FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 22, Nº 1, 2024, pp. 101 - 123
https://doi.org/10.22190/FUME230614026B

Original scientific paper

APPLICATION OF THE DIBR II – ROUGH MABAC DECISION-MAKING MODEL FOR RANKING METHODS AND TECHNIQUES OF LEAN ORGANIZATION SYSTEMS MANAGEMENT IN THE PROCESS OF TECHNICAL MAINTENANCE

Darko Božanić[1], Igor Epler[1], Adis Puška[2], Sanjib Biswas[3], Dragan Marinković[4,5], Stefan Koprivica[5]

[1]Military Academy, University of Defence in Belgrade, Belgrade, Serbia
[2]Department of Public Safety, Government of Brčko District of Bosnia and Herzegovina, Brčko, Bosnia and Herzegovina
[3]Decision Science & Operations Management Area, Calcutta Business School, Diamond Harbour Road, West Bengal, India
[4]Faculty of Mechanical Engineering, University of Niš, Niš, Serbia
[5]TU Berlin, Department of Structural Analysis, Berlin, Germany
[6]Faculty of Construction Management, Union - Nikola Tesla University, Belgrade, Serbia

Abstract. *This paper presents a multi-criteria decision-making model based on the application of two methods, DIBR II and MABAC. The DIBR II method was used to define weight coefficients. The MABAC method was used to rank alternatives, and it was applied in a rough environment. Four experts were engaged in defining the criteria and alternatives as well as in the relation of criteria. The model was applied for ranking the methods and techniques of Lean organization systems management in the maintenance of technical systems of special purposes. At the end of the application was conducted a sensitivity analysis which proved the stability of the obtained results.*

Key words: *Defining Interrelationships Between Ranked criteria II (DIBR II), Multi-Attributive Border Approximation area Comparison (MABAC), Rough number, Lean concept*

Received: June 14, 2023 / Accepted August 11, 2023
Corresponding author: Darko Božanić
Military Academy, University of Defence in Belgrade, Veljka Lukica Kurjaka 33, 11040, Belgrade, Serbia
E-mail: darko.bozanic@va.mod.gov.rs

1. INTRODUCTION

By analyzing basic technological process of technical maintenance (TM) of special purpose technical systems (SPTS) in a real maintenance workshop in the Army of Serbia, and its documentation which often lacks the data related to the organization of the process itself, time gaps were observed between the planned (normed) times of TM cycle of SPTS and the realized times of the SPTS technical maintenance cycle [1]. The periods of time in which SPTS wait for operation (considering administration and logistics) are generally not recorded in the workshop documentation, which makes it difficult to discuss about with the purpose of their reduction or total elimination.

Many SPTS TM processes are not controlled, causing constant losses in the execution of TM on SPTS. Existing technological TM documentation for the most of the SPTS is "poor" regarding maintenance process management. For that reason, preparing computer data for software information system is very difficult as it relies only on currently available information from the TM technological process.

Obviously, under such circumstances the management of SPTS TM processes must be fundamentally changed, primarily in terms of intensifying research and development of practical methods and techniques based on new concepts of maintenance, which are applied and constantly improved by leading companies in the neighborhood and in the world [2]. However, this is easier said than done. There are many difficulties in the management of TM of SPTS, and the most frequent and influential are as follows: poor quality and reliability of input data primarily contained in technological documentation; complexity of the maintenance system (CoM) of SPTS; many years of lack of investment in the management of TM, lack of exchange of work technologies, knowledge and innovations and inadequate training of top management for TM of SPTS to make them able to recognize and decide what is necessary and important to change in the maintenance management of SPTS so as to minimize losses.

By eliminating negative effects of the mentioned factors, based on Lean organization systems management, current state of the work process and organization of TM of SPTS would probably change qualitatively. Qualitative changes would be reflected in [3]:

- shortening of SPTS TM cycle,
- optimal use of available capacities (spatial, human, material),
- reduction of costs per every maintained SPTS (increasing efficiency) and
- increased effectiveness of the TM process of SPTS.

However, the application of all methods and techniques of Lean organization systems management requires significant investments. Considering this, a model for evaluation and ranking of the methods and techniques of Lean concept was developed. Depending on available resources, these methods and techniques (alternatives) would be applied in practice, primarily the first-ranked ones, and when available resources allow, the other alternatives.

Previous research in the field of organization systems management [4,5] have proven positive effects of applying the Lean concept [6,7] in terms of the reduction of resources, both human and material, respectively increasing effectiveness and efficiency. There are indications that the application of the methods and tools of Lean organization systems management [8,9] can contribute to the improvement of current situation considering CoM of SPTS. The problem of applying Lean organization systems management has been discussed in several studies. In the following text, a part of the published research is analyzed.

Tamanna and Rahman [10], based on the data of periods of operations until failure, criticality and consequences of failure of key equipment for maintenance of SIMGA1 shipyard, wanted to analyze and select the optimal ship maintenance strategy with the goal of increasing the reliability and availability of the maintenance equipment and tools, reducing operating and production costs and increasing the shipyard's competitiveness. They observed the opportunity for improvement of shipyard maintenance in the application of Lean management tools. By using the AHP method, it was made a selection of the most effective Lean tools out of ten available.

Singha Mahapatra and Shenoy [11] indicate the constant need of organizations for maintenance and services providing the elimination of activities and processes that do not contribute to the creation of new value for the customer or user, respectively, to the reduction of the price of the product or service. The authors state that the most managers of maintenance systems practically apply the tools of Lean management in different ways, because these proved satisfactory improvements in a relatively short period of use. Through their study, the authors strive to improve the methodology of selecting and applying Lean tools by identifying unique factors consisting the basis for evaluation of the existing rationality of maintenance in any maintenance organization, and which are the basis for measuring improvements after the application of Lean tools in a specific organization.

Bhebhe and Zincume [12] analyzing systematically broad literature and applying general scientific method of deduction concluded that correctly dimensioned, constructed, properly exploited transport network with qualified managers was the key of economic power of every state. Based on the same data sources, they claimed that the most countries improved their economies by investing in transportation sector by identifying unnecessary costs generators, respectively, the losses within the maintenance function in transport companies. Observed cost generators were eliminated or reduced by systematic selection and application of Lean management tools that had already given the best results in the similar systems around the world. The paper provides guidelines for the improvement of overall condition by reducing unnecessary costs within transportation systems maintenance department, but also points out the opportunities for adjustment of application methods and its dynamics taking into account the specificities of as many transport companies as possible.

Korchagin et al. [13] state that nowadays aircraft manufacturers around the world encounter the need and possibility for improvement of position and competitiveness of the aircraft manufacturing industry after the sale of the aircrafts. They quote that for hitting this goal the crucial thing is the improvement of the aircraft maintenance organization within all the phases of its lifespan by using the concepts such as Lean and Industry 4.0. In this paper was performed the integration of Lean management and Industry 4.0 approaches, for the purpose of aircrafts maintenance, their modeling and simulation of their joint impact on the improvement of aircraft maintenance in the AniLogic simulation system. The results of the simulation showed that the simultaneous use of Lean management tools and Industry 4.0 from the beginning of the aircraft exploiting life in aviation industry would provide good results which would reflect in the aircraft maintenance efficiency increase, through the identification of bottlenecks in the process and making the right decisions in the direction of constant management of the maintenance process quality.

Dragone et al. [14] in their paper emphasize that during the lifetime of the residential and commercial buildings are not carried out all the necessary maintenance activities often, which can cause serious damage and accidents. They consider that the maintenance of facilities is essential for the effectiveness of their utility value, as well as for the safety of the facilities. Traditional concepts of building maintenance management became ineffective over time, and do not provide good results because these are not oriented towards the processes and increasingly complex users' demands and of the objects of work themselves – buildings. The authors deem that Lean maintenance management, with its principles and methods, can provide good solutions, applicable in the practice of facility maintenance.

One of the most important parts of any decision-making process is the selection of the methods to be used [15-18]. Of course, additional dilemmas in these processes arise when choosing a possible way to modify standard methods, and for the purpose of better treatment of uncertainty in the decision-making process [19-22]. Through the analysis of the available studies, and taking into account the nature of the problem, two methods of multi-criteria decision-making were used in this research. The first method is Defining Interrelationships between Ranked criteria II (DIBR II), which is used for obtaining weight coefficients of criteria. This method is shown through the process of group decision-making. The DIBR II method is presented only in the study by [23] and it has not been used so far for solving complex decision-making problems. However, the simplicity that this method provides in communication with experts, as well as the simple mathematical model, recommended this method for solving the mentioned problem. The second method used in ranking of alternatives is MABAC, which proved as a very reliable one in up to date conducted researches. Considering the values, which were assigned to the alternatives at the beginning of the decision-making process when these were evaluated according to the criteria, the MABAC method was applied in a rough environment.

