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RANKING OF KEY PERFORMANCE INDICATORS OF THE OVERHAUL PROCESS OF TECHNICAL SYSTEMS

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The paper presents a developed model for measuring key performance indicators (KPI) of processes implemented in business organizations. The goal of the research is to identify problems that affect the processes through the measurement of KPIs, based on which the management of the organization improves its operations. The model was developed in four phases shown by the algorithm, based on higher-order fuzzy sets, more precisely, using Fermatean fuzzy sets (FFS). The first phase includes decomposing the process into sub-processes using the hierarchy-input-output-processing (HIPO) method and defining KPIs for measurements. In the second phase, the relative importance of sub-processes is determined using the Delphi method extended by FFS. In the third phase, KPIs are assessed at the level of each process by experts. In the fourth phase, KPIs are measured using the VIKOR (Multi-Criteria Optimization and Compromise Solution) method extended by FFS. The model was tested in a business organization that mainly deals with the maintenance of technical military systems. The obtained results confirmed the stability of the model by analyzing the comparison with the results of another method and by analyzing the sensitivity of the change of a certain parameter. The results have been verified in practice by the management of the business organization and, as such, serve for the constant improvement of business.

Keywords: Overhaul, Technical system, Fermatean fuzzy set, VIKOR method, Delphi method, Performance indicators.

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1. INTRODUCTION

Maintenance and overhaul of military assets can be considered equally important with other processes of business organizations, which is aligned with the corporate and functional strategies and goals of the organization. Observing the performance of the maintenance process, i.e., the level of achieved goals can be achieved by applying a performance measurement model. The maintenance process plays a key role in extending the useful life of the assets and certainly attracts the attention of the management of the business organization. Regular maintenance creates a prerequisite for increasing the reliability of assets. Problems that generate losses in the maintenance process are often invisible to management, so it is necessary to identify them and take measures to eliminate them. Identification of problems can be achieved by measuring the value of critical activities, that is, by measuring KPIs and analyzing the obtained results. In current practice, various models have been developed for measuring KPIs of various processes. When it comes to measuring the performance of maintenance processes, existing models are often modified and adapted to the current situation. From the above, there has been a need to develop through research a hybrid model for measuring the performance of the maintenance process, which would be tested in an organization that predominantly deals with the overhaul of technical systems for military purposes. The complexity of the process of maintenance and overhaul of technical systems is a challenge for the author, who needs to develop the simplest possible model for such a process, which is efficient and easily applicable to the management of the organization. It is expected that the model shows such results of KPIs which most realistically reflect the real process, thus creating a condition for process analysis. The problems in the process are identified on the basis of KPIs so that, based on the ranking of the values of individual parameters, a conclusion regarding which KPIs have the greatest impact on the process is reached. Then, by analyzing each KPI, all the activities that affect the KPIs are looked at, and in this way, the cause of the problem is established. Based on that, the management of the organization generates clear guidelines on which KPIs should be improved.

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The basis of the developed model is the application of higher-order fuzzy sets in combination with the Multi-Criteria Decision-Making (MCDM) model (Pamučar *et al.*, 2021). Experts in the field of maintenance and repair processes contribute to the development of the highest-quality model. The model has been developed through four phases: phase 1 - decomposition of the process into sub-processes and selection of KPIs; Phase 2 - determining the relative importance of sub-processes; Phase 3 - evaluation of each KPIs at the level of each sub-process; Phase 4 - determining the value of KPIs and ranking KPIs. The results of the developed model are analyzed by asking the sensitivity of the change of a certain parameter, as well as compared with the result of applying another method for determining the value of KPIs.

2. BACKGROUND

In this section, the theoretical basis is presented, which is necessary for the development of the model for measuring the value of KPIs, which is given in section 3.

2.1 Process Decomposition into Subprocesses

The complexity of the maintenance process requires a good knowledge of the process, as it involves various inputs, outputs and stakeholders. For a better understanding of the maintenance process, it is necessary to realize the decomposition of the process into sub-processes, to recognize the mutual consequential connections between them, and to observe the flow of assets and the flow of information through the technological process. One of the models for decomposing processes is Hierarchy - Input - Output - Processing (HIPO). The HIPO model was developed in 1970 with the aim of representing a system using modules that are hierarchically connected. The model serves for easier understanding and communication in the organization. It has a special application in complex systems, where the system is divided into smaller organizational units that are easier to manage. The model consists of three components: input, process and output. These components can be broken down into sub-components, creating a hierarchical structure.

The advantage of the HIPO method is that it favors hierarchically structured processes, monitors the flow of information through the process, identifies the procedural flow from the input to the process output, and monitors the relationships between sub-processes and within the sub-processes themselves (Durugbo *et al*., 2011).

2.2 Modeling Uncertainty with Fermatean Fuzzy Sets

Bearing in mind that the evaluations of KPIs by experts are qualitative, there is a need to model them. For the modeling of grades, that is, the translation of qualitative quantities (linguistic expressions) into scalar values, fuzzy sets of the n-th order are used with an intuitive approach, where n takes the value n=3. Such numbers are called Fermatean fuzzy sets (FFS). Fermatean fuzzy sets are chosen for the reason that they include both decisiveness and indecisiveness in a given evaluation. Also, the justification of the application of FFS is given on the basis of its previous use in research.

The Fermatean fuzzy set (FFS) was developed by Senapati & Yager (2019a), Senapati & Yager (2019b) and Senapati & Yager (2020) with the aim of improving uncertainty modeling. FFS are an upgrade of intuitive fuzzy sets developed by Atanasov (1983) and Atanasov (1986). In the literature review, uncertainty modeling using FFS has found application in various fields, such as: analysis of the advantages of the MABAC method using the r-rung orthopair fuzzy environment (Wang *et al.*, 2019), evolution of pattern recognition techniques (Ganai *et al.*, 2023), statistical concept of decision making for medical applications, Kirisci (2023), application of the Hernian mean operator to the example of electronic surveillance (Ruan *et al.*, 2023), principal component analysis for hospital disaster preparedness (Kirisci *et al.*, 2023), medical waste disposal planning for health centers (Akin *et al.*, 2023), pattern recognition based on similarity measures (Changlin *et al.*, 2021), extended capital budgeting technique (Duygu *et al.*, 2022), choice of antivirus mask (Shahzadi *et al.*, 2021), assessment of challenges for Industry 4.0 adoption for sustainable digital transformation (Saraji *et al.*, 2021), occupational risk assessment of flight school (Gul *et al.*, 2022), selection of warehouse location for the automotive industry (Saha *et al.*, 2023), assessment of green suppliers in a complex uncertain environment (Zeng *et al.*, 2023), a multi-attribute decision-making approach dealing with the significant deficiency in order preference similarity to the ideal solution (Alahmadi *et al.*, 2023), Using type-2 Fermatian phase sets in group decision-making (Akram *et al.*, 2023), an analysis of the trade performance of the European Union and Serbia, Lukic (2023), multi-criteria decision making using similarity measures using Fematean sets (Huang *et al.*, 2023). In addition to the mentioned applications, FFS were also used in the works of authors (Aydemir *et al.*, 2020), (Verma *et al.*, 2021), (Akram *et al.*, 2022 and 2022c), (Shahzadi *et al.*, 2021), (Qin *et al.*, 2023).

The algebra and properties of FFS, according to (Senapati *et al.*, 2019a, 2019b, 2020) are presented:

Definition 1. Let X be a fixed set, a FFS in X is defined as, $F = \{\langle x_j, \mu_F(x_j), \nu_F(x_j)\rangle | x_j \in X\}$ where $\mu_F(x_j)(0 \leq \mu_F(x_j) \leq 1)$ represent the membership and $\nu_F(x_j)(0 \leq \nu_F(x_j) \leq 1)$ nonmembers ship degrees of $x_j \in X$ to the set F, respectively, and they satisfy the following condition: $0 \leq \left(\mu_F(x_j)\right)^3 + \left(\nu_F(x_j)\right)^3 \leq 1$. For all $x_j \in X$, if $\pi_F(x_j) = \sqrt[3]{1 - \left(\mu_F(x_j)\right)^3 - \left(\nu_F(x_j)\right)^3}$, then $\pi_F(x_j)$ is the indeterminacy degree of $x_j \in X$ to the set F.

