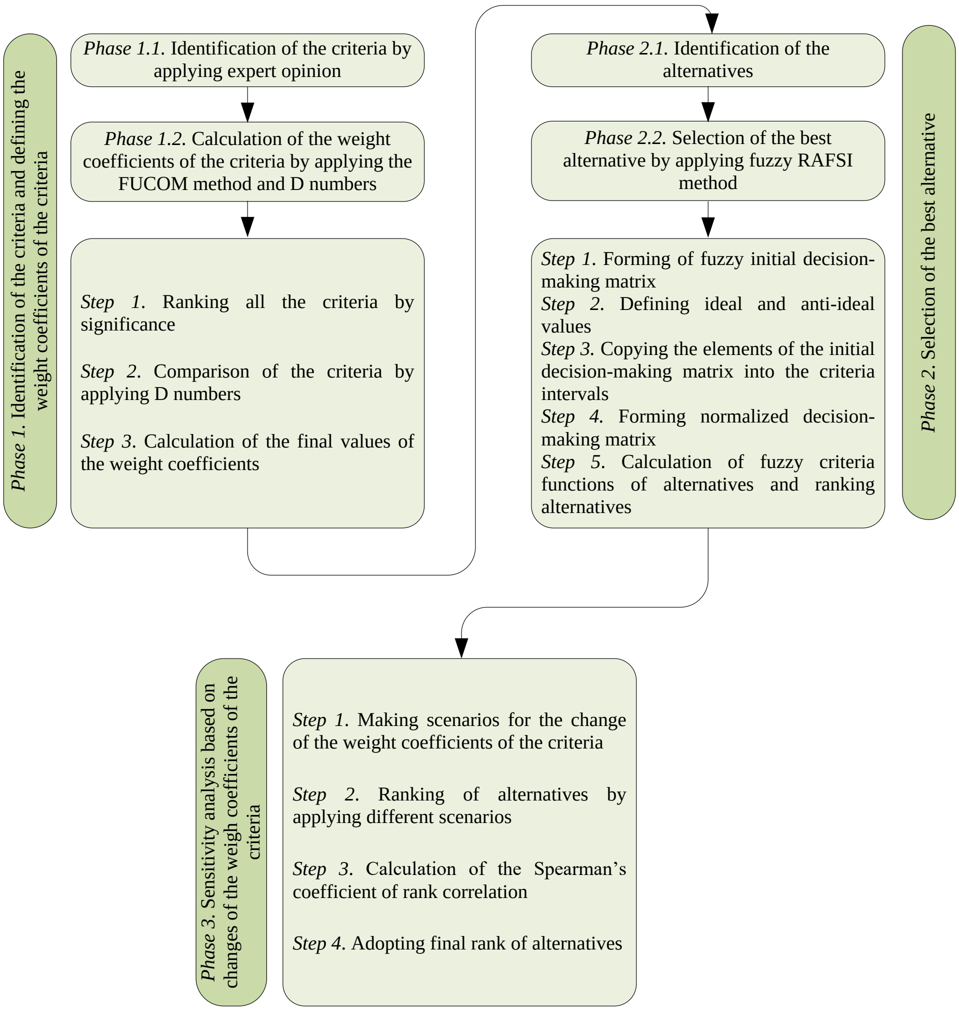

Fig. 1 General overview of the decision-making model including phases and steps

Due to the mentioned problems, an extension of this theory is performed in order to obtain D numbers, which eliminated certain disadvantages of the *Dempster-Shafer's* theory (Fig. 2). D numbers can effectively present uncertain information since: 1) the exclusive property of the elements in the frame of discernment is not required, and 2) the completeness constraint is released if necessary (Fig. 2b). These improvements provided the use of D numbers in solving numerous practical problems.

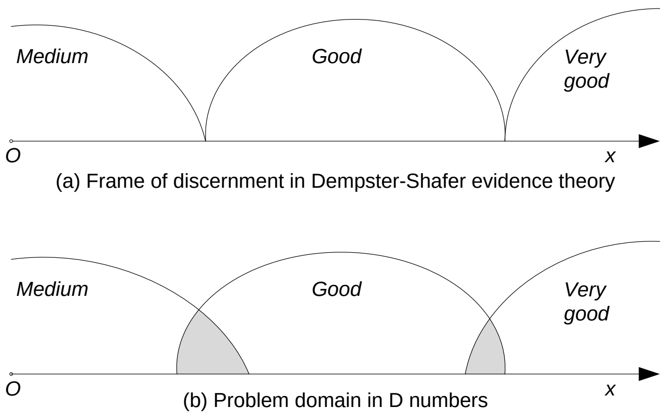

Fig. 2 The frame of discernment in the Dempster-Shafer evidence theory and domain in D numbers [28]

The specific application of D numbers can be found in a large number of publications about solving various issues: risk level assessment [29], supplier selection together with the fuzzy AHP method [30], supplier selection in combination with the AHP method [31], determining the quality of logistics services in order to gain adequate insight into the processes of managing service providers with the DEMATEL method and trapezoidal fuzzy numbers [28], evaluation of the Green Supply Chain management practice, where the fuzzy AHP method was used for calculation of weight coefficients [32], in error mode and effect analysis (FMEA) in the specific case on the rotor blades for aircraft turbines together with the TOPSIS method [33], selection of an autocannon for integration into combat vehicles in the model with the LBWA and MABAC methods [34], selection of suppliers in the tractor production industry with the TOPSIS method [35], etc.

Basic mathematical formulations of D numbers are presented below.

Let Ψ be a finite nonempty set, and a D number is a mapping that $D\colon \Psi \rightarrow [0,1]$, with

$$\sum_{A \subseteq \Psi} D(A) \leq 1 \ \ and \ \ D(\varnothing) = 0 \tag{1}$$

where $\emptyset$ is an empty set and A is any subset of Ψ. In the case the condition is met where $\sum_{A\subseteq\Psi} D(A) \leq 1$ the information is considered complete; otherwise, the information is not complete.

In discrete set $\Psi = \{b_1 b_2, ... b_i, b_j, ..., b_n\}$, where $b_i \in R$ and $b_i \neq b_j$ (when $i \neq j$), D numbers are presented as

$$D(b_1) = v_1, D(b_2) = v_2, ..., D(b_i) = v_i, D(b_j) = v_j, ..., D(b_n) = v_n \tag{2}$$

D numbers presented in expression (2) can be also presented in a simplified way as $D = \{(b_1,v_1),(b_2,v_2)...(b_i,v_i),(b_j,v_j)...(b_n,v_n)\}$, where the condition is met where $v_i > 0$ and $\sum_{i=1}^{n} v_i \leq 1$.