Rough numbers were combined with decision-making methods in a large number of studies. Badi and Abdulshahed [24] used rough numbers to modify the AHP method, while in the study by [25] was presented the combination of rough numbers with DEMATEL method. Qi et al. [26] combine rough numbers with VIKOR method, Song et al. [27] with TOPSIS method, and Arsić et al. [28] with MAIRCA method. Rough numbers are commonly used in combination with fuzzy numbers, as in the studies by [29-31]. The MABAC method is modified in literature by using rough numbers in multiple studies as [32-36].

Through the analysis up so far, two main contributions of this paper stand out. The first one is the application of the DIBR method in multi-criteria group decision-making, and for the first time as a part of the process of solving a real problem. The second contribution of the paper is related to the solving of a case study, respectively, the problem of ranking the methods and techniques of Lean concept in order to improve the management of the work process and the organization of the TM of SPTS in the Army of Serbia.

The paper consists of several parts. In the second part the applied methods are described. Through the third part, that is, the case study, the definition and calculation of the weight coefficients of the criteria and the ranking of alternative solutions are carried out. The fourth part deals with sensitivity analysis, and at the end of the paper is provided the conclusion of this research.

2. DESCRIPTION OF THE APPLIED METHODS

This section describes the methods of DIBR II rough MABAC model. The phases and steps of the model are presented in the Fig. 1.

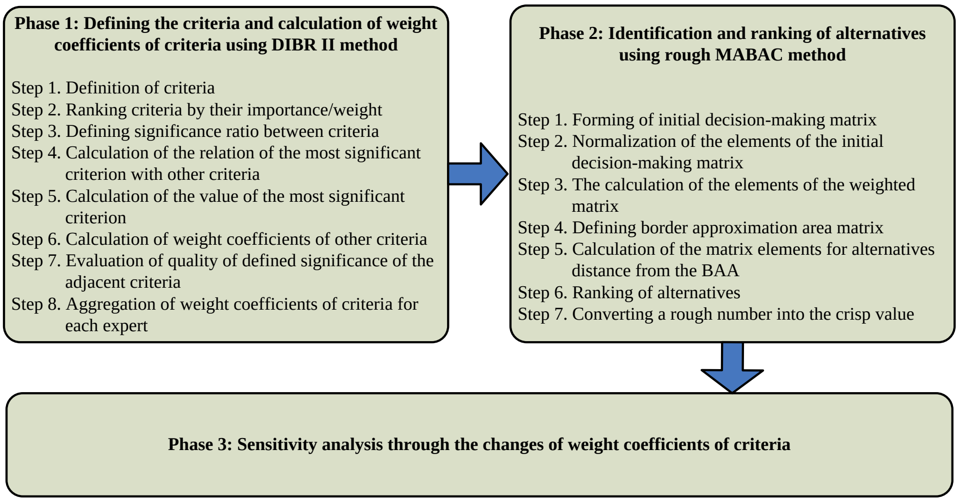

Fig. 1 DIBR II – rough MABAC model

As it can be observed from the Fig. 1, the model has three phases, where the criteria and their weight coefficients are defined first. Next, in the second phase of the model, the selection of the best alternative is made and at the end, it is checked the sensitivity of the model.

2.1. Defining Interrelationships Between Ranked Criteria II Method

The DIBR II method is developed by Božanić and Pamučar [23]. The method was developed for defining weight coefficients of criteria and consists of eight steps presented below.

Step 1. Definition of criteria. As a part of the first step, a set of criteria is defined $C=\{C_1, C_2,...C_n\}$, based on which the alternative solutions are ranked.

Step 2. Ranking criteria by their importance/weight. All the criteria in the set C are ranked from the most to the least significant. For simple presentation of the method, the set of criteria is defined so that the criterion C_1 is the most significant, while the criterion C_n is the least significant, respectively, it is defined as follows $C_1>C_2>C_3>...>C_n$.

Step 3. Defining significance ratio between criteria.

Step 3.1. Defining significance ratio between adjacent criteria. For each two adjacent criteria, their significance ratio is defined ($\eta_{j,j+1}$ where $\eta_{j,j+1} \in \{\eta_{1,2}, \eta_{2,3}, \eta_{3,4}, ..., \eta_{n-1,n}\}$). Thus, for example, for the comparison of the criteria C_1 and C_2 the significance ratio $\eta_{1,2}$ is defined. For this significance ratio it is valid that $\eta_{j,j+1} \geq 1$. The value $\eta_{j,j+1}$ shows how much more significant the criterion C_j is than the criterion C_{j+1}. According to everything stated, the following relations are defined through this step:

$$w_1 : w_2 = \eta_{1,2} : 1 \Rightarrow \frac{w_1}{w_2} = \eta_{1,2} \tag{1}$$

$$w_2 : w_3 = \eta_{2,3} : 1 \Rightarrow \frac{w_2}{w_3} = \eta_{2,3} \tag{2}$$

...

$$w_{n-1} : w_n = \eta_{n-1,n} : 1 \Rightarrow \frac{w_{n-1}}{w_n} = \eta_{n-1,n} \tag{3}$$

Step 3.2. Defining significance relations between the most and the least significant criteria. In this step, the following relation is defined:

$$w_1 : w_n = \eta_{1,n} : 1 \Rightarrow \frac{w_1}{w_n} = \eta_{1,n} \tag{4}$$

This relation has the role of the control factor in evaluating the quality of the defined significance of the adjacent criteria.

Step 4. Calculation of the relation of the most significant criterion with other criteria. Based on Eqs. (1-3), the value of the second and the other lower in range criteria is presented through the most significant criterion, as follows:

- Based on Eq. (1), the value of the weight coefficient w_2 is obtained:

$$w_2 = \frac{w_1}{\eta_{1,2}} \tag{5}$$

- Based on Eqs. (2) and (5), the value of the weight coefficient w_3 is obtained:

$$w_3 = \frac{w_2}{\eta_{2,3}} = \frac{w_1}{\eta_{1,2} \cdot \eta_{2,3}} \tag{6}$$

- Based on Eq. (3), the value of the weight coefficient w_n is obtained:

$$w_n = \frac{w_1}{\eta_{1,2} \cdot \eta_{2,3} \cdot \ldots \cdot \eta_{n-1,n}} \tag{7}$$

Step 5. Calculation of the value of the most significant criterion. If it is as follows:

$$\sum_{j=1}^{n} w_j = 1 \tag{8}$$

upon applying Eqs. (5-8), the result yields:

$$w_1 + \frac{w_1}{\eta_{1,2}} + \frac{w_1}{\eta_{1,2} \cdot \eta_{2,3}} + \ldots + \frac{w_1}{\eta_{1,2} \cdot \eta_{2,3} \cdot \ldots \cdot \eta_{n-1,n}} = 1 \tag{9}$$

From Eq. (9), the value of the weight coefficient of the most significant criterion is obtained as:

$$w_1 = \frac{1}{1 + \frac{1}{\eta_{1,2}} + \frac{1}{\eta_{1,2} \cdot \eta_{2,3}} + ... + \frac{1}{\eta_{1,2} \cdot \eta_{2,3} \cdot ... \cdot \eta_{n-1,n}}} \quad (10)$$

Step 6. Calculation of weight coefficients of other criteria. Applying Eqs. (5-7), the remaining weight coefficients of criteria, w_2, w_3,…,w_n, are obtained.

Step 7. Evaluation of quality of defined significance of the adjacent criteria. The relations of significance of the adjacent criteria need to be checked, to avoid as much as possible subjectivity of the decision makers.

Step 7.1. Evaluation of quality of defined significance values. The evaluation of quality of defined significance values is made based on the relation of the significance of the most and the least significant criterion ($\eta_{1,n}$). The value of the least significant criterion can be obtained from Eq. (4):

$$w_n^k = \frac{w_1}{\eta_{1,n}} \quad (11)$$

where w_n^k presents the control weight coefficient of the criterion C_n.