Definition 2. Let F_1 and F_2 two FFS, then the basic arithmetical operations are defined as follows:

$F_1 \leq F_2$ if and only if $\mu_1 \leq \mu_2$ and $\nu_1 \geq \nu_2$;$F_1 = F_2$ if and only if $\mu_1 = \mu_2$ and $\nu_1 = \nu_2$;
$F_1 \oplus F_2 = \left(\sqrt[3]{\mu_1^3 + \mu_2^3 - \mu_1^3 \cdot \mu_2^3}, \nu_1 \cdot \nu_2\right)$;
$F_1 \otimes F_2 = \left(\mu_1 \cdot \mu_2, \sqrt[3]{\nu_1^3 + \nu_2^3 - \nu_1^3 \cdot \nu_2^3}\right)$;
$\lambda \cdot F_1 = \left(\sqrt[3]{1 - (1 - \mu_1^3)^\lambda}, \nu_1^\lambda\right)$, where $\lambda \geq 0$; $F_1^\lambda = \left(\mu_1^\lambda, \sqrt[3]{1 - (1 - \nu_1^3)^\lambda}\right)$, where $\lambda \geq 0$.

Definition 3. Let $F_1 = (\mu_1, \nu_1)$ and $F_2 = (\mu_2, \nu_2)$ two FFS andλ, λ_1 andλ_2 be three positive real numbers, then the following properties are obtained:

$F_1 \oplus F_2 = F_2 \oplus F_1$; $\lambda(F_1 \oplus F_2) = \lambda \cdot F_1 \oplus \lambda \cdot F_2$; $F_1 \otimes F_2 = F_2 \otimes F_1$; $\lambda_1 \cdot F_1 \oplus \lambda_2 \cdot F_1 = (\lambda_1 + \lambda_2) \cdot F_1$;$F_1^{\lambda_1} \otimes F_1^{\lambda_2} = F_1^{\lambda_1 + \lambda_2}$; $(F_1 \otimes F_2)^\lambda = F_1^\lambda \otimes F_2^\lambda$;
$F_1 - F_2 = \left(\sqrt[3]{\frac{\mu_1^3 - \mu_2^3}{1 - \mu_2^3}}, \frac{\nu_1}{\nu_2}\right) if \mu_1 \geq \mu_2 and \nu_1 \leq min\left\{\nu_2, \frac{\nu_2 \pi_1}{\pi_2}\right\}$;
$F_1 \div F_2 = \left(\frac{\mu_1}{\mu_2}, \sqrt[3]{\frac{\nu_1^3 - \nu_2^3}{1 - \nu_2^3}}\right) if \nu_1 \geq \nu_2 and \mu_1 \leq min\left\{\mu_2, \frac{\mu_2 \pi_1}{\pi_2}\right\}$;
$F = (\mu, \nu), sc(F) = \mu^3 - \nu^3; acc(F) = \mu^3 + \nu^3$

Definition 4. Let $F_1 = (\mu_1, \nu_1)$ and $F_2 = (\mu_2, \nu_2)$ two FFSs, then they ranked according to the following rules:

If$sc(F_1) < sc(F_2), then F_1 < F_2,$
If$sc(F_1) > sc(F_2), then F_1 > F_2,$
If$sc(F_1) = sc(F_2), then$:
$a) If acc(F_1) < acc(F_2), then F_1 < F_2,$
$b) If acc(F_1) > acc(F_2), then F_1 > F_2,$
$c) If acc(F_1) = acc(F_2), then F_1 \approx F_2.$

Definition 5. Let $F_1 = (\mu_1, \nu_1)$ and $F_2 = (\mu_2, \nu_2)$ are two FFS. Then, the Euclidean distance between F_1 and F_2 is defined as: $d_e(F_{1,}F_1) = \sqrt{\frac{1}{2}[|\mu_1^3 - \mu_2^3|^2 + |\nu_1^3 - \nu_2^3|^2 + |\pi_1^3 - \pi_2^3|^2]}$.

2.3 Determination of The Relative Importance of Sub-Processes

For the purposes of the model, it is necessary to determine the relative importance of sub-processes (ω_{PPi}). Bearing in mind that experts are involved for the purposes of the research, as well as the necessity of reaching a consensus on the value of ω_{PPi}, the Delphi method is used. The Delphi method, as one of the models for decision-making based on a group of experts, has found wide application in solving complex problems. The significance of the Delphi method is the verification of the decision made by experts. The model is formed for the purposes of decision-making while reaching consensus. Its use is essential for model development, as it is determines the relative importance of maintenance sub-processes. The application of the Delphi method can be found in the following areas: determination of E-Portfolio elements in the learning process using fuzzy Delphi analysis (Mohamad *et al.*, 2015), modeling and evaluation analysis of online reputation management (Kumar *et al.*, 2017), consumer research in the purchase of tour packages in the city of Isfahan (Abdollahi *et al.*, 2020), customer engagement on social networking sites (Jani *et al.*, 2018), improving workplace safety (Komatina *et al.*, 2021), forecasting statistical time series on a case study of the dry bulk market (Duru *et al.*, 2012), a strategic planning approach on the example of Indian industry (Prusty *et al.*, 2010), constructing a measurement model performance of the semiconductor industry (Hsu *et al.*, 2011), determination of constraints affecting the future size of shipping containers (Gomez *et al.*, 2015), identification of road safety performance indicators (Ma *et al.*, 2011) and industry sales forecasting (Chang *et al.*, 2006).

The Delphi method algorithm and the required mathematical algebra are given through the following steps:

Step 1. Forming survey questions and sending the survey to evaluators. The survey, as a form of data collection, allows the moderator to collect answers to the questions. Surveys are anonymous in order to reduce the subjectivity of the persons filling out the survey. The questions are formulated in such a way that they are understandable, unambiguous and comprehensible.

Step 2. Collection of surveys processing of results. After receiving the surveys, the results are processed. Bearing in mind that the answers are linguistic expressions, modeling and translation into numerical values are performed using FFS. Aggregation of KPIs at the level of each maintenance sub-process is realized using the operator FFWPA (3).

Step 3. Determination of consensus is realized using expression (1) for the determination of standard deviation σ (Saraji *et al.*, 2021). Consensus is reached if the value is $\sigma \leq 0.25$. For higher values of the standard deviation than the defined threshold, the survey and the results from the previous step are returned to the experts for re-evaluation so that all evaluators have an insight into the evaluations of other persons and thereby possibly correct their evaluation.

$$\sigma^2 = \frac{1}{m} \sum_{i=1,\dots,e} \left(W_j - W_j^e\right)^2 \tag{1}$$

where is: $W_j - W_j^e = d_e$ and W_j is represents the aggregated value of sub-process relative importance (PPi) obtained by FFWPA, while W_j^e represents the relative importance (PPi) assigned by the i-th expert. The variance σ is a measure of the consensus for the obtained relative importance.

Step 4. Data collection and re-modeling and consensus determination. If the evaluator's consensus is reached, the obtained results of relative importance are accepted, however, if the consensus is not reached, the next iteration of the survey continues. The number of iterations is not limited, but practice has shown that a maximum of five iterations is done.

2.4 Ranking the KPIs at the sub-process level

The result of the model should present the values of KPIs, i.e. their ranking, in order to be able to establish which KPIs have the greatest or least impact on the process. The answer to the given question is the application of the Multi-Criteria Decision-Making (MCDM) method. For the purposes of the model, the VIKOR method is used. The multi-category decision-making method developed by (Opricović *et al.*, 1980) for solving decision-making problems with conflicting and diverse criteria, where it is assumed that a compromise is acceptable for resolving the conflict, that the decision-maker wants a solution that is closest to the ideal and that the alternatives are evaluated according to all criteria. The output is a ranking of alternatives that represents the compromise solution that is closest to the ideal.