If two D numbers are provided: $D_1=\{(b_1,v_1),...(b_i,v_i)...(b_n,v_n)\}$ and $D_2=\{(b_n,v_n),...(b_i,v_i)...(b_1,v_1)\}$, the combination of D numbers $D=D_1 \oplus D_2$ is defined as [26]

$$\begin{cases} D(\varnothing)=0 \\ D(B)=\dfrac{1}{1-K_D}\sum\limits_{B_1\cap B_2=B} D_1(B_1)D_2(B_2), \quad B\neq\varnothing \end{cases}$$
$$\text{with}$$
$$K_D=\frac{1}{Q_1Q_2}\sum_{B_1\cap B_2=\varnothing} D_1(B_1)D_2(B_2) \tag{3}$$
$$Q_1=\sum_{B_1\subseteq\Theta} D_1(B_1)$$
$$Q_2=\sum_{B_2\subseteq\Theta} D_2(B_2)$$

If D_1 and D_2 are defined in the frame of discernment and if Q_1=1 and Q_2=1, then D number combination rule (3) is transformed into the Dempster's rule (4).

$$m(A)=\frac{1}{1-k}\sum_{B\cap C=A} m_1(B)m_2(B)$$
$$\text{where} \tag{4}$$
$$k=\sum_{B\cap C=\varnothing} m_1(B)m_2(B)$$

where A, B and C are three elements of 2^{Ψ}, and k is a normalization constant, called a conflict coefficient between two basic probability assignment (BPA) functions.

The rule for contamination of D numbers presents a mechanism allowing fusion of uncertain information presented in D numbers:

Permutation invariability: If there are two D numbers presented as $D_1=\{(b_1,v_1),...(b_i,v_i)...(b_n,v_n)\}$ and $D_2=\{(b_n,v_n),...(b_i,v_i)...(b_1,v_1)\}$ than $D_1 \Leftrightarrow D_2$, where „$\Leftrightarrow$" means „equal to".

Integration: For discrete D number $D=\{(b_1,v_1),(b_2,v_2)...(b_i,v_i),(b_j,v_j)...(b_n,v_n)\}$ the integration operator can be defined as follows:

$$I(D)=\sum_{i=1}^{n} d_i v_i \tag{5}$$

where $d_i \in R^+$, $v_i > 0$ and $\sum_{i=1}^{n} v_i \leq 1$.

2.2. The FUCOM method

The FUCOM (Full Consistency Method) method is intended for determining the weight coefficients of the evaluation criteria. The method was first presented by Pamučar et al. [36]; since then it has been applied in a large number of papers for solving various problems, such as:

- landfill site selection, together with the CODAS method [37],
- assessment of critical success factors for continuous academic quality assurance and accreditation, in the model with fuzzy AHP method [38],
- evaluation of the provisional sizing process in the clothing industry, with the fuzzy PIPRECIA method [39],
- selection of the best solution for business balance of the passenger railway operator, as a part of the validation test with the fuzzy AHP method [40],
- determination of macro location for railway network, in the model with the fuzzy TOPSIS method [41],
- selection of a distribution channel, in combination with the MARCOS method [42],
- solving the case study in the rubber glove industry, used in a hybrid model with the VIKOR method [43],
- for the purpose of assessing human resources, on which the overall efficiency of the enterprise depends, together with the MARCOS method [44],
- mineral potential mapping in greenfields, in the model with the MOORA and MOOSRA method [45],
- selection of vehicles with automatic guidance (AGVs), in combination with the R-ROV (Rough Range of Value) method [46],
- improvement of service quality measurement in the hybrid Delphi-FUCOM-SERVQUAL model [47],
- selection of a terrain vehicle for equipping military units, through the validation test of the AHP-DEA model, with the BWM method [48],
- selection of a sustainable supplier in a construction company, with the COPRAS method, while for the validation of the results the ARAS, WASPAS, SAW and MABAC methods were used in combination with rough numbers [49],
- evaluation of the sustainable performance of suppliers, with the MAIRCA method [50],
- selection of a location for a textile manufacturing facility, in combination with the GIS[51], and,
- selection of a fighter aircraft, with the ARAS method [52].

In addition to the classic FUCOM method, a fuzzified version of this method was used for solving practical problems, such as:

- selection of a system for desalination of renewable energy sources with a perspective of sustainability, with the DANP and Vector-aided TOPSIS methods [53],
- selection and prioritization of appropriate measures for the management of transport requirements in urban mobility system in Istanbul, in the fuzzy FUCOM-Dombi-Bonferroni model [54],
- in the example of suppliers of electricity from renewable sources [55],
- determining sustainability of sewage sludge in terms of energy source with the consideration of hybrid data, together with the FUSION approach [56].

The application of the FUCOM method with rough numbers is discussed in the problem of selecting the location of logistics centers in the Spanish autonomous communities with the CoCoSo method (Combined Compromise Solution) and it is presented in Yazdani et al. [57], while the selection of the contractors for solar panel installations is made by applying gray numbers in the Gray SWARA-FUCOM model [58].

The problem of the group decision-making solved by FUCOM method is presented in [42, 52,59].

The FUCOM method has a fairly simple mathematical apparatus, providing the results similar or the same as other methods for defining weight coefficients of criteria, such as the AHP and the Best-Worst methods. The FUCOM method consists of three steps:

Step 1 In the first step are ranked all the criteria influencing the decision $C=\{C_1,C_2,...,C_n\}$. The criteria are ranked from the most significant to the least significant criterion, respectively, from the criterion assuming to have the largest weight coefficient to the criterion with the smallest weight coefficient:

$$C_{j(1)} > C_{j(2)} > ... > C_{j(k)} \tag{6}$$

where k presents the rank of the observed criterion. If there is an opinion of the existence of two or more criteria with the same significance, the sign of equality is placed instead of ">" between these criteria in the expression (6).

Step 2 In the second step the first-ranked criterion is compared to the other criteria. The comparison of the criteria is performed by experts by applying D numbers. Applying expressions (1) to (5), aggregated criteria significance ($\varpi_{C_{j(k)}}$) is calculated. In accordance with the calculated comparison, comparative significance of criteria is calculated ($\varphi_{k/(k+1)}$, $k=1,2,...,n$, where k presents the rank of the criteria). The vector of the comparative priorities of the evaluation criteria are obtained, as in expression (7):

$$\Phi = (\varphi_{1/2}, \varphi_{2/3}, ..., \varphi_{k/(k+1)}) \tag{7}$$

Step 3 In the third step, final values of the weight coefficients of the evaluation criteria $(w_1,w_2,...,w_n)^T$ are calculated. Final values of the weight coefficients should meet two conditions:

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)} \tag{8}$$

$$\frac{w_k}{w_{k+2}} = \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \tag{9}$$

where $\varphi_{k/(k+1)}$ presents the significance (priority) that the criterion of $C_{j(k)}$rank is compared to the criterion of $C_{j(k+1)}$rank.