The values w_n and w_n^k should be approximately equal. If their deviation amounts to 10% approximately, it can be concluded that the relations of significance of the adjacent criteria are defined with quality, and vice versa. Checking of the deviation is done by applying the expression:

$$d_n = \left| 1 - \frac{w_n}{w_n^k} \right| \quad (12)$$

where d_n presents the value of the deviation of the weight coefficients of the criterion C_n.

If the condition $0 \le d_n \le 0.1$ is met, then the evaluations of the significance relations of the adjacent criteria are defined with quality, i.e. these meet the requirements. If $d_n > 0.1$, it is necessary to define new relations between the criteria. However, since the research is usually an extensive process engaging significant resources, an additional step can be applied in order to find an error. In such cases, Step 7.2 is applied.

Step 7.2. Additional evaluation of quality of the defined significance of the adjacent criteria. Before returning to defining relations of significance of the adjacent criteria, it is possible to make additional quality control. For this purpose, the step from Step 7.1 is repeated, in which the relations between the criteria C_{n-1} and C_{n-2} are defined.

For this procedure, it is necessary for the decision-maker to define new relations:

$$w_1 : w_{n-1} = \eta_{1,n-1} : 1 \Rightarrow \frac{w_1}{w_{n-1}} = \eta_{1,n-1} \quad (13)$$

$$w_1 : w_{n-2} = \eta_{1,n-2} : 1 \Rightarrow \frac{w_1}{w_{n-2}} = \eta_{1,n-2} \quad (14)$$

Then, it is calculated:

$$w_{n-1}^{k} = \frac{w_1}{\eta_{1,n-1}} \tag{15}$$

$$w_{n-2}^{k} = \frac{w_1}{\eta_{1,n-2}} \tag{16}$$

where w_{n-1}^{k} and w_{n-2}^{k} are the control weight coefficients of the criterion $C_{n\text{-}1}$ respectively, $C_{n\text{-}2}$.

Finally, the value is obtained:

$$d_{n-1} = \left|1 - \frac{w_{n-1}}{w_{n-1}^{k}}\right| \tag{17}$$

$$d_{n-2} = \left|1 - \frac{w_{n-2}}{w_{n-2}^{k}}\right| \tag{18}$$

Here, $d_{n\text{-}1}$ and $d_{n\text{-}2}$ are the values of deviation of the weight coefficients of the criteria $C_{n\text{-}1}$ and $C_{n\text{-}2}$, respectively.

If the conditions $d_{n-1} \in [0,0.1]$ and $d_{n-2} \in [0,0.1]$ are met, it can be concluded that there was an error in defining the relations of significance between the most and the least significant criterion ($\eta_{1,n}$). In that case, the existing results can be accepted or the values can be defined again ($\eta_{1,n}$) and quality checked again as well. Briefly said, if $d_{n-1} \notin [0,0.1]$ or $d_{n-2} \notin [0,0.1]$, the complete procedure of defining the relations of significance and calculation of the weight coefficients must be repeated.

Step 8. Aggregation of weight coefficients of criteria for each expert. The previous seven steps refer to the definition of weight coefficients when decisions are made by a single decision maker, i.e. an expert. In situations where the decision is made by several people, it is necessary to aggregate their opinions. For the purposes of this model, the weigh coefficients of the criteria were aggregated, which were obtained for each expert separately, using the Bonferroni aggregator:

$$w_i^a = \left(\frac{1}{l(l-1)} \sum_{\substack{e,u=1 \\ e \neq u}}^{l} (w_i^e)^p (w_i^u)^q \right) \tag{19}$$

where l is the number of experts, w_i^a are the aggregated values obtained by applying the Bonferroni aggregator, $p,q \geq 0$ are the stabilization parameters of Bonferroni aggregator, e and u are the e-th or u-th expert, where $1 \leq e, u \leq l$.

2.2. Rough MABAC method

The MABAC (Multi-Attributive Border Approximation area Comparison) method belongs to the group of newer and frequently applied methods. This method was developed by Pamučar i Ćirović [37]. In this paper, the method is improved by applying rough numbers. In the next part of the paper, the basic assumptions about rough numbers and the presentation of the steps of the MABAC method in rough environment are given.

In the 1990s, Pawlak [38,39], developed rough sets. Some twenty years later, inspired by the idea of rough sets, Zhai et al. [40], developed rough numbers. Rough numbers prove to be very useful in considering uncertainty. A brief description of rough numbers is given below.

Definition 1 [40]. Let's assume that there is a set F consisting of (K_1, K_2, K_3, ..., K_t), which represents all the objects in a particular universe U. At the same time, there is Y presenting boundary objects of the universe U. If all the elements form part of the sequence $K_1<K_2<K_3<...<K_t$, where it is valid that $\forall Y \in U,\ K_q \in F,\ 1 \le q \le t$, then the following parameters can be defined:

$$\underline{Apr}(K_q) = \bigcup \left\{ Y \in U \,/\, F(Y) \le K_q \right\} \tag{20}$$

$$\overline{Apr}(K_q) = \bigcup \left\{ Y \in U \,/\, F(Y) \ge K_q \right\} \tag{21}$$

$$\begin{aligned} Bnd(K_q) = \bigcup \left\{ Y \in U \,/\, F(Y) \ne K_q \right\} = \\ \left\{ Y \in U \,/\, F(Y) > K_q \right\} \bigcup \left\{ Y \in U \,/\, F(Y) < K_q \right\} \end{aligned} \tag{22}$$

where $\underline{Apr}(K_q)$ is the lower approximation, and $\overline{Apr}(K_q)$ is the upper approximation, while $Bnd(K_q)$ is boundary interval of the element K_q.

Definition 2 [40]. The element G_q can be presented as a rough number ($RN(K_q)$). The rough number $RN(K_q)$ is defined by its lower limit ($\underline{Lim}(K_q)$) and the upper limit ($\overline{Lim}(K_q)$), where

$$\underline{Lim}(K_q) = \frac{1}{N_L} \sum F(\mathrm{Y}) \left| Y \in \underline{Apr}(K_\mathrm{q}) \right. \tag{23}$$

$$\overline{Lim}(K_q) = \frac{1}{N_U} \sum F(\mathrm{Y}) \left| Y \in \overline{Apr}(K_\mathrm{q}) \right. \tag{24}$$

$$RN(K_q) = \left[\underline{Lim}(K_q), \overline{Lim}(K_q) \right] \tag{25}$$

Here, N_L and N_U are the number of objects contained in $\underline{Apr}(K_q)$ and $\overline{Apr}(K_q)$, respectively. Upper and lower limits indicate average value of the elements included into the upper and lower approximation, respectively. The difference between them represents the rough boundary interval ($RBnd(K_q)$):

$$RBnd(K_q) = \overline{Lim}(K_q) - \underline{Lim}(K_\mathrm{q}) \tag{26}$$

Rough boundary interval represents uncertainty of the element K_q, where a higher number indicates higher imprecision, while a lower number indicates better precision, based on what subjective information only now can be marked with a rough number.

By using the rough numbers shown, the classic MABAC method is modified. The steps of the rough MABAC method are given in the following [32-36].

Step 1. Forming of initial decision-making matrix (*X*). In the first step, the values of *m* alternatives are being defined by *n* criteria.