The idea of solving multi-criteria problems through compromise originated in 1973 by Po-Ling Yu (1973) and Zeleni (1973). Vikor was developed with the aim of proposing alternatives to the decision-maker that represent a compromise between possibilities and desires. The compromise solution is based on the determination of a narrower set of possible solutions, which, in terms of values, approach the ideal point, that is, the reference point in the space of criterion functions, Puška (2011).

The advantages of the VIKOR method are reflected in the following: easy to use and apply, takes into account the relative distances of ideal and anti-ideal solutions, the number of steps remains the same regardless of the number of criteria, provides a well-structured analytical framework for ranking alternatives, used in the case of a large number of alternatives and criteria, the ranking of alternatives expressed as a numerical value provides a better understanding of the results, one of the best methods for solving of the rank change problem, applicable when accurate and complete information is collected, applicable for the qualitative and quantitative type of criteria and the possibility of analyzing a stable interval of weighting factors.

VIKOR, as one of the (MCDMs) is often modified with different fuzzy sets. The justification for using the VIKOR method extended with higher-order fuzzy sets for solving problems in different areas is given in the following researches: ranking of investment projects, Puška (2011), application in the selection of a laboratory for testing COVID-19, where uncertainty is modeled by Fermatean fuzzy sets, Gul (2021), multi-criteria decision analysis based on distance index, VIKOR extended with Pythagorean fuzzy set, Chen (2018), VIKOR method extended with intuitive fuzzy sets, Devi (2011), application of aggregation operator and VIKOR method for complex q-rung Orthopair fuzzy sets (Garg *et al.*, 2020a), safety risk assessment in the mining industry using the Pythagorean fuzzy sets VIKOR approach (Gul *et al.*, 2019), warehouse location selection using the VIKOR method extended with spherical fuzzy sets (Gundogdu *et al.*, 2019), water resource planning using fuzzy VIKOR, Opricovic (2011), financing rural tourism project risk assessment using intuitionistic fuzzy VIKOR (Wu *et al.*, 2019), improvement of VIKOR method with Fermatean fuzzy sets (Akram *et al.*, 2022), assessment of challenges for the adoption of renewable energy technologies in rural areas using Fermatean fuzzy VIKOR (Saraji *et al.*, 2023), modification of VIKOR method with Fermatean hesitant sets (Mishra *et al.*, 2022), MCGDM based on the VIKOR method using Fermatean fuzzy soft (Palanikumar *et al.*, 2022), selection of schools for financing that are in rural areas, using VIKOR with Fermatean fuzzy sets (Palanikumar *et al*., 2022), risk assessment for health and safety at work using Fermatean fuzzy sets (Chen *et al.*, 2022), Fermatean fuzzy sets with Dombi aggregation operators (Aydemir *et al.*, 2020).

The basic VIKOR method algorithm, according to (Opricović *et al.*, 2004), which is extended with the Fermatean fuzzy set according to Gul (2021), was developed in seven steps:

Step 1. Formation of the decision matrixX_{ij} where x_{ij} represents the performance of the alternative A_i in relation to the criteria C_j. where $(C_1, C_2, \dots, Cm)$ number of criteria, and $(A_1, A_2, \dots, Am)$ represents the total number of alternatives. With decision matrix X_{ij}, the n number of alternatives and the m number of criteria are defined as

$$X_{ij} = \begin{matrix} \\ \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{matrix} \begin{matrix} C_1 & C_2 \cdots & C_m \\ \omega_1 & \omega_1 \cdots & \omega_j \\ \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \vdots & \vdots & \dots & \vdots \\ x_{n1} & x_{i2} & \dots & x_{nm} \end{bmatrix} \tag{2}$$

i.e., extended with Fermatean fuzzy set:

$$X_{ij} = \begin{matrix} KPI_1 \\ KPI_2 \\ \vdots \\ KPI_i \end{matrix} \overset{\begin{matrix} PP_1 & PP_2 \cdots & PP_j \\ \omega_1 & \omega_1 \cdots & \omega_i \end{matrix}}{\begin{bmatrix} (\mu_{11}, v_{11}) & (\mu_{12}, v_{12}) & \dots & (\mu_{1j}, v_{1j}) \\ (\mu_{21}, v_{21}) & (\mu_{22}, v_{22}) & \dots & (\mu_{2j}, v_{2j}) \\ (\mu_{31}, v_{31}) & (\mu_{32}, v_{32}) & \dots & (\mu_{3j}, v_{3j}) \\ (\mu_{i1}, v_{m1}) & (\mu_{i2}, v_{m2}) & \dots & (\mu_{ij}, v_{ij}) \end{bmatrix}} \tag{3}$$

Step 2. Aggregation or unification of KPIs scores at the sub-process level (PP_i), using the operators Fermatean fuzzy weighted power average (FFWPA) and Fermatean fuzzy weighted geometric average (FFWGA) according to Senapati & Yager (2019a):

$$FFWPA(F_1, F_2, \dots, F_n) = \left(\left(\sum_{i=1}^{n} \omega_i \mu_i^3 \right)^{\frac{1}{3}}, \left(\sum_{i=1}^{n} \omega_i v_i^3 \right)^{\frac{1}{3}} \right) \tag{4}$$

where ω_i represents the importance of the i-th expert, μ_i - the degree of decisiveness of the expert, or υ_i - the degree of indecision of the expert.

$$FFWPG(F_1, F_2, \dots, F_n) = \left(\left(1 - \prod_{i=1}^{n} (1 - \mu_i^3)^{\omega_i} \right)^{\frac{1}{3}}, \left(1 - \prod_{i=1}^{n} (1 - \nu_i^3)^{\omega_i} \right)^{\frac{1}{3}} \right) \tag{5}$$

Step 3. Normalization of Fermatrean fuzzy set according to Senapati & Yager (2020):

$$x_{ij} = \begin{cases} x_{ij} = (\mu_{ij}, v_{ij}), if j is a benefit attribute, \\ (x_{ij})^c = (v_{ij}, \mu_{ij}), if j is a \cos t\ attribute. \end{cases} \tag{6}$$

Step 3. Determination of the largestx_i^+ and minimal x_i^- value given by the criteria Gul (2021):

$$\begin{aligned} x_i^+ &= max(x_{ij}, i = 1, \dots, n) \text{ i.e. } A^+ = \left\{ x_{ij} where \max_i < sc(x_{ij}) i = 1, \dots, m > \right\} \\ x_i^- &= min(x_{ij}, i = 1, \dots, n) \text{ and } A^- = \left\{ x_{ij} where \min_i < sc(x_{ij}) i = 1, \dots, m > \right\} \end{aligned} \tag{7}$$

While the elements of A^+ are depicted as $x_i^+ = (\mu_j^+, \nu_j^+)$ the elements of A^- is shown as $x_i^- = (\mu_j^-, \nu_j^-)$.

Step 4. Calculation of value S_j (pessimistic solution) and R_j (expected solution) Gul (2021):

$$S_j = \sum_{i=1}^{n} \omega_i (x_i^+ - x_{ij}) / (x_i^+ - x_i^-), j = 1,2,..,m \text{i.e. } S_j = \sum_{i=1}^{n} \omega_i \frac{d_{euc}(x_{ij}, x_i^+)}{d_{euc}(x_i^-, x_i^+)} \quad (8)$$

$$R_j = \max_i [\omega_i (x_i^+ - x_{ij}) / (x_i^+ - x_i^-)], j = 1,2,..,m \text{i.e. } R_j = \max_i \left\{ \omega_i \frac{d_{euc}(x_{ij}, x_i^+)}{d_{euc}(x_i^-, x_i^+)} \right\} \quad (9)$$

Step 5. Calculating the value for Q_j(compromise solution) Opricović (2004):

$$Q_j = \upsilon \times \frac{S_j - S^*}{S^- - S^*} + (1 - \upsilon) \times \frac{R_j - R^*}{R^- - R^*}; j = 1,2,..,m \quad (10)$$

where:

$$S^- = \max_i (S_j, j = 1, \ldots, n), S^+ = \min_i (S_j, j = 1, \ldots, n), \quad (11)$$

$$R^- = \max_i (R_j, j = 1, \ldots, n), R^+ = \min_i (R_j, j = 1, \ldots, n). \quad (12)$$

Step 6. Determination of weight υ, which represents the weight of the group feature maximization criterion, and $1 - \upsilon$ is the weight of individual opportunity loss, Opricović (2005).

$$\upsilon = \frac{(n+1)}{(2 \times n)}, \quad (13)$$

where n - represents the number of criteria, that is, the number of sub-processes in this model.