The calculation of final values is performed by applying expression (10), and solving the obtained system of equities.

$$\begin{aligned} &\min \chi \\ &s.t. \\ &\left| \frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \right| \le \chi,\ \forall j \\ &\left| \frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \right| \le \chi,\ \forall j \\ &\sum_{j=1}^{n} w_j = 1,\ \forall j \\ &w_j \ge 0,\ \forall j \end{aligned} \tag{10}$$

where χ presents maximum consistency, respectively, tends to be χ =0.

2.3. Fuzzy RAFSI method

Ranking of Alternatives through Functional mapping of criterion sub-intervals into a Single Interval (RAFSI) is a method first presented in the paper by Žižović et al. [60]. Using the RAFSI method, Žižović et al. [60] evaluated the researchers who applied for a job in a scientific research center, and the results obtained by their application are compared with those obtained using the TOPSIS, VIKOR and COPRAS methods. Since this method was published in mid-2020, its application in various fields has not been widely represented yet. So far, it has been used in the problem of sustainable health system reorganization in the emergency caused by the COVID-19 virus pandemic, along with fuzzy sets and the LBWA and MACBETH methods [61].

In this paper, the fuzzified RAFSI method (FRAFSI) is used. Fuzzification is performed by applying triangular fuzzy numbers $T = (t_1, t_2, t_3)$, as in Fig. 3, where t_1 presents the left, t_3 the right distribution of the confidence interval of fuzzy number T while t_2, where the function of fuzzy number membership has a maximum value, one.

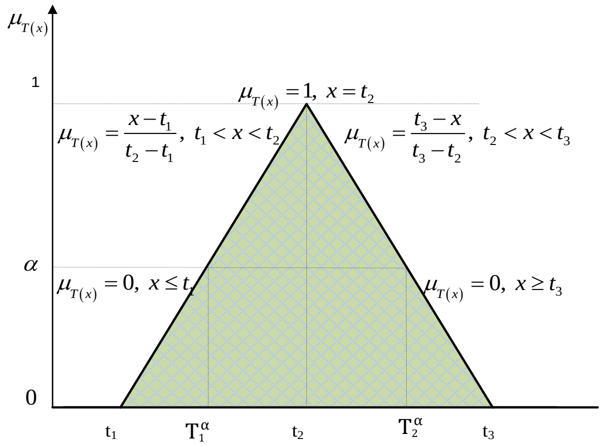

Fig. 3 Triangular fuzzy number [62]

The steps of the fuzzy RAFSI (FRAFSI) method are presented below [61].

Step 1 Forming fuzzy initial decision-making matrix. This matrix is formed by the evaluation of the defined alternatives from set $A_i(i=1,2,...,m)$ in relation to the defined set of criteria C_j $(j=1,2,...,n)$.

$$X = \begin{bmatrix} \tilde{\xi}_{11} & \tilde{\xi}_{12} & \cdots & \tilde{\xi}_{1n} \\ \tilde{\xi}_{21} & \tilde{\xi}_{22} & \cdots & \tilde{\xi}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\xi}_{m1} & \tilde{\xi}_{m2} & \cdots & \tilde{\xi}_{mn} \end{bmatrix}_{m \times n} \tag{11}$$

where $\tilde{\xi}_{ij} = (\xi_{ij}^{l}, \xi_{ij}^{s}, \xi_{ij}^{u})$ denotes the value of the i-th alternative for the j-th criterion ($i=1,2,...,m$; $j=1,2,...,n$). Experts can also be engaged in obtaining the elements of the X matrix, where the initial decision-making matrix would be obtained by averaging the elements from all expert initial decision-making matrices. Considering the specificity of the described problem, a decision will most often be made based on the assessment/calculation of one person.

Step 2 Defining ideal and anti-ideal values. For every criterion C_j (j=1,2,...,n) a decision-maker defines ideal value by criterion C_j ($\tilde{\xi}_{I_j}$) and anti-ideal value by criterion C_j($\tilde{\xi}_{N_j}$). Defining mentioned values are determined criteria intervals which depend on the character of the criterion:

$$C_j \in \begin{cases} [\tilde{\xi}_{N_j}, \tilde{\xi}_{I_j}], \; \textit{for benefit criteria} \\ [\tilde{\xi}_{I_j}, \tilde{\xi}_{N_j}], \; \textit{for cost criteria} \end{cases} \tag{12}$$

Step 3 Copying elements from the decision-making matrix into the criteria intervals. For every alternative from set A_i (i=1,2,...,m), function $\tilde{f}_{A_i}(C_j)$ which copies the criteria intervals from the initial decision-making matrix (11) into the criteria interval [n_1,n_b] is defined, as in expression (13):

$$\tilde{f}_{A_i}(C_j) = \tilde{\varphi}_{ij} = \frac{n_b - n_1}{\tilde{\xi}_{I_j} - \tilde{\xi}_{N_j}} \tilde{\xi}_{ij} + \frac{\tilde{\xi}_{I_j} \cdot n_1 - \tilde{\xi}_{N_j} \cdot n_b}{\tilde{\xi}_{I_j} - \tilde{\xi}_{N_j}} \tag{13}$$

where n_b and n_1 represent the relations showing how better the ideal value is when compared to the anti-ideal value, $\tilde{\xi}_{I_j}$and$\tilde{\xi}_{N_j}$respectively, represent ideal and anti-ideal value by criterion C_j, while $\tilde{\xi}_{ij}$ denotes the value of the i-th alternative for the j-th criterion from the initial decision-making matrix. The relation of the ideal and anti-ideal value can be different, but it should not be lower than 1:6, respectively, n_1=1 and n_b=6.

Applying expression (13) standardized decision-making matrix $T = [\tilde{\varphi}_{ij}]_{mxn}$ (i=1,2,...,m; j=1,2,...,n) is obtained, as in Eq. (14).

$$T = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{\varphi}_{11} & \tilde{\varphi}_{12} & \cdots & \tilde{\varphi}_{1n} \\ \tilde{\varphi}_{21} & \tilde{\varphi}_{22} & \cdots & \tilde{\varphi}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\varphi}_{m1} & \tilde{\varphi}_{m2} & \cdots & \tilde{\varphi}_{mn} \end{bmatrix} \end{array} \tag{14}$$

In matrix T all the elements of the initial decision-making matrix are transferred into interval $\tilde{\varphi}_{ij} \in [n_1, n_b]$.