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ A_3 \\ \cdots \\ A_m \end{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \\ \left(\begin{matrix} RN(x_{11}) & RN(x_{12}) & \cdots & RN(x_{1n}) \\ RN(x_{21}) & RN(x_{22}) & \cdots & RN(x_{2n}) \\ RN(x_{31}) & RN(x_{32}) & \cdots & RN(x_{3n}) \\ \cdots & \cdots & \cdots & \cdots \\ RN(x_{m1}) & RN(x_{m2}) & \cdots & RN(x_{mn}) \end{matrix}\right) \end{matrix} \tag{27}$$

Step 2. Normalization of the elements of the initial decision-making matrix. In this step, the elements of the initial decision-making matrix (*X*) are normalized, in order to obtain the normalized matrix (*N*), by using the following expressions:

$$\underline{t_{ij}} = \frac{\underline{x_{ij}} - x_j^-}{x_j^+ - x_j^-}, \quad \overline{t_{ij}} = \frac{\overline{x_{ij}} - x_j^-}{x_j^+ - x_j^-} \tag{28}$$

$$\underline{t_{ij}} = \frac{\underline{x_{ij}} - x_j^+}{x_j^- - x_j^+}, \quad \overline{t_{ij}} = \frac{\overline{x_{ij}} - x_j^-}{x_j^- - x_j^+} \tag{29}$$

By using Eq. (28) the normalization of the benefit type criteria is done, while using Eq. (29) the normalization of the cost type criteria is made, where:

$$x_j^+ = \begin{cases} \max\limits_{1\le i\le m}(\overline{x_{ij}}), \ \textit{for benefit type criteria}, \min\limits_{1\le i\le m}(\underline{x_{ij}}), \ \text{for cost type criteria} \end{cases} \tag{30}$$

$$x_j^- = \begin{cases} \min\limits_{1\le i\le m}(\underline{x_{ij}}), \ \textit{for benefit type criteria}, \max\limits_{1\le i\le m}(\overline{x_{ij}}), \ \text{for cost type criteria} \end{cases} \tag{31}$$

Step 3. The calculation of the elements of the weighted matrix (*V*) is performed by using the following equation:

$$\underline{v_{ij}} = w_i^a x(\underline{t_{ij}} + 1), \ \overline{v_{ij}} = w_i^a x(\overline{t_{ij}} + 1) \tag{32}$$

Step 4. Defining border approximation area matrix (BAA). The BAA matrix (*G*) has a form n x 1, that is, the BAA s formed for each criterion separately, using the following equations:

$$\underline{g_j} = \left(\prod_{i=1}^{m} \underline{v_{ij}}\right)^{1/m}, \ \overline{g_j} = \left(\prod_{i=1}^{m} \overline{v_{ij}}\right)^{1/m} \tag{33}$$

Step 5. Calculation of the matrix elements for alternatives distance from the BAA (Q)

$$Q = \left([\underline{q_{ij}}, \overline{q_{ij}}]\right)_{m\,x\,n} \tag{34}$$

where:

$$q_{ij} = \begin{Bmatrix} d_E(v_{ij}, g_j), \ if \ RN(v_{ij}) > RN(g_j) \\ -d_E(v_{ij}, g_j), \ if \ RN(v_{ij}) < RN(g_j) \end{Bmatrix}, \ for \ benefit \ type \ criteria \tag{35}$$

$$q_{ij} = \begin{Bmatrix} -d_E(v_{ij}, g_j), \ if \ RN(v_{ij}) > RN(g_j) \\ d_E(v_{ij}, g_j), \ if \ RN(v_{ij}) < RN(g_j) \end{Bmatrix}, \ for \ cost \ type \ criteria \tag{36}$$

$$d_E(v_{ij}, g_j) = \begin{Bmatrix} \sqrt{(\underline{v_{ij}} - \overline{g_j})^2 + (\overline{v_{ij}} - \underline{g_j})^2}, \ for \ benefit \ type \ criteria \\ \sqrt{(\underline{v_{ij}} - \underline{g_j})^2 + (\overline{v_{ij}} - \overline{g_j})^2}, \ \text{for cost type criteria} \end{Bmatrix} \tag{37}$$

Belonging of the alternative A_i to certain approximation area (G, G+ ili G-) is determined as follows:

$$A_i = \begin{Bmatrix} G^+ \ if \ q_{ij} > 0 \\ G \ \ if \ q_{ij} = 0 \\ G^- \ if \ q_{ij} < 0 \end{Bmatrix} \tag{38}$$

Step 6. Ranking of alternatives. Final values of criteria functions are calculated by summing the elements of the matrix Q by rows:

$$\underline{s_i} = \sum_{j=1}^{n} \underline{q_{ij}}, \ \overline{s_i} = \sum_{j=1}^{n} \overline{g_{ij}}, \ j = 1, 2, ..., n, \ i = 1, 2, ..., m. \tag{39}$$

Step 7. To convert a rough number $RN(K_i) = \left[\underline{Lim}(K_i), \overline{Lim}(K_i) \right]$ into the crisp value, the following equation is used [35]:

$$K_i^{crisp} = \min_i \left\{ \underline{Lim}(K_i) \right\} + K_i^N x \left[\max_i \left\{ \overline{Lim}(K_i) \right\} - \min_i \left\{ \underline{Lim}(K_i) \right\} \right] \tag{40}$$

For the needs of calculation of individual equation elements (40), the following is used [35]:

$$RN(K_i) = \left[\underline{Lim}(K_i), \overline{Lim}(K_i) \right] = \begin{Bmatrix} \underline{Lim}(K_i) = \dfrac{\underline{Lim}(K_i) - \min_i \left\{ \underline{Lim}(K_i) \right\}}{\max_i \left\{ \overline{Lim}(K_i) \right\} - \min_i \left\{ \underline{Lim}(K_i) \right\}} \\ \overline{Lim}(K_i) = \dfrac{\overline{Lim}(K_i) - \min_i \left\{ \underline{Lim}(K_i) \right\}}{\max_i \left\{ \overline{Lim}(K_i) \right\} - \min_i \left\{ \underline{Lim}(K_i) \right\}} \end{Bmatrix} \tag{41}$$

$$K_i^N = \frac{\underline{Lim}(K_i)\, x \left\{1 - \underline{Lim}(K_i)\right\} + \overline{Lim}(K_i)\, x\, \overline{Lim}(K_i)}{1 - \underline{Lim}(K_i) + \overline{Lim}(K_i)} \tag{42}$$

3. Case Study

The decision supporting model, as shown above, is applied to the evaluation of the methods and tools of Lean concept of management. In the following two sections is given the description of the criteria and the calculation of the weight coefficients of the criteria, followed by a description of the alternatives and their ranking.

3.1. Calculation of weight coefficients of criteria

In the following, the weight coefficients of the criteria were obtained by applying the DIBR II method, considering that the DIBR II method is used for the first time in solving a real problem through group decision-making, a detailed description of all calculations is given below.

Step 1. By analyzing available literature and with the help of four experts who deal with maintenance problems, five key criteria were reached according to which it is possible to evaluate the methods and tools of the Lean CoM management. These criteria are given in the following text.

Reduction of a SPTS maintenance cycle time (C_1), enables overview of basic factors in failures occurrence, distribution and duration of maintenance preparation and execution, and represents a basis for maintenance procedures establishment and analysis of overall efficiency and effectiveness of SPTS TM.

Time preview of SPTS condition consist of their alternating states of operations and failures, which represent time intervals expressed in kilometers, motor hours or hours of SPTS work. Research in SPTS maintenance area is reduced to the analysis of causes of stated conditions. The analysis of those causes enables determination of basic parameter values, essential for designing the procedures and CoM of SPTS as a whole.

Failure time consists of a number of time segments. The goal of all improvement procedures is to reduce time of waiting for the operation, by which maintenance cycle time is optimized.

Optimization level of equipment and working positions arrangement (LAYOUT) within the maintenance system structure of technical systems for special purposes (C_2). Proper and purposeful spatial arrangement of equipment and tools is very important for those who want to apply Lean management in organization systems, especially in production or SPTS maintenance. Layout helps the management in defining equipment, tools and work positions arrangement, in order to minimize circulation of SPTS, tools and equipment, at the expense of higher circulation of spare parts and consumables, resulting in greater system operational readiness, due to shorter logistical and administrative waiting times, and lower transportation costs The assumption is that operators working in such a conceived organization system are qualified and trained to quickly and precisely perform all activities of the basic process of the system [8].

SPTS effectiveness increase percentage, E(t) (C_3) can be mathematically defined as probability that maintenance tasks will be performed in a certain period of time, with the prescribed functioning regime and with the implementation of prescribed maintenance activities - preventive/corrective maintenance programs, and it is expressed as the product of reliability P(t), functional suitability (suitability for functional use) FP(t) and availability (readiness) for intended use R(t). Each of the effectiveness components can take a value in the interval from 0 to 1. Therefore, the effectiveness can have the same values. The components of effectiveness and overall effectiveness of SPTS, should be projected and adopted already in the development phase, but their values should also be monitored and analyzed throughout the lifetime. Improvement is achieved if the effectiveness expressed in percentage is increased after the application of the alternatives.

System efficiency increase level E_{fik} (C_4) can be defined as the ratio between the output and input, i.e. as the ratio between the products and resources (benefits and investments, needs and possibilities, planned and realized). It is also a number between 0 and 1.