Step 7. The ranking of alternatives is realized by sorting the alternatives according to the values of the measures R_j, $S_j$and Q_j. According to Opricović (2005) the best alternative is the one for which the value of the measure is the smallest and it takes the first place, that is a_j better than a_k if $Q_j < Q_k$. The best alternative is the alternative that is the least distant from the ideal value, i.e., whose value Q_j is minimal and vice versa.

3. A MODEL FOR THE KPIs VALUE MEASUREMENT

The model's algorithm enables an easier insight into the model's operation, as well as a more efficient and simpler application of the model for measuring KPIs of the process.

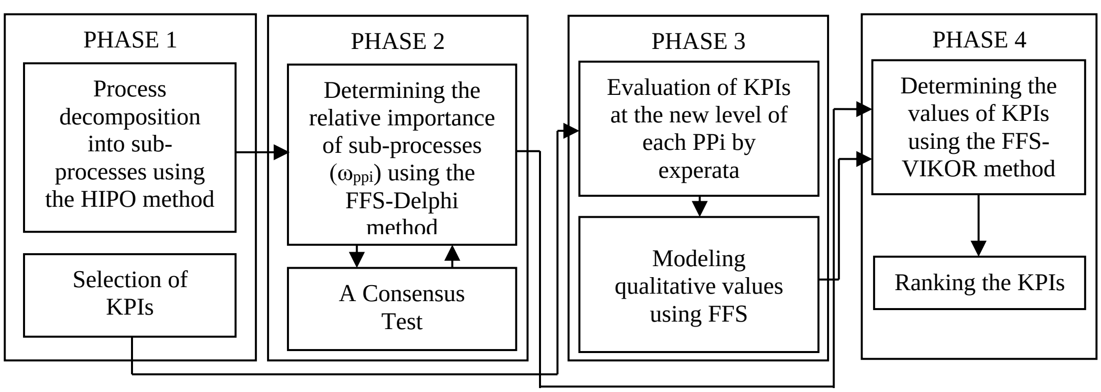

Figure 1. Performance measurement model

The developed model is shown in Figure 1 and is realized through four phases:

Phase 1. Dividing the process into sub-processes, using the HIPO method. Also, the selection of KPIs to be measured is carried out by experts.

Phase 2. Determining the relative importance of sub-processes ω_{PPi} using the Delphi method extended with FFS. Experts rate the importance of each sub-process using a survey. Based on the data from the survey, qualitative quantities are modeled using FFS. The acceptance of the obtained values of ω_{PPi} is done by checking the consensus. If the values are in the defined range, they are accepted. If the values deviate from the defined range, then the experts are polled again with the availability of the results from the previous round. Experts can correct their assessments or stay with their previous positions. For Delphi methods, up to five iterations are recommended, after which it is considered that consensus is not reached.

Phase 3. Experts evaluate the values of each KPIs at the level of each sub-process. Survey values are modeled with FFS. Then, they are combined using operators, where the output value of KPIs is obtained for each sub-process.

Phase 4. The input values in the VIKOR model are the relative importance of sub-processes and the values of KPIs for each sub-process. By applying the VIKOR model, the values of KPIs are obtained. Based on the obtained results, the ranking and determination of the importance of KPIs is performed.

4. NUMERICAL EXAMPLE

This section shows the application of the developed model on the example of the process of maintenance and overhaul of technical military systems, following the algorithm from section 3, according to the following:

Step 1: The maintenance process is defined based on the maintenance technology according to the complexity of the technical system. Using the HIPO method, the maintenance process is decomposed into key technological sub-processes: PP_1 - Previous defection, PP_2 - Disassembly of assemblies, sub-assemblies and spare parts, PP_3 - Repair of aggregates and equipment, PP_4 - Assembly, adjustments and partial tests, PP_5 - Final checks, PP_6 - Painting, PP_7 - Ground and flight tests, PP_8 - Overhaul process verification and PP_9 - Risk identification and assessment.

The business organization is already defined the following key performance indicators: KPI_1 - Availability of protective equipment needed in the process of asset maintenance, KPI_2 - User satisfaction with the maintenance service, KPI_3 - Material provision of spare parts and consumables, KPI_4 - Degree of application of safety measures in the overhaul process, KPI_5 - Availability of general and special tools and equipment, KPI_6 - Level of necessary knowledge and skills of employees, KPI_7 - Degree of coordination with other parts of the overhaul organization, KPI_8 - Ability to follow modern maintenance trends, KPI_9 - Degree of conformity of procedures, KPI_{10} - Availability of experts, KPI_{11} - Availability of technical literature and KPI_{12} - Availability of workshop capacities.

Step 2: Determining the relative importance of sub-processes at the level of each KPI. Ten experts ($e=E_1,..., E_{10}$) from the overhaul organization participate in determining the weight of the sub-process. Suppose the expert's weighting vector of equal importance is (0.1). The experts evaluated the KPI at the level of each sub-process with linguistic statements based on Table 1.

Table 1. Performance ratings of sub-process as linguistic values (Zhou *et al*., 2022)

Linguistic variables	FFS
Absolutely Good (AG)	(0.98, 0.02)
Very Good (VG)	(0.9, 0.6)
Good (G)	(0.8, 0.65)
Medium Good (MG)	(0.75, 0.6)
Average (A)	(0.5, 0.5)
Medium Bad (MB)	(0.6, 0.7)
Bad (B)	(0.7, 0.8)
Very bad (VB)	(0.6, 0.9)
Absolutely Bad (AB)	(0.02, 0.98)

The collection of evaluations by experts is carried out using a survey. To achieve consensus, the variance is used, where the experts unanimously agreed that the value of the variance should be $\delta \leq 0.25$. Based on the survey results, FFS modeling and unification using operator *FFWPA* Equation (4) is performed. Consensus is not reached in this iteration because the variance based on expression Equation (1) is above the variance threshold $\delta > 0.25$.

In the second iteration, the survey is returned to the experts, as well as the results obtained from the previous iteration, with the idea of converging opinions. After the second iteration, a consensus is reached, the variance is $\delta \leq 0.25$, and the results of the survey are given in Table 2.

Table 2. Evaluation of the importance of sub-processes by experts

Eks.	PP_1	PP_2	PP_3	PP_4	PP_5	PP_6	PP_7	PP_8	PP_9
E_1	VG	G	MG	MG	AG	VG	G	G	VB
E_2	AG	MG	MG	VG	MB	B	G	G	G
E_3	VG	MG	G	MG	MB	MG	B	MG	G
E_4	AG	A	G	G	G	VG	VG	MG	G
E_5	VG	MG	MG	MG	MG	A	G	A	VG
E_6	AG	MB	MG	G	G	B	VB	VG	MB
E_7	B	AG	VG	MG	AG	G	VG	G	VG
E_8	MG	MG	G	VG	G	VB	G	MB	MB
E_9	VG	AG	G	MG	MG	VG	G	MG	G
E_{10}	AG	MG	VG	VB	MG	G	VG	MB	G

The experts reached a consensus and decided that the sub-processes have the following relative importance:

$\omega_{pp_1} = 0.26; \omega_{pp_2} = 0.13; \omega_{pp_3} = 0.12; \omega_{pp_4} = 0.10; \omega_{pp_5} = 0.12;$
$\omega_{pp_6} = 0.06; \omega_{pp_7} = 0.09; \omega_{pp_8} = 0.07; \omega_{pp_9} = 0.06;$

Based on the obtained results, the experts assigned the greatest weight to the "previous defection" sub-process, which aims to accurately determine the failure of the asset as well as to establish the reason for the failure. The sub-processes "disassembly", "repair of aggregates and equipment", "assembly, adjustments and partial tests", "final checks", and "ground and flight tests" have approximate relative importance because they are almost equally important to experts in the maintenance process. The sub-processes "painting the asset", "verification of the repair process," and "risk identification and assessment" have less relative importance according to the opinion of the experts.