Step 4 Forming normalized decision-making matrix $N = [\tilde{\varphi}_{ij}]_{mxn}$($i$=1,2,...,$m$; j=1,2,...,n).

$$N = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{\gamma}_{11} & \tilde{\gamma}_{12} & \cdots & \tilde{\gamma}_{1n} \\ \tilde{\gamma}_{21} & \tilde{\gamma}_{22} & \cdots & \tilde{\gamma}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\gamma}_{m1} & \tilde{\gamma}_{m2} & \cdots & \tilde{\gamma}_{mn} \end{bmatrix} \end{array} \tag{15}$$

where $\tilde{\gamma}_{ij} \in [0,1]$ present normalized elements of matrix N.

The way of normalization of the elements of matrix N depends on the type of criteria. The way of calculation of the normalized values is provided in the expression:

$$\tilde{\gamma}_{ij}=\begin{cases}\dfrac{\tilde{\varphi}_{ij}}{2A}, & \text{for benefit criteria}\\ \dfrac{H}{2\tilde{\varphi}_{ij}}, & \text{for cost criteria}\end{cases} \tag{16}$$

In expression (16) A represents arithmetic value of elements n_1 and n_b, which is calculated by applying the expressions:

$$A=\frac{n_1+n_b}{2} \tag{17}$$

Value H presents harmonic mean of elements n_1 and n_b, and it is obtained by applying the expression:

$$H=\frac{2}{\frac{1}{n_1}+\frac{1}{n_b}} \tag{18}$$

Step 5 Calculation of fuzzy criteria functions of alternatives $\tilde{Q}(A_i)$ and ranking alternatives. The criteria functions of alternatives $\tilde{Q}(A_i)$ are calculated by applying the expression:

$$\tilde{Q}(A_i)=\sum_{j=1}^{n} w_j \tilde{\gamma}_{ij} \tag{19}$$

where w_j re represents the weight coefficient of the criteria, and $\tilde{\gamma}_{ij}$ normalized value of the alternative A_i (i=1,2,...,m) by the criterion C_j (j=1,2,...,n).

The alternatives considered are ranked from the largest (the first-ranked alternative) to the smallest (the last-ranked alternative) value of fuzzy criteria function $\tilde{Q}(A_i)$. Instead of ranking the value of fuzzy criteria function $\tilde{Q}(A_i)$, defuzzification can be carried out before ranking, thus making the ranking process much simpler. Defuzzification can be performed in different ways. One example is provided in expression (20):

$$Q(A_i)=(Q(A_i)^l+4\cdot Q(A_i)^s+Q(A_i)^u)/6 \tag{20}$$

where $Q(A_i)$ is the defuzzified value of fuzzy criteria function $\tilde{Q}(A_i)$, $Q(A_i)^l$ the left distribution of the confidence interval of fuzzy criteria function $\tilde{Q}(A_i)$, $Q(A_i)^u$ the right distribution of the confidence interval of fuzzy criteria function $\tilde{Q}(A_i)$, and $Q(A_i)^s$ the value of fuzzy criteria function $\tilde{Q}(A_i)$ where the membership degree is the highest, receptively, one.

3. Application of the D Numbers – FUCOM – FRAFSI Model

In this section presents an application of the proposed multi-criteria methodology for the selection of the composition of the group of construction machines for enabling mobility. In the first part, the criteria are determined, on which the selection of the best alternative and the calculation of the weight coefficients of the criteria depend. Determining the criteria and initial elements for the calculation of the weight coefficients of the criteria was done by engaging seven experts. In the second part of this section the process of selection of the best alternative is presented.

3.1 Defining the criteria and their weight coefficients

The complexity of the research issue influences the determination of criteria and their weight coefficients to be done in several iterations. At the end of the process, the experts agreed that selecting the best alternative was influenced by six criteria, which are explained below.

Criterion 1 (C_1) - Performance (m^3): Expressing the degree of use of construction machines and training of operators is done by work performance [63]. In this specific case, after the calculation, the performance of the key machine is taken as the value according to this criterion. The key machine is the one whose performance is the lowest. It is important to emphasize it because most machines in the group are connected, so that the duration of the key machine's work is also the duration of the whole group work [63].

Criterion 2 (C_2) - Operational reliability of the group of construction machines: The reliability of construction machines is usually defined as the probability of performing a specific function without failure under given conditions for a particular time [64]. To evaluate the alternatives according to this criterion, the frequency of failures is estimated (expected number of machine failures in a certain period). The practice has shown that many failures are not expected with the machines of a newer (more recent) production date. Simultaneously with the increase in age, the number of expected failures in a certain period of time increases. Considering that the group comprises machines with different years of production and made by different producers, special fuzzy linguistic descriptors were made to evaluate this criterion, as presented in Fig. 4. The scale shown has six fuzzy linguistic descriptors: very low (VL), low (L), satisfactory (S), medium (M), high (H), and very high (VH).

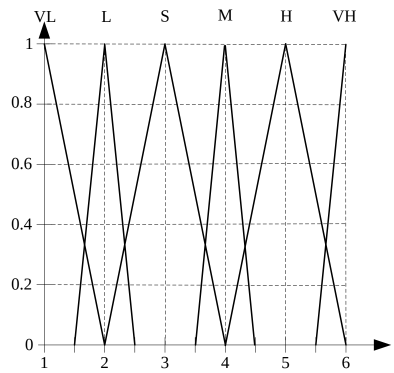

Fig. 4 Fuzzy linguistic descriptors for the C2 criterion description

Criterion 3 (C_3) - Possibility of movement outside regulated roads: This criterion presents the possibility of movement of the construction machines to the directions where the terrain is not adjusted to the needs of the machine. Since the criterion is evaluated in relation to the group, the device's value with the least possibilities of movement outside regulated roads is taken into the calculation. The value of the criterion is expressed in percentage.

Criterion 4 (C_4) - The need for a means of transport (tow truck): The movement of the machine on a certain terrain is conditioned by the technical possibilities of the machine itself and the dependency of the machine on the terrain features. During the work engagement of the device, the device needs to be moved from one location to another. In such situations, it is necessary to consider the possibility of self-propelled movement, respectively, the necessity of engaging appropriate means of transport to reduce negative characteristics of the devices for moving construction machines and create necessary conditions for timely arrival at work. The criterion is linguistic, and the values are assigned using fuzzy linguistic descriptors, as in Fig. 5. The scale shown has four fuzzy linguistic descriptors: A - rarely (R), B - occasionally (Occ), C - often (O), D - almost always (AA).