The mathematical interpretation of efficiency, in general, is as follows:

$$E_{fik} = \frac{O(output)}{I(input)} \tag{43}$$

An improvement is achieved if the reached value is lower after the application of the alternatives, compared to the moment before the application of the alternatives, because the quantity being compared is the maintenance cycle time before and after the application of the alternatives.

Reduction in number of executors (C_5) is the goal of optimization of technological process, based on consideration of combining certain work positions, which are similar in terms of technological procedures, additional education and training of executors to perform more related operations by better planning, scheduling SPTS maintenance operations and eliminating unnecessary idling losses in TM of SPTS.

Step 2. After defining the criteria, the experts performed criteria ranking by their significance. The criteria ranking by four experts E_e, where $e \in (1,2,3,4)$, is shown as follows:

$$E_1 : C_1 > C_2 > C_3 > C_4 > C_5$$
$$E_2 : C_1 > C_3 > C_2 > C_4 > C_5$$
$$E_3 : C_1 > C_2 = C_3 > C_4 > C_5$$
$$E_4 : C_1 > C_2 > C_3 > C_5 > C_4$$

Step 3. Table 1 shows the assessment of the significance ratio performed by the experts.

Table 1 Criteria significance ratios defined by experts

Expert 1	Expert 2	Expert 3	Expert 4
C_1:C_2=2.0	C_1:C_3=2.5	C_1:C_2=1.8	C_1:C_2=1.7
C_2:C_3=1.1	C_3:C_2=1.2	C_2:C_3=1.0	C_2:C_3=1.3
C_3:C_4=1.6	C_2:C_4=1.6	C_3:C_4=1.5	C_3:C_5=1.5
C_4:C_5=1.3	C_4:C_5=1.4	C_4:C_5=1.1	C_5:C_4=1.1
C_1:C_5=5.0	C_1:C_5=7.0	C_1:C_5=3.0	C_1:C_4=3.5

Step 4. In this step, by using Eqs. (5-7), the relation of the most significant criterion to the other criteria is calculated. If the weight coefficient is marked with w_i^e, where *e* are the experts, $e \in (1,2,3,4)$, and i is the criterion, $i \in (1,2,3,4,5)$, then the following relations are obtained:

E1: $w_2^1 = \frac{w_1^1}{2}$; $w_3^1 = \frac{w_1^1}{2 \cdot 1.1} = \frac{w_1^1}{2.2}$; $w_4^1 = \frac{w_1^1}{2 \cdot 1.1 \cdot 1.6} = \frac{w_1^1}{3.52}$; $w_5^1 = \frac{w_1^1}{2 \cdot 1.1 \cdot 1.6 \cdot 1.3} = \frac{w_1^1}{4.576}$

E2: $w_2^2 = \frac{w_1^2}{2.5 \cdot 1.2} = \frac{w_1^2}{3}$; $w_3^2 = \frac{w_1^2}{2.5}$; $w_4^2 = \frac{w_1^2}{2.5 \cdot 1.2 \cdot 1.6} = \frac{w_1^2}{4.8}$;
$w_5^2 = \frac{w_1^2}{2.5 \cdot 1.2 \cdot 1.6 \cdot 1.4} = \frac{w_1^2}{6,72}$

E3: $w_2^3 = \frac{w_1^3}{1.8}$; $w_3^3 = \frac{w_1^3}{1.8 \cdot 1} = \frac{w_1^3}{1.8}$; $w_4^3 = \frac{w_1^3}{1.8 \cdot 1 \cdot 1.5} = \frac{w_1^3}{2.7}$; $w_5^3 = \frac{w_1^3}{1.8 \cdot 1 \cdot 1.5 \cdot 1.1} = \frac{w_1^3}{2.97}$

E4: $w_2^4 = \frac{w_1^4}{1.7}$; $w_3^4 = \frac{w_1^4}{1.7 \cdot 1.3} = \frac{w_1^4}{2.21}$; $w_4^4 = \frac{w_1^4}{1.7 \cdot 1.3 \cdot 1.5 \cdot 1.1} = \frac{w_1^4}{3.647}$;
$w_5^4 = \frac{w_1^4}{1.7 \cdot 1.3 \cdot 1.5} = \frac{w_1^4}{3.315}$

Step 5. By using Eq. (10), the weight coefficient of the most significant criterion is calculated. The detailed calculation for each expert is provided as follows:

$$w_1^1 = \frac{1}{1 + \frac{1}{2} + \frac{1}{2.2} + \frac{1}{3.52} + \frac{1}{4.576}} = 0.407$$

$$w_1^2 = \frac{1}{1 + \frac{1}{3} + \frac{1}{2.5} + \frac{1}{4.8} + \frac{1}{6.72}} = 0.478$$

$$w_1^3 = \frac{1}{1 + \frac{1}{1.8} + \frac{1}{1.8} + \frac{1}{2.7} + \frac{1}{2.97}} = 0.355$$

$$w_1^4 = \frac{1}{1 + \frac{1}{1.7} + \frac{1}{2.21} + \frac{1}{3.647} + \frac{1}{3.315}} = 0.382$$

Step 6. Based on the ratios defined in the fourth step of this method, the weight coefficients of the other criteria were calculated:

E1: $w_2^1 = \frac{0.407}{2} = 0.203$; $w_3^1 = \frac{0.407}{2.2} = 0.185$; $w_4^1 = \frac{0.407}{3.52} = 0.116$; $w_5^1 = \frac{0.407}{4.576} = 0.089$

E$_2$: $w_2^2 = \frac{0.478}{3} = 0.16$; $w_3^2 = \frac{0.478}{2.5} = 0.191$; $w_4^2 = \frac{0.478}{4.8} = 0.1$; $w_5^2 = \frac{0.478}{6,72} = 0.071$

E$_3$: $w_2^3 = \frac{0.355}{1.8} = 0.197$; $w_3^3 = \frac{0.355}{1.8} = 0.197$; $w_4^3 = \frac{0.355}{2.7} = 0.131$; $w_5^3 = \frac{0.355}{2.97} = 0.12$

E$_4$: $w_2^4 = \frac{0.382}{1.7} = 0.225$; $w_3^4 = \frac{0.382}{2.21} = 0.173$; $w_4^4 = \frac{0.382}{3.647} = 0.105$; $w_5^4 = \frac{0.382}{3.315} = 0.115$

Step 7. The weight coefficient of the least significant criterion was recalculated by applying the last (control) relation from Table 1 and the deviation from the obtained values was checked. The calculation was made using Eqs. (11) and (12).

$$\text{E}_1\text{: } w_5^1 = \frac{0.407}{5} = 0.081 \Rightarrow d_5^1 = \left|1 - \frac{0.089}{0.081}\right| = 0.099 \Rightarrow d_5^1 \in [0, 0.1];$$

$$\text{E}_2\text{: } w_5^2 = \frac{0.478}{7} = 0.068 \Rightarrow d_5^2 = \left|1 - \frac{0.071}{0.068}\right| = 0.044 \Rightarrow d_5^2 \in [0, 0.1];$$

$$\text{E}_3\text{: } w_5^3 = \frac{0.355}{3} = 0.118 \Rightarrow d_5^3 = \left|1 - \frac{0.12}{0.118}\right| = 0.017 \Rightarrow d_5^3 \in [0, 0.1];$$

$$\text{E}_4\text{: } w_5^4 = \frac{0.382}{3.5} = 0.109 \Rightarrow d_5^4 = \left|1 - \frac{0.115}{0.109}\right| = 0.055 \Rightarrow d_5^4 \in [0, 0.1].$$

Considering the fact that the provided deviation is less than 10%, it can be concluded that the experts were consistent in their opinions.

Step 8. At the very end, the weight coefficients of the criteria were aggregated using standard Bonferroni aggregator and Eq. (19), with the value of the stabilization parameters *p, q=1*, which resulted in obtaining the final values of the weight coefficients of the criteria:

$$w_1^a = 0.405; w_2^a = 0.196; w_3^a = 0.187; w_4^a = 0.113; w_5^a = 0.099.$$

3.2. Ranking Alternative Solutions

The methods and tools of Lean organization systems management, which also include the systems for TM of SPTS, represent the alternatives or possible solutions by implementation of which the improvement of the existing SPTS CoM condition is expected, reflected through the change (decrease or increase) of defined parameters (values) previously presented as criteria in the paper. By the help of experts, five alternative solutions were defined:

Visual systems - VS (A_1) present Lean method which with the help of visual aids (notice boards, and on warning lights about status of a process, displays, lines on the floors and walls of spare parts and consumables in the working environment) provides all the needed information for employees [5], related to:

- basic system processes procedures;
- costs;
- required or achieved quality of the product/service;
- product/service delivery/completion times;

- current state of the process;
- condition of tools;
- number of employees;
- workplace markings (yellow, green, red lines on plant or storage floors, *etc*.);
- costs, attendance at work, injuries or safety at work and similar.