Step 3: The KPI evaluation at the level of each sub-process, Table 3. Five experts from the overhaul organization participated in this activity (e=E_1, E_2, E_3, E_4 and E_5). Assume that the vector of equal importance expert weights is (0.2, 0.2, 0.2, 0.2, 0.2).

Table 3. The KPI evaluation at the level of each sub-process as linguistic values (Zeng *et al*., 2023)

Linguistic variables	FFS
Very Eligible (VE)	(0.9, 0.2)
Eligible (E)	(0.8, 0.3)
Medium Eligible (ME)	(0.7, 0.5)
Medium (G)	(0.6, 0.6)
Medium Unqualified (MU)	(0.5, 0.7)
Unqualified (U)	(0.3, 0.8)
Very Unqualified (VU)	(0.2, 0.9)

The evaluation is carried out through a survey, where experts gave ratings according to Table 4.

Table 4. Evalution values describes as linguistic variables by five experts

E	KPI_i/Subprocess	PP_1	PP_2	PP_3	PP_4	PP_5	PP_6	PP_7	PP_8	PP_9
E_1	KPI_1	E	VE	E	VE	E	VE	VE	E	M
E_2		VE	ME	E	E	E	ME	VE	M	E
E_3		E	M	E	M	E	E	VE	VE	E
E_4		VE	U	ME	U	VE	ME	VE	VE	MU
E_5		E	E	VE	ME	VE	ME	VE	E	ME
E_1	KPI_2	E	E	VE	E	E	E	VE	E	E
E_2		E	E	ME	VE	VE	VE	ME	E	U
E_3		VE	E	M	U	E	ME	ME	M	MU
E_4		E	M	E	M	VE	VE	ME	M	VU

E	KPI_i/Subprocess	PP_1	PP_2	PP_3	PP_4	PP_5	PP_6	PP_7	PP_8	PP_9
E_5		VE	VE	VE	E	MU	ME	ME	E	VE
E_1	KPI_3	VE	VE	VE	M	ME	ME	E	VE	E
E_2		VE	VE	VE	E	E	VE	ME	VE	E
E_3		VE	VE	E	VE	E	ME	ME	VE	E
E_4		VE	VE	E	VE	E	VE	ME	VE	E
E_5		VE	VE	U	ME	E	E	E	E	E
E_1	KPI_4	VE	VE	ME	VE	E	M	E	ME	E
E_2		E	M	VE	VE	E	VE	E	E	VE
E_3		VE	VU	ME	E	E	ME	E	ME	ME
E_4		E	VE	VE	ME	E	E	E	E	E
E_5		MU	E	E	ME	E	VE	E	M	ME
E_1	KPI_5	VE	VE	VE	VE	VE	E	VE	VE	VE
E_2		ME	M	ME	E	VE	ME	VE	ME	M
E_3		VE	E	VE	VE	E	ME	VE	VE	VE
E_4		ME	ME	E	E	VE	VE	VE	VE	E
E_5		E	M	VE	ME	VE	M	VE	ME	VE
E_1	KPI_6	E	E	ME	VE	E	ME	VE	ME	E
E_2		ME	VE	M	E	E	VE	VE	ME	ME
E_3		E	ME	VE	ME	E	M	VE	VE	VE
E_4		E	VE	M	VE	E	ME	VE	ME	VE
E_5		VE	VE	VE	E	M	M	VE	VE	ME
E_1	KPI_7	ME	E	M	VE	E	E	E	E	MU
E_2		E	E	M	E	E	ME	E	E	M
E_3		E	M	M	E	E	VE	E	E	E
E_4		E	E	M	VE	E	E	E	E	E
E_5		ME	M	M	VE	ME	ME	E	E	E
E_1	KPI_8	E	ME	VE	E	M	ME	E	MU	ME
E_2		E	VE	E	E	E	E	E	E	E
E_3		ME	ME	E	M	ME	VE	E	E	M
E_4		E	VE	VE	E	E	E	E	MU	ME
E_5		E	ME	VE	ME	E	M	E	E	M
E_1	KPI_9	VE	VE	E	VE	VE	MU	ME	VE	E
E_2		VE	E	E	E	VE	VE	VE	E	E
E_3		VE	E	E	E	VE	E	VE	ME	E
E_4		E	E	M	E	M	VE	VE	M	E
E_5		E	ME	E	VE	ME	U	VE	VE	E
E_1	KPI_{10}	VE	VE	VE	ME	VE	MU	VE	VE	VE
E_2		VE	M	VE	E	E	ME	ME	E	E
E_3		VE	E	VE	E	VE	VE	M	ME	ME
E_4		VE	E	VE	ME	M	VE	VE	ME	M
E_5		VE	VE	VE	E	E	E	E	ME	E
E_1	KPI_{11}	E	VE	VE	VE	E	ME	ME	M	VE
E_2		E	ME	VE	ME	VE	VE	VE	M	M
E_3		E	ME	VE	ME	ME	E	VE	ME	MU
E_4		ME	VE	E	VE	E	VE	E	M	E
E_5		E	VE	VE	VE	VE	MU	VE	VE	VE
E_1	KPI_{12}	E	VE	E	VE	E	E	VE	ME	M
E_2		VE	ME	VE	E	ME	VE	ME	VE	ME
E_3		VE	M	E	M	E	E	VE	VE	E
E_4		VE	VE	ME	VE	VE	VE	VE	E	VE
E_5		E	E	VE	ME	VE	VE	VE	VE	ME

Modeling of the grades in FFS, which are given in the form of linguistic expressions, are realized based on the values given in Table 1, and the results are shown in Table 5.