Criterion 5 (C_5) - Technical capability of fast troubleshooting: It is not possible to engage construction machines without an adequately organized technical support. Technical support in combat operations, in addition to ongoing maintenance, is also intended for fast troubleshooting. The speed of troubleshooting depends on several elements: the type of failure, the development of technical support (training of people), the type of machine, the uniformity of devices by types and categories (availability of spare parts), and the like. In this context, a particular linguistic scale is defined to assess this criterion, as in Fig. 5. There is a well-developed technical support for older assets, which would monitor the group; however, for the assets in the warranty period, failures are fixed by maintenance companies, which can be a significant problem in combat operations. The scale shown has four fuzzy linguistic descriptors (Fig. 5): A - very small (VS), B - small (S), C - medium (M), and D - high (H).

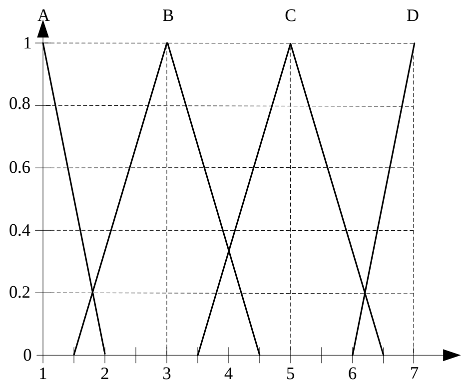

Fig. 5 Fuzzy linguistic descriptors for the C4 criterion description

Criterion 6 (C_6) - Conveniences of construction features (possibility of setting different types of working tools): Its construction features predetermine the purpose of the machine based on its equipment with appropriate tools for realizing its tasks. The possibility of using more tools on one device significantly improves the work process. It can reduce the number of machines in the group or create a better potential for solving problems, which is difficult to predict in the initial phase. The criterion has a numerical character, and it is defined through the number of additional work tools, which can be placed on construction machines and thus engage the machine in other tasks.

From the previous explanation, it can be concluded that the evaluation of alternatives by criteria is performed numerically (C_1, C_3 and C_6) and linguistically (C_2, C_4 and C_5). In addition to the above mentioned, the set of criteria C_j (j=1,2,...,6) can be divided into two subsets: a subset of benefit-type criteria (C_j^+- where a higher value of the alternative by criteria is more desirable, and which consists of the criteria C_1, C_2, C_3, C_5 and C_6) and a subset of cost-type criteria (C_j^-- where a lower value of alternative by criteria is more desirable), which consists of criterion C_4.

After defining the criteria, the conditions for calculating the weight coefficients of the criteria using D numbers and the FUCOM method are met.

Step 1 In the first step, the criteria are ranked from the most important to the least important. The rank of the criteria is reached by the consensus of experts. The experts agreed with the following ranking of criteria: $C_1 > C_2 > C_3 > C_4 > C_5 > C_6$.

Step 2 In the second step, every expert compares the first-ranked with the other criteria by applying D numbers, after which their opinions are aggregated into one. The comparison is performed using a scale $\varpi_{C_{j(k)}} \in [1, 9]$. The following are the values of D_e (where e represents the number of experts e=1,2,...,7) for the comparison of the first-ranked (C_1) and the second-ranked (C_2) criterion:

D_1={(1,0.2),(1;2,0.2),(2,0.6)}
D_2={(1,0.5),(1;2,0.3),(2,0.1)}
D_3={(1,0.1),(2,0.2),(3,0.7)}
D_4={(1,0.3),(2,0.5),(2;3,0.2)}
D_5={(2,0.5),(2;3,0.1),(3,0.4)}
D_6={(2,0.6),(3,0.1),(4,0.1)}
D_7={(2,0.22),(2;3,0.25),(3,0.5)}

After the aggregation, the following values are obtained:

$D_{1\text{-}2}$={(1,0.403),(1;2,0.093),(2,0.403)}
$D_{3\text{-}4}$={(1,0.097),(2,0.452),(3,0.452)}
$D_{5\text{-}6}$={(2,0.702),(3,0.098)}
$D_{5\text{-}7}$={(1,0.159),(2,0.741)}
$D_{1\text{-}4}$={(2,0.635),(3,0.014)}
$D_{1\text{-}7}$={(2,0.698)}

Based on experts' opinion, the relation of the first-ranked (C_1) and the second-ranked (C_2) criteria is $\varpi_{C_{j(1)}} = 1.397$.

The importance of the comparison of the first-ranked (C_1) in relation to other criteria is $\varpi_{C_{j(k)}} = (1, 1.397, 1.882, 2.298, 2.601, 4.489)$.

Based on the obtained importance values of the criteria, we calculate the comparison importance values of the criteria $\varphi_{C_1/C_2} = 1.397/1 = 1.397$, $\varphi_{C_2/C_3} = 1.882/1.397 = 1.347$, $\varphi_{C_3/C_4} = 2.298/1.882 = 1.221$, $\varphi_{C_4/C_5} = 2.601/2.298 = 1.132$ and $\varphi_{C_5/C_6} = 4.489/2.601 = 1.726$.

Applying expression (10) the final model for determining weight coefficients is defined

$$\min \chi$$

$$\left|\frac{w_1}{w_2}-1.397\right|=\chi,\ \left|\frac{w_2}{w_3}-1.347\right|=\chi,\ \left|\frac{w_3}{w_4}-1.221\right|=\chi,\ \left|\frac{w_4}{w_5}-1.132\right|=\chi,\left|\frac{w_5}{w_6}-1.726\right|=\chi,$$

$$\left|\frac{w_1}{w_3}-1.882\right|=\chi,\ \left|\frac{w_2}{w_4}-1.645\right|=\chi,\ \left|\frac{w_3}{w_5}-1.382\right|=\chi,\left|\frac{w_4}{w_6}-1.954\right|=\chi,$$

$$\sum_{j=1}^{6} w_j = 1,\ w_j \geq 0, \forall j$$

By solving the previous expression the weight coefficients of the criteria are obtained, as shown in Table 1.

Table 1 Weight coefficients of criteria

Criteria	Weight coefficients of criteria
C_1	0.304
C_2	0.218
C_3	0.162
C_4	0.132
C_5	0.117
C_6	0.067

Criterion C_1 has the highest weight coefficient. The difference compared to the least significant criterion (C_6) is quite large, which is the result of expert evaluation. Criterion C_1 has the highest weight coefficient, which presents the expected decision of the expert because it is the criterion directly related to the execution of the task in which the group of construction machines is engaged for the entire time of the task. Unlike criterion C_1, criteria C_2 and C_5 are related to the assessment assuming the occurrence of problems in operation and their solution, criteria C_3 and C_4 are related only to the part of the task, and criterion C_6 presents the assessment of possibilities, which does not have to be used during the task.