By using this tool of Lean organization systems management, such environment is created where everything is precisely defined, from entry to exit, and where visual information is timely and useful [8].

Arrangement of workplace and surrounding area - 5 S (A_2) is a set of rules for organizing a workplace for each employee. The name 5S was given by five English words starting with the letter "S". The set of 5 S rules (Sort, Stabilize, Sustain, Shine, Standardize) refers to good maintenance of the plants in the organization system, offices, workplaces, spare parts and consumables warehouses, and it is useful for the analysis of improvements in an organization system [8]. The goal is for every work position inside organizational system to be arranged in such manner so it is maximally efficient, without unnecessary movement, making faster and easier work for each employee, by organizing all tools at their designed place, clearly visible, clean and ready for use in every moment. One of the most important 5 S method rule is that workers themselves take care of their workplace and thus contribute to the overall effectiveness of the process. Five S is the most recognizable method of the Lean concept [4] of managing organization systems because it is the easiest one to be applied and the results are immediately visible. By implementing the rules of the 5 S method, employees become encouraged in the easiest way to continue with the "lean" transformation. Five S represents a method by which an excessive use of materials, energy, effort, *etc*. is reduced, while, on the other side, the quality and productivity of the system are raised to the optimal level.

Computer maintenance management system – CMMS (A_3) is reflected in the development, implementation and use of a software informational system that minimally does the following functions: management of work orders, maintenance planning, scheduling of maintenance activities, collection of data on maintenance history, management of approved funds in relation to costs, human resources management, management of spare parts and consumables for maintenance purposes, reporting on maintenance and consumption of spare parts and consumables, as well as on the level of their stock [8]. To achieve its purpose, a CMMS must be applied with complete and accurate data about SPTS, spare parts and consumables, plans, norms for maintenance activities and descriptions of maintenance activities, that is, all SPTS maintenance procedures.

Work ticket system – KANBAN (A_4) represents a system for making order in executions of process operations, control and management of spare parts stocks.

The most common types of Kanban are [3]:

- pull Kanban - circulates between spatially organized production structures and define the sequence of process activities between them;
- production Kanban - circulates between workplaces within spatially organized production structures and define the quantities that must be produced in a given process, following the order of operations;
- supplier Kanban - circulates between the producer and the supplier, and the delivery time to the producer, respectively, the consumer (customer), is pre-defined by instructions and procedures in the organization system. For example, commodity is transported once a day to the customer - every day at eight o'clock. The driver who

hands over the commodity, that is, the realized Kanban for a certain delivery, takes over, at the same place, the Kanban for the next delivery. The quantity of goods, defined by the next Kanban, must be delivered to the customer the next day, at the same time.

Kanbans can, with certain modifications, be used as warehouse record cards and identification cards in spare parts and consumables storages [3].

Continuous improvement – KAIZEN (A_5) is the way towards continuous process improvements in order to eliminate losses.

The word Kaizen originates from the Japanese language and it is composed of two Japanese words: *kai* - to separate and *zen* - to fix. The purpose of this Lean tool is recognition, separation, analysis and solution of problems, and then implementation and confirmation of that solution in practice. Kaizen bases its methods on the teachings of Edwards Deming and his PDCA (Plan-Do-Check-Act) quality circle. Small but constant improvements of the maintenance process are the goal of Kaizen tool implementation.

Kaizen method involves all levels of employees, who are engaged in improvement process. Participants in Kaizen events are [8]: workers, heads of departments, mid-level managers, but also top managers. All of them, together in teamwork, should contribute to achieving gradual step by step improvements every day in every place.

The Kaizen approach encourages small daily continuous improvements and process that never ends, involving everyone's progression, from workers to managers, using common sense as a basic principle for survival. Reasonable judgement and rational decision-making are essential for Kaizen approach.

Balanced workforce engagement - NAGARA SYSTEM (A_6) emphasizes human factor as very important in all organization systems, because there is no process without it, so it is essential to pay attention to effective and efficient use of human labor power. The Lean organization systems management resolves the effective and efficient use of human potential by applying the Nagara system tool [5], which requires "interdisciplinarity" from each individual (broader view of the work performed in the system, better understanding of work operations for which worker is not directly responsible), respectively, the ability to perform multiple tasks and serve multiple workplaces to a certain extent as needed, which contributes to increasing overall, not just work efficiency. Such practice reduces manpower to optimal without endangering working technology, work distribution is easier, and process flow more economical. The management of the organization system should take care of the timely personnel trainings for various related jobs in the organization systems in order to achieve their interdisciplinary skills.

After defining the alternatives, the rough MABAC method is applied.

Firstly, it is defined the initial decision-making matrix, as shown in the Table 2.

Table 2 Initial decision-making matrix

	C_1	C_2	C_3	C_4	C_5
A_1	[6.2,6.5]	S-M	[13,15]	H-VH	[1,2]
A_2	[4.5,5]	H-EH	[10,12]	S-M	[3,4]
A_3	[6.8,7.2]	ES-M	[17,19]	H-EH	[2,3]
A_4	[7.3,7.5]	H-VH	[18,22]	ES-M	[1,2]
A_5	[3,3.7]	M-H	[12,16]	M-H	[2,3]
A_6	[3.2,4]	VH-EH	[15,20]	VH-EH	[4,5]

As a part of the first step, the quantification of qualitative criteria was performed. It was done by using the scale shown in Table 3, consisting of seven linguistic descriptors.

Table 3 Linguistic scale for quantifying of qualitative criteria

Descriptor name	Abbreviation	Numeric value
Extremely small	ES	1
Very small	VS	2
Small	S	3
Medium	M	4
High	H	5
Very high	VH	6
Extremely high	EH	7

By using the scale from Table 3, the initial decision-making matrix was quantified, as presented in Table 4.

Table 4 Quantified initial decision-making matrix

	C_1	C_2	C_3	C_4	C_5
A_1	[6.2,6.5]	[3,4]	[13,15]	[5,6]	[1,2]
A_2	[4.5,5]	[5,7]	[10,12]	[3,4]	[3,4]
A_3	[6.8,7.2]	[1,4]	[17,19]	[5,7]	[2,3]
A_4	[7.3,7.5]	[5,6]	[18,22]	[1,4]	[1,2]
A_5	[3,3.7]	[4,5]	[12,16]	[4,5]	[2,3]
A_6	[3.2,4]	[6,7]	[15,20]	[6,7]	[4,5]

By applying steps 2-7, the ranking of the alternatives is obtained. The final ranking of the alternatives is provided in Table 5.

Table 5 Rank of alternatives

	$RN(K_i)$	K_i^{crisp}	Rank
A_1	[0.15,0.478]	0.106	3
A_2	[0.028,0.406]	0.000	5
A_3	[0.226,0.647]	0.228	2
A_4	[0.317,0.705]	0.307	1
A_5	[-0.115,0.281]	-0.143	6
A_6	[0.103,0.522]	0.096	4

From Table 4, it is clearly visible that the alternative A_4 is the first-ranked- the best, while the alternative A_5 is the worst one.

4. Sensitivity Analysis

Sensitivity analysis is an indispensable part of the entire decision-making process [41,42]. This segment of the decision-making model is mostly implemented through the changes of weight coefficients of criteria and can be found in a large number of recent researches such as [43-45]. The main purpose of sensitivity analysis is to determine how much the most influential criteria affect the final output - whether there are any and what the changes in ranking of alternatives are. In this particular case, the most influential is the criterion C_1, which is two times more influential than the second-ranked C_2. Considering significant difference between these two criteria, only changes to the criterion C_1 were considered. For this purpose, 20 strategies with different weight coefficients of criteria were developed. The scenarios were created so that the value of the most significant criterion in each scenario was reduced by 5%, and the value that was reduced from the criterion C_1 was evenly distributed among the other criteria. The values of the weight coefficients of the criteria according to the scenarios are given in Fig. 2.