Table 5. Modeling the grades in FFS

$$X_{ij}=\begin{pmatrix}
\begin{pmatrix}0,8&0,3\\0,9&0,2\\0,8&0,3\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,6&0,6\\0,3&0,8\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,7&0,5\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,6&0,6\\0,3&0,8\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,8&0,3\\0,7&0,5\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,6&0,6\\0,9&0,2\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,8&0,3\\0,8&0,3\\0,5&0,7\\0,7&0,5\end{pmatrix}\\
\begin{pmatrix}0,8&0,3\\0,8&0,3\\0,9&0,2\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,6&0,6\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,6&0,6\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,3&0,8\\0,6&0,6\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,8&0,3\\0,9&0,2\\0,5&0,7\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,7&0,5\\0,9&0,2\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,7&0,5\\0,7&0,5\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,6&0,6\\0,6&0,6\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,3&0,8\\0,5&0,7\\0,2&0,9\\0,9&0,2\end{pmatrix}\\
\begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,8&0,3\\0,8&0,3\\0,3&0,8\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,8&0,3\\0,9&0,2\\0,9&0,2\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,7&0,5\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,7&0,5\\0,7&0,5\\0,7&0,5\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix}\\
\begin{pmatrix}0,9&0,2\\0,8&0,3\\0,9&0,2\\0,8&0,3\\0,5&0,7\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,6&0,6\\0,2&0,9\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,7&0,5\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,8&0,3\\0,7&0,5\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,9&0,2\\0,7&0,5\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,8&0,3\\0,7&0,5\\0,8&0,3\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,7&0,5\\0,8&0,3\\0,7&0,5\end{pmatrix}\\
\begin{pmatrix}0,9&0,2\\0,7&0,5\\0,9&0,2\\0,7&0,5\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,6&0,6\\0,8&0,3\\0,7&0,5\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,9&0,2\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,9&0,2\\0,8&0,3\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,8&0,3\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,7&0,5\\0,7&0,5\\0,9&0,2\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,9&0,2\\0,9&0,2\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,6&0,6\\0,9&0,2\\0,8&0,3\\0,9&0,2\end{pmatrix}\\
\begin{pmatrix}0,8&0,3\\0,7&0,5\\0,8&0,3\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,7&0,5\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,6&0,6\\0,9&0,2\\0,6&0,6\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,7&0,5\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,6&0,6\\0,7&0,5\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,7&0,5\\0,9&0,2\\0,7&0,5\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,7&0,5\\0,9&0,2\\0,9&0,2\\0,7&0,5\end{pmatrix}\\
\begin{pmatrix}0,7&0,5\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,6&0,6\\0,8&0,3\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,6&0,6\\0,6&0,6\\0,6&0,6\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,8&0,3\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,7&0,5\\0,9&0,2\\0,8&0,3\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,5&0,7\\0,6&0,6\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix}\\
\begin{pmatrix}0,8&0,3\\0,8&0,3\\0,7&0,5\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,7&0,5\\0,9&0,2\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,8&0,3\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,6&0,6\\0,8&0,3\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,8&0,3\\0,7&0,5\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,8&0,3\\0,9&0,2\\0,8&0,3\\0,6&0,6\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,5&0,7\\0,8&0,3\\0,8&0,3\\0,5&0,7\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,8&0,3\\0,6&0,6\\0,7&0,5\\0,8&0,3\end{pmatrix}\\
\begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,8&0,3\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,6&0,6\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,6&0,6\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,5&0,7\\0,9&0,2\\0,8&0,3\\0,9&0,2\\0,3&0,8\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,7&0,5\\0,6&0,6\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\\0,8&0,3\end{pmatrix}\\
\begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,6&0,6\\0,8&0,3\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,8&0,3\\0,8&0,3\\0,7&0,5\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,9&0,2\\0,6&0,6\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,5&0,7\\0,7&0,5\\0,9&0,2\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,6&0,6\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,7&0,5\\0,7&0,5\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,7&0,5\\0,6&0,6\\0,8&0,3\end{pmatrix}\\
\begin{pmatrix}0,8&0,3\\0,8&0,3\\0,8&0,3\\0,7&0,5\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,7&0,5\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,9&0,2\\0,9&0,2\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,7&0,5\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,7&0,5\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,8&0,3\\0,9&0,2\\0,5&0,7\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,9&0,2\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,6&0,6\\0,7&0,5\\0,6&0,6\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,6&0,6\\0,5&0,7\\0,8&0,3\\0,9&0,2\end{pmatrix}\\
\begin{pmatrix}0,8&0,3\\0,9&0,2\\0,9&0,2\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,6&0,6\\0,9&0,2\\0,8&0,3\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,8&0,3\\0,7&0,5\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,8&0,3\\0,6&0,6\\0,9&0,2\\0,7&0,5\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,7&0,5\\0,8&0,3\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,8&0,3\\0,9&0,2\\0,8&0,3\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,9&0,2\\0,7&0,5\\0,9&0,2\\0,9&0,2\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,7&0,5\\0,9&0,2\\0,9&0,2\\0,8&0,3\\0,9&0,2\end{pmatrix} & \begin{pmatrix}0,6&0,6\\0,7&0,5\\0,8&0,3\\0,9&0,2\\0,7&0,5\end{pmatrix}
\end{pmatrix}$$

Step 4: Unification of the KPI score at the level of each sub-process was realized using operator *FFWPG* Equation (5), where the decision matrix X_{ij} is formed based on the expression Equation (3):

$$X_{ij}=\begin{pmatrix}
(0,8502\ \ 0,2693) & (0,7484\ \ 0,5873) & (0,8143\ \ 0,3527) & (0,7484\ \ 0,5873) & (0,8502\ \ 0,2693) & (0,7839\ \ 0,4375) & (0,9001\ \ 0,2003) & (0,8322\ \ 0,3938) & (0,7117\ \ 0,5394) \\
(0,8502\ \ 0,2693) & (0,8059\ \ 0,4015) & (0,8195\ \ 0,4324) & (0,7679\ \ 0,5702) & (0,8276\ \ 0,4543) & (0,8271\ \ 0,3923) & (0,7663\ \ 0,4687) & (0,7432\ \ 0,4759) & (0,7083\ \ 0,7314) \\
(0,9001\ \ 0,2003) & (0,9001\ \ 0,2003) & (0,8231\ \ 0,5267) & (0,8195\ \ 0,4324) & (0,7843\ \ 0,3624) & (0,8271\ \ 0,3923) & (0,7471\ \ 0,4435) & (0,88600,2282) & (0,8002\ \ 0,3004) \\
(0,8276\ \ 0,4543) & (0,7998\ \ 0,6488) & (0,8271\ \ 0,3923) & (0,8271\ \ 0,3923) & (0,8002\ \ 0,3004) & (0,8195\ \ 0,4324) & (0,8002\ \ 0,3004) & (0,7344\ \ 0,4749) & (0,7998\ \ 0,4000) \\
(0,8271\ \ 0,3923) & (0,7628\ \ 0,4975) & (0,8602\ \ 0,3315) & (0,8392\ \ 0,3425) & (0,88600,2282) & (0,7737\ \ 0,4697) & (0,9001\ \ 0,2003) & (0,85000,3842) & (0,8542\ \ 0,3858) \\
(0,8143\ \ 0,3527) & (0,8602\ \ 0,3315) & (0,7966\ \ 0,4929) & (0,8392\ \ 0,3425) & (0,7741\ \ 0,4088) & (0,7427\ \ 0,5212) & (0,9001\ \ 0,2003) & (0,81400,4312) & (0,8271\ \ 0,3923) \\
(0,7667\ \ 0,4074) & (0,7432\ \ 0,4759) & (0,6003\ \ 0,6003) & (0,8695\ \ 0,2504) & (0,7843\ \ 0,3624) & (0,7998\ \ 0,4000) & (0,8002\ \ 0,3004) & (0,8002\ \ 0,3004) & (0,7352\ \ 0,5178) \\
(0,7843\ \ 0,3624) & (0,81400,4312) & (0,8695\ \ 0,2504) & (0,7553\ \ 0,4447) & (0,7553\ \ 0,4447) & (0,7906\ \ 0,4386) & (0,8002\ \ 0,3004) & (0,7268\ \ 0,5526) & (0,7344\ \ 0,4749) \\
(0,8695\ \ 0,2504) & (0,8143\ \ 0,3527) & (0,7741\ \ 0,4088) & (0,8502\ \ 0,2693) & (0,8435\ \ 0,4259) & (0,7951\ \ 0,5950) & (0,87800,3198) & (0,8195\ \ 0,4324) & (0,8002\ \ 0,3004) \\
(0,9001\ \ 0,2003) & (0,8322\ \ 0,3938) & (0,9001\ \ 0,2003) & (0,7667\ \ 0,4074) & (0,8322\ \ 0,3938) & (0,8145\ \ 0,4832) & (0,8195\ \ 0,4324) & (0,7839\ \ 0,4375) & (0,7906\ \ 0,4386) \\
(0,7843\ \ 0,3624) & (0,85000,3842) & (0,88600,2282) & (0,85000,3842) & (0,8392\ \ 0,3425) & (0,8145\ \ 0,4832) & (0,8602\ \ 0,3315) & (0,7296\ \ 0,5432) & (0,8061\ \ 0,5093) \\
(0,8695\ \ 0,2504) & (0,8195\ \ 0,4324) & (0,8392\ \ 0,3425) & (0,8195\ \ 0,4324) & (0,8392\ \ 0,3425) & (0,8695\ \ 0,2504) & (0,87800,3198) & (0,8602\ \ 0,3315) & (0,7737\ \ 0,4697)
\end{pmatrix}$$

Based on the expression Equation (6), the matrix X_{ij} is normalized, as well as the determination of the score value according to (Senapati *et al.*, 2020), based on which the following matrix is obtained.