3.2. Selection of the best alternative

The sizing of potential alternative solutions, respectively, the groups of construction machines that would be engaged in enabling mobility of the Serbian Army units to realize the task of repairing and reconstructing the road section, is performed for the needs of selecting the best alternative. The group generally consists of the following types of machines: dozers, loaders, diggers, motor vehicles for the transport of loose material (self-unloaders), road rollers, compressor stations, pavers, transport vehicles (for transport of machines whose technical capabilities do not allow self-propelled movement over longer distances), and others.

Practical works on the repair and reconstruction of certain road sections have indicated that the dozers and loaders, based on their performance and mode of operation, can be classified into a group of critical machines. In order to understand more fully the possibility of reducing (eliminating) the impact of the critical machine on the success of the assigned task, the formation of alternatives (groups of construction machines) is performed. The groups are composed of variable and permanent composition, in accordance with the construction machines forming part of the Serbian Army (Table 2).

Table 2 Overview of alternatives

Alternative	Variable composition of group	Permanent composition of group
A_1	Dozer (IMK 14. oktobar - TG-170) Loader (IMK 14. oktobar - 160)	Digger, Self-unloader, Roller, Compressor station, Transport vehicles
A_2	Dozer (Caterpillar D5K2 XL) Loader (Caterpillar 966M)	
A_3	Dozer (Dressta TD-15M) Loader (Caterpillar 966M)	
A_4	Dozer (Shantui SD 20-5) Loader (JCB 436 HT)	
A_5	Dozer (IMK 14. oktobar - TG-170) Loader (Caterpillar 966M)	
A_6	Dozer (IMK 14. oktobar - TG-170) Loader (JCB 436 HT)	
A_7	Dozer (Caterpillar D5K2 XL) Loader (IMK 14. oktobar - 160)	
A_8	Dozer (Dressta TD-15M) Loader (IMK 14. oktobar - 160)	

After the alternatives are defined, the conditions for the application of the FRAFSI method are met.

Step 1 In the first step, the initial decision-making matrix (*X)* is defined.

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{array} \\ \begin{bmatrix} (37,40,44) & VL & (60,70,75) & AA & H & 2 \\ (22,25,27) & VH & (75,80,85) & O & VS & 14 \\ (43,45,49) & M & (72,75,80) & Occ & VS & 14 \\ (25,30,33) & H & (75,78,80) & O & S & 2 \\ (37,40,44) & L & (60,70,75) & AA & M & 15 \\ (37,40,44) & L & (60,65,70) & AA & H & 3 \\ (22,25,27) & H & (75,80,85) & O & M & 1 \\ (43,45,49) & S & (65,75,80) & Occ & S & 1 \end{bmatrix} \end{array}$$

Considering the existence of the qualitative criteria, by applying fuzzy linguistic descriptors (Figs. 4 and 5), their quantification is performed by matrix X_k.

$$X_k = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{array} \\ \begin{bmatrix} (37,40,44) & (1,1,2) & (60,70,75) & (6,7,7) & (6,7,7) & 2 \\ (22,25,27) & (5.5,6,6) & (75,80,85) & (3.5,5,6.5) & (1,1,2) & 14 \\ (43,45,49) & (3.5,4,4.5) & (72,75,80) & (1.5,3,4.5) & (1,1,2) & 14 \\ (25,30,33) & (4,5,6) & (75,78,80) & (3.5,5,6.5) & (1.5,3,4.5) & 2 \\ (37,40,44) & (1.5,2,2.5) & (60,70,75) & (6,7,7) & (3.5,5,6.5) & 15 \\ (37,40,44) & (1.5,2,2.5) & (60,65,70) & (6,7,7) & (6,7,7) & 3 \\ (22,25,27) & (4,5,6) & (75,80,85) & (3.5,5,6.5) & (3.5,5,6.5) & 1 \\ (43,45,49) & (2,3,4) & (65,75,80) & (1.5,3,4.5) & (1.5,3,4.5) & 1 \end{bmatrix} \end{array}$$

Step 2 In this step we defined ideal set $\tilde{\xi}_{I_j}$ and anti-ideal value $\tilde{\xi}_{N_j}$ for every criterion C_j (j=1,2,...6):

$$\tilde{\xi}_{I_j} = \{65, 6, 100, 1, 7, 15\},$$

$$\tilde{\xi}_{N_j} = \{15, 1, 50, 7, 1, 1\}.$$

According to the defined ideal and anti-ideal points, the interval values of all the criteria are defined, including:

- For benefit-type criteria: $C_1 \in [15, 65]$, $C_2 \in [1, 6]$, $C_3 \in [50, 100]$, $C_5 \in [1, 7]$, $C_6 \in [1, 15]$,
- For cost-type criteria: $C_1 \in [1, 7]$.

Step 3 For making standardized matrix, the relation of the ideal and anti-ideal value of 1:6 ($n_1=1$ and $n_b=6$) is accepted. Applying expression (13) standardized decision-making matrix (T) is obtained.

$$T = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{array} \\ \begin{bmatrix} (3.2,3.5,3.9) & (1,1,2) & (2,3,3.5) & (5.17,6,6) & (5.17,6,6) & 1,36 \\ (1.7,2,2.2) & (5.5,6,6) & (3.5,4,4.5) & (3.08,4.33,5.58) & (1,1,1.83) & 5,64 \\ (3.8,4,4.4) & (3.5,4,4.5) & (3.2,3.5,4) & (1.42,2.67,3.92) & (1,1,1.83) & 5,64 \\ (2,2.5,2.8) & (4,5,6) & (3.5,3.8,4) & (3.08,4.33,5.58) & (1.42,2.67,3.92) & 1,36 \\ (3.2,3.5,3.9) & (1.5,2,2.5) & (2,3,3.5) & (5.17,6,6) & (3.08,4.33,5.58) & 6,00 \\ (3.2,3.5,3.9) & (1.5,2,2.5) & (2,2.5,3) & (5.17,6,6) & (5.17,6,6) & 1,71 \\ (1.7,2,2.2) & (4,5,6) & (3.5,4,4.5) & (3.08,4.33,5.58) & (3.08,4.33,5.58) & 1,00 \\ (3.8,4,4.4) & (2,3,4) & (2.5,3,5.4) & (1.42,2.67,3.92) & (1.42,2.67,3.92) & 1,00 \end{bmatrix} \end{array}$$

Step 4 Applying expressions (17) and (18), the values of geometric and harmonic means (A=3.5 and H=1.71) are obtained, and by using expression (16) the calculation of normalized matrix (N) is done.