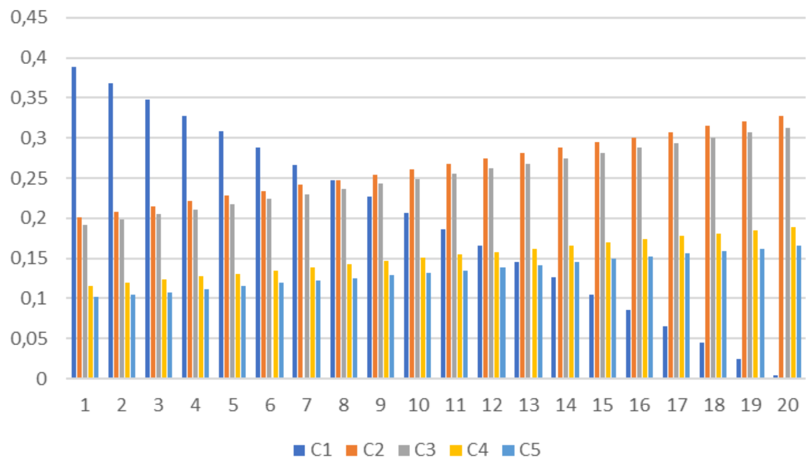

Fig. 2 Review of criteria weight coefficients changes

According to the reviewed weight coefficients, the rough MABAC method was applied again and a new ranking was made for each scenario, as in Table 5.

Table 5 Ranking alternatives using different scenarios

	Si	S1-S5	S6-S9	S10-S11	S12-S16	S17-S20
A_1	3	4	4	4	5	6
A_2	5	5	5	5	4	4
A_3	2	2	3	3	3	3
A_4	1	1	1	2	2	2
A_5	6	6	6	6	6	5
A_6	4	3	2	1	1	1

Considering Table 5, it is easily noticeable that there are changes in the ranking of alternatives when the weight coefficients change. This clearly indicates that the model is sensitive to weight coefficients change. What is important is that it should not be overly sensitive, which is analyzed below:

- The alternative A_1 is ranked from the fourth to sixth place. In relation to the initial ranking, the change already occurs in the first scenario, but it remains until the scenario S11. From the scenarios S12 to S20, this alternative moves to the fifth and sixth place.
- The alternatives A_2, A_3, A_4 and A_5 as a part of the scenario analysis have only one change in ranking. The alternative A_2, from the scenario S12, moves from the fifth-ranked place to the fourth-ranked alternative. The alternative A_3 from the scenario S6, moves from the second-ranked place to the third-ranked alternative. The alternative A_4 from the scenario S10 moves from the first-ranked position to the second-ranked alternative. The alternative A_5 from the scenario S17 moves from the sixth-ranked place to the fifth-ranked alternative.
- The alternative A_6 has more significant changes. Namely, from the fourth-ranked alternative in the initial scenario (Si), it gradually takes the first place from scenario S10.
- As it can be observed, greater changes occur from the tenth scenario, when the most significant criterion is already reduced by 50%.
- The alternative A_4, which was ranked first in the initial scenario, and due to major changes in the weight coefficients, retains the first ranking until the scenario S9, while from the scenario S10 until the end, it is the second-ranked. The lowest-ranked alternative, A6, retains this position in almost all scenarios.

The above analysis clearly shows that there are changes in the ranking of alternatives following the changes in the weight coefficients of the criteria, but these changes are gradual. Accordingly, it is very clear that the presented model is quite stable. Regardless the stated, mathematical proof of the stability of the model was also conducted. By applying Spearman's rank correlation coefficient, it was defined whether the changes in the rankings of alternatives can be considered large and unacceptable. The equation for calculating Spearman's rank correlation coefficient is as follows:

$$S_{rcc} = 1 - \frac{6\sum_{i=1}^{n} \Xi_i^2}{n(n^2-1)} \tag{44}$$

Here, Ξ_i is the difference of rank according to the given scenario and the rank in the corresponding scenario, and n is the number of ranked elements.

The Spearman's rank correlation coefficient values are given in Table 6.

Table 6 Spearman's coefficient values

	Si	S1-S5	S6-S9	S10-S11	S12-S16	S17-S20
Si	1	0.943	0.886	0.657	0.543	0.371
S1-S5		1	0.943	0.829	0.771	0.657
S6-S9			1	0.943	0.886	0.771
S10-S11				1	0.943	0.829
S12-S16					1	0.943
S17-S20						1

The Spearman's coefficient of correlation of the ranking of considered strategies falls within the range of $S_{rcc} \in [0.371,1]$. The most important values of this coefficient are in relation of the initial strategy to other strategies. There it is observable that the Spearman coefficient is very high up to the strategy S11. Only from the strategy S12 to S16 it is significantly lower (0.513), but still quite high. From the strategy S17 up to S20, this value decreases more significantly, but still shows there is a certain correlation. This is expected since the most influential criterion is reduced to the minimum. Both mathematical and theoretical analysis clearly indicate that changes in alternatives rankings by different strategies, due to the changes in weight coefficients of the criteria, are gradual and expected. Everything above mentioned confirms the conclusion of model stability.

5. Conclusion

This paper deals with the issue of ranking methods and techniques of Lean concept, with the purpose of improvement of work process and organization management of SPTS TM in the Army of Serbia. Resulting conclusion suggests that in order to achieve the best results in conditions of limited opportunities for investment in the work process and organization of SPTS TM, should be used the best-ranked methods or techniques.

For ranking alternative solutions, a hybrid model based on two methods, DIBR II and MABAC, was applied in a rough environment. Research showed that proposed model could successfully evaluate the methods and techniques of the Lean concept. Considering that the MABAC method was applied in a rough environment, the values from reality were very successfully reflected in the model.

In this paper, the DIBR II method was applied for the first time in solving a specific case study. Expert evaluation of the criteria carried out in this research, showed that the way of comparing the criteria used in this method was very suitable for understanding and use by the experts who had never encountered this issue before.

Presented model quality was tested in sensitivity analysis. Through this process, it was checked the way the changes in the weight coefficients affect the ranking of alternatives. It is clearly observable, through the analysis, that the model is sensitive enough, but not too sensitive. High correlation of alternatives rankings during different changes in weight coefficients of the criteria indicates the stability of the model.

Basic limitation of the model is the fact that the experts were only able to use crisp values for comparison when defining the ratio of criteria. In some situations, where experts were not certain, there was a clear space for the application of scientific fields that treat uncertainties well, such as fuzzy numbers, rough numbers, gray numbers, *etc*. The improvement of this DIBR II method should be the subject of future research.

References

1. Epler, I.J., 2013, *Models of technical system maintenance management*, Military technical courier, 61(1), pp. 178-195.
2. Wireman, T., 2004, *Benchmarking BEST Practices in Maintenance Management*, Industrial Press, New York.
3. Epler, I.J., Božičković, R.C., Arsić, S.N., Dinić, J.B., 2016, *Real improvement processes in the army based on the lean six sigma concept*, Military technical courier, 64(4), pp. 1132-1156.
4. Božičković, R., 2005, *Lean koncept u efektivnim proizvodnim sistemima*, PhD Thesis, University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, Bosnia and Herzegovina.