$$X_{ij}=\begin{pmatrix}
0,595 & 0,217 & 0,496 & 0,217 & 0,595 & 0,398 & 0,721 & 0,515 & 0,204 \\
0,595 & 0,459 & 0,469 & 0,267 & 0,473 & 0,506 & 0,347 & 0,303 & -0,036 \\
0,721 & 0,721 & 0,411 & 0,469 & 0,435 & 0,506 & 0,330 & 0,684 & 0,485 \\
0,473 & 0,239 & 0,506 & 0,506 & 0,485 & 0,469 & 0,485 & 0,289 & 0,448 \\
0,506 & 0,321 & 0,600 & 0,551 & 0,684 & 0,359 & 0,721 & 0,557 & 0,566 \\
0,496 & 0,600 & 0,386 & 0,551 & 0,396 & 0,268 & 0,721 & 0,459 & 0,506 \\
0,383 & 0,303 & 0,000 & 0,642 & 0,435 & 0,448 & 0,485 & 0,485 & 0,259 \\
0,435 & 0,459 & 0,642 & 0,343 & 0,343 & 0,410 & 0,485 & 0,215 & 0,289 \\
0,642 & 0,496 & 0,396 & 0,595 & 0,523 & 0,292 & 0,644 & 0,469 & 0,485 \\
0,721 & 0,515 & 0,721 & 0,383 & 0,515 & 0,428 & 0,469 & 0,398 & 0,410 \\
0,435 & 0,557 & 0,684 & 0,557 & 0,551 & 0,428 & 0,600 & 0,228 & 0,392 \\
0,642 & 0,469 & 0,551 & 0,469 & 0,551 & 0,642 & 0,644 & 0,600 & 0,359
\end{pmatrix}.$$

Step 5: Determination of the largest x_i^+ and the least x_i^- values for certain criteria Equation (7):

$$A^+=(0,721\quad 0,721\quad 0,721\quad 0,642\quad 0,684\quad 0,642\quad 0,721\quad 0,684\quad 0,566).$$
$$x_1^+=(0,90010,2003);\ x_2^+=(0,90010,2003);$$
$$x_3^+=(0,90010,2003);\ x_4^+=(0,86950,2504);$$
$$x_5^+=(0,88600,2282);\ x_6^+=(0,86950,2504);$$
$$x_7^+=(0,88600,2282);\ x_8^+=(0,85420,3858);$$
$$x_9^+=(0,90010,2003).$$
$$A^-=(0,383\quad 0,217\quad 0,000\quad 0,217\quad 0,343\quad 0,268\quad 0,330\quad 0,215\quad -0,036).$$
$$x_1^-=(0,76670,4074);\ x_2^-=(0,74840,5873);\ x_3^-=(0,60030,6003);$$
$$x_4^-=(0,74840,5873);\ x_5^-=(0,75530,4447);\ x_6^-=(0,74270,5212);$$
$$x_7^-=(0,74710,4435);\ x_8^-=(0,72680,5526);\ x_9^-=(0,70830,7314).$$

Step 6: Calculation the value of the S_j (pessimistic solution) Equation (8):

$S_1 = 0{,}493; S_2 = 0{,}558; S_3 = 0{,}290; S_4 = 0{,}567; S_5 = 0{,}359;$
$S_6 = 0{,}471; S_7 = 0{,}763; S_8 = 0{,}701; S_9 = 0{,}368; S_{10} = 0{,}310;$

$S_{11} = 0{,}472; S_{12} = 0{,}302.$, where according to Equation (11): $S^+ = (0{,}290)$ i.e.: $S^+ = (0{,}763)$ and R_j (the expected solution) Equation (9):

$R_1 = 0{,}126; R_2 = 0{,}113; R_3 = 0{,}091; R_4 = 0{,}146; R_5 = 0{,}149;$
$R_6 = 0{,}180; R_7 = 0{,}263; R_8 = 0{,}237; R_9 = 0{,}081; R_{10} = 0{,}069;$
$R_{11} = 0{,}237; R_{12} = 0{,}073.$, where according to Equation (12) $R^+ = (0{,}069); R^- = (0{,}263);$

Applying Equation (13), the weight of the group feature maximization criterion is obtained $\upsilon = 0{,}556$.

Step 7: Calculation the values of the Q_j (compromise solution) Equation (10):

$Q_6 = 0{,}468; Q_7 = 1; Q_8 = 0{,}870; Q_9 = 0{,}120; Q_{10} = 0{,}024;$ $Q_1 = 0{,}370; Q_2 = 0{,}416; Q_3 = 0{,}051; Q_4 = 0{,}501; Q_5 = 0{,}266; Q_{11} = 0{,}601; Q_{12} = 0{,}023.$

Comparing the obtained values of Q_j in relation to S_j and R_j is given in the following Table 6.

Table 6. Ranking of KPIs based on Q_j values

KPI_i	S_i	R_i	Q_i
KPI_1	8	6	6
KPI_2	9	5	7
KPI_3	1	4	3
KPI_4	10	7	9
KPI_5	4	8	5
KPI_6	6	9	8
KPI_7	12	12	12
KPI_8	11	10	11
KPI_9	5	3	4
KPI_{10}	3	1	2
KPI_{11}	7	10	10
KPI_{12}	2	2	1

The results of the model determined the ranking of KPIs, i.e., the importance and impact of each KPIs on the maintenance and overhaul process. KPIs that have a greater influence on the maintenance process are ranked from 1 to 8, and KPIs with less influence from 9 to 12. KPIs that are ranked as less influential are certainly important for the maintenance and overhaul process and are not excluded from consideration.

5. DISCUSSION OF THE RESULTS

The developed model for measuring KPIs of the maintenance process on the example of technical military systems showed the values of KPIs, based on which the conclusion is reached: what is their impact on the process; how easy it is to identify the problem; how to direct the management of a business organization which KPIs should pay attention.

The obtained results showed that KPI_7 - "degree of coordination with other units" has the least impact on the maintenance process, while KPI_{12} - "availability of workshop capacities" has the greatest impact on the maintenance process. In addition, KPI_{12}, KPI_{10} and KPI_3 play a very important role in the maintenance process, i.e., "availability of experts" and "availability of spare parts and consumables". The Delphi method is used in the model, with which a compromise is reached in determining the relative importance of sub-processes. The greatest importance is assigned to sub-process PP_1 - "preliminary defection," which is carried out on the asset in order to find failure and identify the cause of failure. In practice, this sub-process is very important, considering that it channels the further flow of assets through maintenance. The quality of the failure defection determines which specialists should be hired, how long it takes to procure spare parts, and how long it takes to dismantle the defective ones and to assemble the correct assemblies. For management, time is a very important factor for two reasons. The first reason is to return the asset to the user for use as soon as possible, and the second is to prepare the capacities for the maintenance and overhaul of other assets as soon as possible. The time that the asset spends in the process more than the normatively prescribed time for a certain type of repair represents losses. Issues generated from the most important KPIs (ranked from 1 to 8) are bottlenecks for the maintenance process. Therefore, it is necessary to pay attention to the capacities where maintenance is carried out in terms of being equipped with modern devices for measurements and tests, tools for disassembly and assembly, working conditions, the presence of safety equipment at work, as well as other auxiliary means that are necessary for the maintenance process.

The sensitivity test of the proposed model itself is shown through the analysis of the value of the compromise solution when the weight value of the criterion of the maximized group feature is changed and the analysis of the results obtained by applying another model.

The analysis of the value of the compromise solution Q_j in relation to other solutions was realized by examining the behavior of the developed model when the value of υ - the weight of the criterion of the maximized group feature is changed. Table 7 shows the results of ranked KPIs based on the value of Q_j when υ takes a value from 0 to 1. The graphical representation of the results is given in Figure 2. Based on the obtained results, it can be seen that for values of υ from 0 to 0.5, the majority of KPIs have the same rank, while for the values from 0.6 to 1, there is a change in rank for half of the KPIs. Also, the results have shown that the value υ =0.556, which is obtained based on equation (9), is the limit value when a change of rank occurs, i.e., a compromise solution is reached. It could be concluded that for different υ, there are no big changes in the rank of KPIs, which is a confirmation that the model is stable and less sensitive to the changes of υ.