$$N = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{array} \\ \begin{bmatrix} (0.46,0.5,0.56) & (0.14,0.14,0.29) & (0.29,0.43,0.5) & (0.14,0.14,0.17) & (0.74,0.86,0.86) & 0.19 \\ (0.24,0.29,0.31) & (0.79,0.86,0.86) & (0.5,0.57,0.64) & (0.15,0.2,0.28) & (0.14,0.14,0.26) & 0.81 \\ (0.54,0.57,0.63) & (0.5,0.57,0.64) & (0.46,0.5,0.57) & (0.22,0.32,0.61) & (0.14,0.14,0.26) & 0.81 \\ (0.29,0.36,0.4) & (0.57,0.71,0.86) & (0.5,0.54,0.57) & (0.15,0.2,0.28) & (0.2,0.38,0.56) & 0.19 \\ (0.46,0.5,0.56) & (0.21,0.29,0.36) & (0.29,0.43,0.5) & (0.14,0.14,0.17) & (0.44,0.62,0.8) & 0.86 \\ (0.46,0.5,0.56) & (0.21,0.29,0.36) & (0.29,0.36,0.43) & (0.14,0.14,0.17) & (0.74,0.86,0.86) & 0.24 \\ (0.24,0.29,0.31) & (0.57,0.71,0.86) & (0.5,0.57,0.64) & (0.15,0.2,0.28) & (0.44,0.62,0.8) & 0.14 \\ (0.54,0.57,0.63) & (0.29,0.43,0.57) & (0.36,0.5,0.57) & (0.22,0.32,0.61) & (0.2,0.38,0.56) & 0.14 \end{bmatrix} \end{array}$$

Step 5 Final calculation of fuzzy criteria functions of alternatives $\tilde{Q}(A_i)$ is made by applying expression (19). Final ranking is done after the defuzzification of fuzzy criteria functions of alternatives, as in Table 3.

Table 3 Ranking of alternatives

Alternative	$\tilde{Q}(A_i)$	$Q(A)$	Ranking of alternatives
A_1	(0.335,0.385,0.448)	0.3871	8
A_2	(0.418,0.464,0.509)	0.4637	2
A_3	(0.449,0.493,0.589)	0.5018	1
A_4	(0.35,0.436,0.516)	0.4351	5
A_5	(0.361,0.433,0.502)	0.4326	6
A_6	(0.354,0.408,0.455)	0.4068	7
A_7	(0.361,0.443,0.526)	0.4435	4
A_8	(0.347,0.445,0.563)	0.4484	3

Using the FRAFSI method, alternative A_3 was ranked first, while alternative A_1 was ranked last. Such rank of alternatives is expected when considering the data in the initial decision-making matrix (X), respectively, the quantified decision-making matrix (X_k). Alternative A_3, in addition to alternative A_8, has the highest value according to the most important criterion (C_1). It has significantly high values according to criteria C_3, C_4 and C_6, and slightly lower than the highest one according to criterion C_2. Alternative A_3 is poorly rated, only by criterion C_5. On the other hand, alternative A_1 , which is the last in the rank, has the values tending to be minimal by all criteria except criterion C_5. Therefore, the rank of alternative A_1 is expected. Overall, the final values of decision preferences do not indicate the absolute dominance of the first-ranked alternative, but still are sufficient to consider it the best one.

Logically, the last step to be made in the model development is a sensitivity analysis.

4. Sensitivity Analysis

Decision-making is a complex process in which various mistakes are possible. Due to the above, and before adopting the model, a more detailed analysis is necessary to be performed. A sensitivity analysis is usually performed. The sensitivity analysis can be performed by different approaches including: changes in weight coefficients of criteria, change of measurement units in which the values of alternatives are expressed, change of scales presenting linguistic criteria, change of type of criteria (cost/benefit), application of dynamic matrices, comparison with other methods, etc. [65]. In most cases, the authors perform a sensitivity analysis based on the changes in weight coefficients of criteria [66-76], as is the case in this paper as well.

The objective goal of the sensitivity analysis is to evaluate the influence of the most effective influential criterion on the ranking performance of the proposed model [54]. For the sensitivity analysis by the change of weight coefficients, 20 scenarios are developed. The basis for the change in weight coefficients makes the change in the weight coefficient of the best criterion C_1. The changes in the weight coefficients of this criterion are made in interval $w_{C_1} \in [0.003, 0.292]$, and the values for which the reduction is made are proportionally allocated to the other criteria by applying the proportion

$$w_n : (1 - w_{C_1}) = w_n^* : (1 - w_{C_1}^*) \tag{21}$$

where $w_{C_1}^*$ represents the corrected value of the weight coefficient of criterion C_1, w_n^* the reduced value of the considered criterion, w_n the original value of the considered criterion and w_{C_1} the original value of criterion C_1.

The proportion set in this way always provides the condition where $\sum_{j=1}^{6} w_j = 1$. Through every correction of criterion C_1, the correction respectively, the reduction is done by 5%. The values of the weight coefficients in all scenarios are shown in Fig. 6.

Applying the developed scenarios, changes in the ranks of alternatives are established. The ranking of alternatives by scenarios is shown in Table 4. In Table 4 are grouped the scenarios according to which the ranking of alternatives is identical.

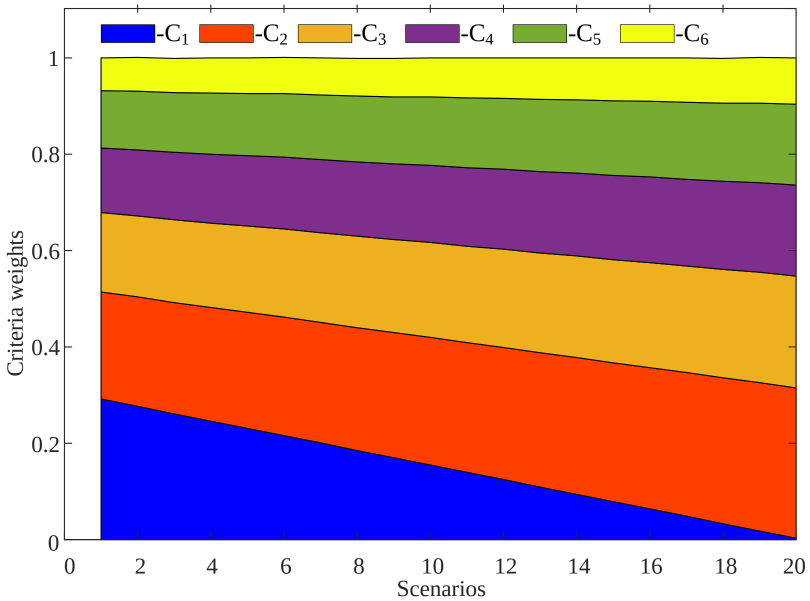

Fig. 6 Overview of the changes in the weight coefficients of criteria through 20 scenarios