5. Marić, B., 2010, *Model upravljanja proizvodnim procesom u remontno – proizvodnim sistemima na bazi Lean koncepta*, PhD Thesis, University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, Bosnia and Herzegovina.
6. Womack, J., Jones, D., Roos, D., 1991, *The Machine that Change the World*, Free Press, New York.
7. Womack, J., Jones, D., 1996, *Lean Thinking*, Free Press, New York.
8. Epler, I., 2017, *Lean koncept u održavanju tehničkih sistema specijalne namene*, PhD Thesis, University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, Bosnia and Herzegovina.
9. Srinivasan, M.M., Bowers, M.R., Gilbert, K., 2014, *Lean maintenance Repair on Overhaul*, Mc Graw Hill Education.
10. Tamanna, S., Rahman, M.M., 2022, *Prioritization of Effective Lean Tools for Reliability Analysis & Maintenance Strategy*, Journal of Engineering Advancements, 3(3), pp. 112-130.
11. Singha Mahapatra, M., Shenoy, D., 2022, *Lean maintenance index: a measure of leanness in maintenance organizations*, Journal of Quality in Maintenance Engineering, 28(4), pp. 791-809.
12. Bhebhe, M., Zincume. P.N., 2022, *Application of Lean principles in railway maintenance*, Proc. 33rd Annual Southern African Institute for Industrial Engineering Conference (SAIIE33), The Capital, Zimbali, South Africa, pp. 1134-1148.
13. Korchagin, A., Deniskin, Y., Pocebneva, I., Vasilyeva, O., 2022, *Lean Maintenance 4.0: implementation for aviation industry*, Transportation Research Procedia, 63, pp. 1521-1533.
14. Dragone, I.S., Biotto, C.N., Serra, S.M.B., 2021, *Evaluation of Lean Principles in Building Maintenance Management*, Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC), 13-22, Lima, Peru.
15. Puška, A., Maksimović, A., Stojanović, I., 2018, *Improving organizational learning by sharing information through innovative supply chain in agro-food companies from Bosnia and Herzegovina*, Operational Research in Engineering Sciences: Theory and Applications, 1(1), pp. 76-90.
16. Riaz, M., Athar Farid, H.M., 2022, *Picture fuzzy aggregation approach with application to third-party logistic provider selection process*, Reports in Mechanical Engineering, 3(1), pp. 227–236.
17. Bošković, S., Švadlenka, L., Dobrodolac, M., Jovčić, S., Zanne, M., 2023, *An Extended AROMAN Method for Cargo Bike Delivery Concept Selection*, Decision Making Advances, 1(1), pp. 1–9.
18. Ali, A., Ullah, K., Hussain, A., 2023, *An approach to multi-attribute decision-making based on intuitionistic fuzzy soft information and Aczel-Alsina operational laws,* Journal of Decision Analytics and Intelligent Computing, 3(1), pp. 80–89.
19. Mahmood, T., ur Rehman, U., 2023, *Bipolar complex fuzzy subalgebras and ideals of BCK/BCI-algebras*, Journal of Decision Analytics and Intelligent Computing, 3(1), pp. 47–61.
20. Ashraf, A., Ullah, K., Hussain, A., Bari, M., 2022, *Interval-Valued Picture Fuzzy Maclaurin Symmetric Mean Operator with application in Multiple Attribute Decision-Making*, Reports in Mechanical Engineering, 3(1), pp. 210–226.
21. Maurya, J.K., Mishra, S.K., 2022, *Strong Complementary Approximate Karush-Kuhn-Tucker Conditions for Multiobjective Optimization Problems*, Yugoslav Journal of Operations Research, 32(2), pp. 219-234.
22. Badi, I., Stević, Ž., Bayane Bouraima, M., 2023, *Overcoming Obstacles to Renewable Energy Development in Libya: An MCDM Approach towards Effective Strategy Formulation*. Decision Making Advances, 1(1), pp. 17–24.
23. Božanić, D., Pamucar, D., 2023, *Overview of the Method Defining Interrelationships Between Ranked Criteria II and Its Application in Multi-criteria Decision-Making*, In: Chatterjee, P., Pamucar, D., Yazdani, M., Panchal, D. (Eds.) *Computational Intelligence for Engineering and Management Applications. Lecture Notes in Electrical Engineering*, 984, Springer, Singapore. pp. 863-873.
24. Badi, I., Abdulshahed, A., 2021, *Sustainability performance measurement for Libyan Iron and Steel Company using Rough AHP,* Journal of Decision Analytics and Intelligent Computing, 1(1), pp. 22–34.
25. Roy, J., Adhikary, K., Kar, S., Pamucar, D., 2018, *A rough strength relational DEMATEL model for analysing the key success factors of hospital service quality*, Decision Making: Applications in Management and Engineering, 1(1), pp. 121-142.
26. Qi, J., Hu, J., Peng, J.-H., 2020, *Integrated rough VIKOR for customer-involved design concept evaluation combining with customers' preferences and designers' perceptions*, Advanced Engineering Informatics, 46, 101138.
27. Song, W., Ming, X., Wu, Y., Zhu, B., 2014, *A rough TOPSIS Approach for Failure Mode and Effects Analysis in Uncertain Environments*, Quality and Reliability Engineering, 30(4), pp. 473-486.
28. Arsić, S.N., Pamučar, D., Suknović, M., Janošević, M., 2019, *Menu evaluation based on rough MAIRCA and BW methods*, Serbian Journal of Management, 14(1), pp. 27-48.
29. Jangid, V., Kumar, G.A., 2022, *Novel Technique for Solving Two-Person Zero-Sum Matrix Games in a Rough Fuzzy Environment*, Yugoslav Journal of Operations Research, 32(2), pp. 251-278.

30. Pamucar, D., Žižović, M., Đuričić, D., 2022, *Modification of the CRITIC method using fuzzy rough numbers*, Decision Making: Applications in Management and Engineering, *5*(2), pp. 362–371.
31. Sahu, R., Dash, S.R., Das, S., 2021, *Career selection of students using hybridized distance measure based on picture fuzzy set and rough set theory*, Decision Making: Applications in Management and Engineering, 4(1), 104–126.
32. Chakraborty, S., Dandge, S.S., Agarwal, S., 2020, *Non-traditional machining processes selection and evaluation: A rough multi-attributive border approximation area comparison approach,* Computers & Industrial Engineering, 139, 106201.
33. Tešić, D., Radovanović, M., Božanić, D., Pamucar, D., Milić, A., Puška, A., 2022, *Modification of the DIBR and MABAC Methods by Applying Rough Numbers and Its Application in Making Decisions,* Information, 13(8), p. 353.
34. Tešić, D.Z., Božanić, D.I., Miljković, B.D., 2023, Application of MCDM DIBR-Rough MABAC Model for Selection of Drone for Use in Natural Disaster Caused by Flood. In: Filipovic, N. (eds) *Applied Artificial Intelligence: Medicine, Biology, Chemistry, Financial, Games, Engineering. AAI 2022. Lecture Notes in Networks and Systems*, 659, Springer, Cham, pp. 151-169.
35. Roy, J., Chatterjee, K., Bandhopadhyay, A., Kar, S. (2018). *Evaluation and selection of Medical Tourism sites: A rough Analytic Hierarchy Process based Multi Attributive Border Approximation area Comparison approach,* Expert Systems, 35(1), e12232.
36. Chattopadhyay, R., Das, P.P., Chakraborty, S., 2022, *Development of a Rough-MABAC-DoE-based Metamodel for Supplier Selection in an Iron and Steel Industry*, Operational Research in Engineering Sciences: Theory and Applications, 5(1), pp. 20–40.
37. Pamučar, D., Ćirović, G., 2015, *The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC)*, Expert Systems with Applications, 42(6), pp. 3016-3028.
38. Pawlak, Z., 1991, *Rough sets-theoretical aspects of reasoning about data*; Kluwer Academic Publishers, Dordrecht, Netherlands.
39. Pawlak, Z., 1996, *Rough sets, rough relations and rough functions,* Fundamenta Informaticae, 27(2-3), pp. 103-108.
40. Zhai, L.-Y., Khoo, L.-P., Zhong, Z.-W., 2009, *A rough set based QFD approach to the management of imprecise design information in product development,* Advanced Engineering Informatics, 23(2), pp. 222–228.
41. Čubranić-Dobrodolac, M., Švadlenka, L., Čičević, S., Trifunović, A., Dobrodolac, M., 2020, *Using the Interval Type-2 Fuzzy Inference Systems to Compare the Impact of Speed and Space Perception on the Occurrence of Road Traffic Accidents*, Mathematics, 8(9), 1548.
42. Tešić, D.Z., Božanić, D.I., Pamučar, D.S., Din, J., 2022, *DIBR - Fuzzy MARCOS model for selecting a location for a heavy mechanized bridge,* Military technical courier, 70(2), pp. 314-339.
43. Ulutaş, A., Topal, A., Pamučar, D., Stević, Ž., Karabašević, D., Popović, G., 2022, *A New Integrated Multi-Criteria Decision-Making Model for Sustainable Supplier Selection Based on a Novel Grey WISP and Grey BWM Methods,* Sustainability, 14(24), 16921.
44. Radovanović, M., Petrovski, A., Žnidaršič, V., Ranđelović, A., 2021, *Application of the Fuzzy AHP - VIKOR Hybrid Model in the Selection of an Unmanned Aircraft for the Needs of Tactical Units of the Armed Forces,* Scientific Technical Review, 71(2), pp. 26-35.
45. Radovanović, M., Milić, A., Petrovski, A., 2021, *Analysis of accuracy and precision of shooting with home: Made automatic rifles using the AHP method,* Scientific Technical Review, 71(1), pp. 30-37.