Table 4 Ranking of alternatives by different scenarios

Alternative	S1-S3	S4-S7	S8-S11	S12-S13	S14-S19	S20
A_1	8	8	8	8	8	8
A_2	2	2	1	1	1	1
A_3	1	1	2	3	3	4
A_4	5	4	4	4	4	3
A_5	6	6	6	6	5	5
A_6	7	7	7	7	7	7
A_7	4	3	3	2	2	2
A_8	3	5	5	5	6	6

The analysis of the results obtained by applying different scenarios shows certain changes in the rank of alternatives. This indicates that the presented model is sensitive enough to register changes in the weight coefficients of the criteria. It is clear from Table 4 that the rank of the last two alternatives did not change, regardless of the scenario. It is also observed that the first-ranked alternative (A_3) retained its position until the eighth scenario, when its place is taken by alternative A_2, which is ranked first until the end. In general, changes in the rank of alternatives occur in only five cases:

- The rank of alternatives from scenario S1 to scenario S3 (change of the weight coefficient w_1 in interval $0.261 \le w_1 \le 0.292$) is identical to the initial rank;
- The rank of alternatives from scenario S4 to scenario S7 (change of the weight coefficient w_1 in interval $0.201 \le w_1 \le 0.246$) changed in three positions: alternative A_4 was ranked fourth while according to the initial rank it was the fifth, alternative A_7 was ranked third while according to the initial rank it was the fourth, alternative A_8 was ranked fifth while according to the initial rank it was the third;
- The rank of alternatives from scenario S8 to scenario S11 (change of the weight coefficient w_1 in interval $0.140 \le w_1 \le 0.185$) changes in the position of the first-ranked alternative, which is now occupied by alternative A_2 and retains that position until the end;
- The rank of alternatives for scenarios S12 and S13 (change of weight coefficient w_1 in interval $0.109 \le w_1 \le 0.125$) changes through the replacement of the second and the third alternative position, respectively (alternatives A_3 and A_7);
- In scenarios S14 to S19 (change of weight coefficient w_1 in interval $0.018 \le w_1 \le 0.094$) changes are observed in the replacement of the place of the fifth-ranked and the sixth-ranked alternative (alternatives A_5 and A_8);
- Scenario S20 (change of the weight coefficient where w_1=0.003) brings the change at the positions three and four (alternatives A_3 and A_4);

As can be seen from the previous explanation, the changes are gradual and expected because there is a significant change in the weight coefficient of criterion C_1. However, it should be noted that the dominance of alternative A_3 is not so significant that it retains the first-ranked position in all scenarios. Theoretical analysis is confirmed by the statistical correlation of ranks performed using the Spearman's correlation coefficient:

$$S = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n(n^2-1)} \tag{22}$$

where D_i presents the difference of the rank according to the given scenario and the rank in the corresponding scenario, and n is the number of ranked elements.

The Spearman's coefficient takes the values from the interval from minus one ("ideal negative correlation") to one ("ideal positive correlation").

In Table 5 the values of the Spearman's coefficient are provided, comparing the results obtained by applying different scenarios, as well as the initial rank (Si).

Table 5 The values of the Spearman's coefficient

Scenarios	Si	S1-S3	S4-S7	S8-S11	S12-S13	S14-S19	S20
Si	1	1	0.929	0.905	0.833	0.762	0.667
S1-S3		1	0.929	0.905	0.833	0.762	0.667
S4-S7			1	0.976	0.929	0.905	0.833
S8-S11				1	0.976	0.952	0.905
S12-S13					1	0.976	0.952
S14-S19						1	0.976
S20							1

From Table 5, it can be noted that the Spearman's coefficient of the rank correlation of the considered strategies ranges within the interval $S\in[0.667, 1]$, presenting a very high correlation degree.

General conclusion that can be reached from this analysis is that the developed model registers changes in weight coefficients, through changes in the range of alternatives, as well as that these changes are not significantly large, which is proven by the Spearman's coefficient. As the final rank of alternatives the initial rank can be accepted, taking into consideration that the change of the first-ranked alternative occurred when the weight coefficient of criterion C_1 decreased from 0.304 to 0.185, which is a significant decrease.

4. CONCLUSION

This paper is dedicated to solving the problem of selecting the group of construction machines composition for enabling mobility of the Serbian Army units based on structural characteristics of construction machines. In order to solve it, a hybrid model based on several methods including: D numbers, the FUCOM method and fuzzified RAFSI method is used. The use of the mentioned methods provided a good treatment of uncertainty following the problem being solved. By applying D numbers, the input parameters for the calculation of the weight coefficients of the criteria were obtained. Experts were engaged to define the criteria and their weight coefficients, who were able, due to using D numbers, to present the dilemmas related to the weighting ratios in a way that is closest to their spoken language. In other words, the experts did not have to decide on crisp values when defining the relations of the criteria, but they presented their dilemmas and uncertainty through several different statements. This approach proved to be very applicable in the process of collecting data from experts. The calculation of the weight coefficients of the criteria was performed by the FUCOM method.

Eight alternatives were defined for the selection of the best alternative. The defined selection criteria conditioned the use of some of the areas treating uncertainty well when making decisions. In this particular case, triangular fuzzy numbers, respectively, the fuzzified RAFSI method, were used to present the values of the alternatives by criteria. Using the FRAFSI method, alternative A_3 was selected as the best one, which has the dozer - Dressta TD-15M and the loader - Caterpillar 966M in its variable composition.

The stability of the obtained results was tested through a sensitivity analysis. The sensitivity analysis was performed by changing the weight coefficients of the criteria through 20 different scenarios. The results obtained by the sensitivity analysis show that the model reacts to changes in weight coefficients, respectively, that there are changes in the rank of alternatives. These changes are gradual and small. Through the analysis of rank correlation, applying the Spearman's coefficient, it was determined that almost all the values tended towards ideal rank correlation. In addition to the stability of the results, the sensitivity analysis indicated that any minor errors in defining the weight coefficients of the criteria did not significantly affect the output results.

In future research, the presented model and similar models based on D-numbers could be applied to solving other, similar problems, which are followed by uncertainty. This is important if we consider that the application of the model with D - numbers is not widely used, given that this is a relatively new area dealing with uncertainty. Unlike D-numbers, the fuzzy numbers which are also used in this paper occupy a significant place in this area. Therefore, the application of D-numbers with other methods, as presented in this paper, but also in other possible ways, is crucial for comparing the results with other areas that basically describe uncertainty well, such as fuzzy numbers, rough numbers, neutrosophic numbers, etc.

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