Table 7. Rank of the KPIs based on the value of Q_j, when υ takes values from 0 to 1

KPI_i	υ=0	υ=0,1	υ=0,2	υ=0,3	υ=0,4	υ=0,5	**υ=0,556**	υ=0,6	υ=0,7	υ=0,8	υ=0,9	υ=1
KPI_1	6	6	6	7	6	6	**6**	6	6	6	6	6
KPI_2	5	5	5	5	7	7	**7**	7	7	7	7	8
KPI_3	4	4	4	3	3	3	**3**	3	3	3	3	3
KPI_4	7	8	8	8	8	9	**9**	9	9	9	9	9
KPI_5	8	7	7	6	5	5	**5**	5	5	5	5	5
KPI_6	9	9	9	9	9	8	**8**	8	8	8	8	7
KPI_7	12	12	12	12	12	12	**12**	12	12	12	12	12
KPI_8	11	11	11	11	11	11	**11**	11	11	11	11	11
KPI_9	3	3	3	4	4	4	**4**	4	4	4	4	4
KPI_{10}	1	1	1	1	1	1	**2**	2	2	2	2	2
KPI_{11}	11	10	10	10	10	10	**10**	10	10	10	10	10
KPI_{12}	2	2	2	2	2	2	**1**	1	1	1	1	1

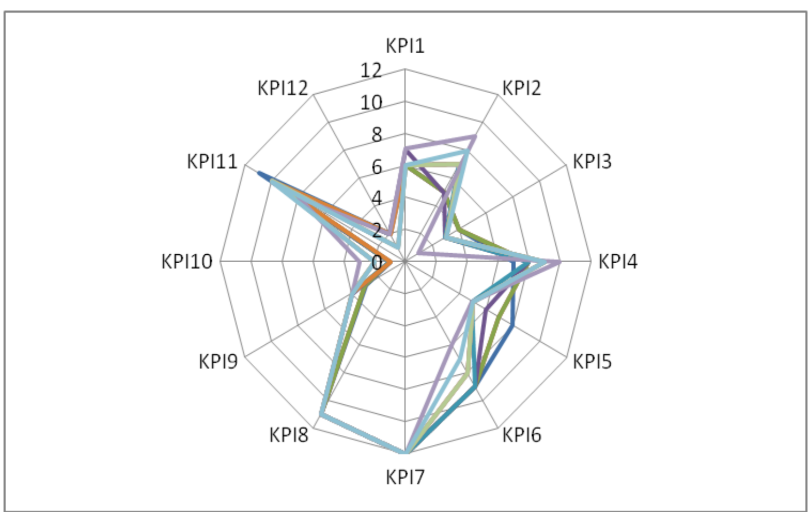

Figure 2. Values of the KPIs for different values of υ

The results of the developed model, which are based on the calculation of the values of KPIs obtained by the VIKOR method, were compared with the results obtained by the model that used the method ELECTRE (Elimination and Choice Translating Reality) to calculate the values of KPIs. The results of the two models are given in Table 8 and graphically shown in Figure 3. The two models used the same input results modeled by FFS, with the same sub-process weights ω_{ppi} obtained using the Delphi method extended with FFS. By comparing the results, it can be seen that in both models, the best-ranked KPI_{12} and the lowest-ranked KPI_7. Although these are two different models, one of which is based on the principle of compromise (VIKOR) and the other on the principle of conflicts (ELECTRE), the results confirmed that the developed model gives the same results for most of the KPIs.

Table 8. Comparison of the results of KPIs obtained by VIKOR and ELECTRE method

KPI_i	ELECTRE	VIKOR
KPI_1	11	6
KPI_2	7	7
KPI_3	5	3
KPI_4	9	9
KPI_5	2	5
KPI_6	6	8
KPI_7	12	12
KPI_8	10	11
KPI_9	4	4
KPI_{10}	3	2
KPI_{11}	8	10
KPI_{12}	1	1

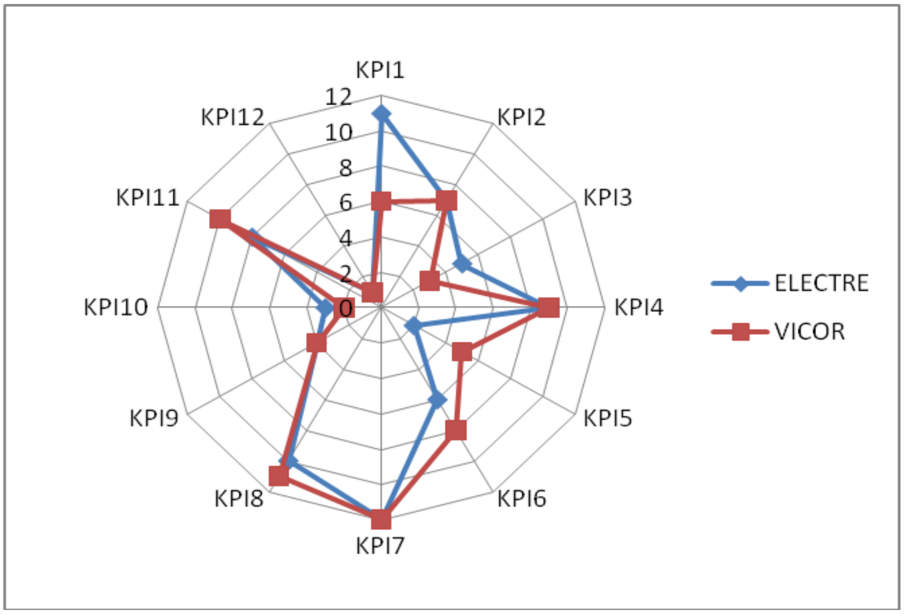

Figure 3. Graphic representation of KPIs values using the VIKOR and ELECTRE methods

6. CONCLUSION

Process performance measurement enables business organizations to gain insight into the extent to which goals have been achieved. For the stated needs of organizations, performance measurement models have been developed. Organizations used a number of standard models such as the Performance Pyramid, Balanced Scorecard (BSC), SCOR model, EFQM and others. However, in some cases, due to the complexity of technology and processes, the application of standard models is not possible. That is, the results obtained by their application would not reflect the true picture of the process, which would lead the organization's management in the wrong direction of management.

The specificity of the maintenance process required the development of a hybrid model, which is efficient and easily applicable in practice.

The structure of the model required a fuzzy approach to problem-solving because the input data have a qualitative nature. Fermatean fuzzy sets are applied in the model, which is an upgrade of the intuitive fuzzy numbers created by Atanassov (1983). Based on the analysis of previous research, the justification of application in different areas has been demonstrated. During the assessment, there is often uncertainty about the final decision. Intuitive numbers are precisely developed to include certainty or uncertainty in the decision made by the decision maker. Evaluation of KPIs of complex processes cannot be carried out by incompetent persons but by experts in the given field. The fastest way to collect data while reaching consensus is possible using the Delphi method.

Obtaining the values of KPIs is realized using the VIKOR method. The VIKOR method is proved to be a less complex method for application than others, and the analysis of the results of the method has shown that the method is stable to changes in certain parameters, as well as that the same or similar results are obtained by applying more complex methods such as the ELECTRE method.

Model testing is carried out on the example of maintenance and overhaul of technical military systems. The obtained results have helped the management of the organization to improve the maintenance process.

The contribution of the work is the development of a hybrid model for measuring process performances, which improved the existing theory and practice. The application of the model has been confirmed in practice by measuring the KPIs of the process in a complex business organization that deals with the maintenance and overhaul of military-technical systems. The proposed model is confirmed by the management of the business organization in terms of efficiency and simplicity of application in practice. With the proposed model, existing methods for performance measurement are enriched by using a flexible combination of well-established tools for group decision-making under conditions of complexity and uncertainty with multi-criteria optimization methods. The proposed model enable a better insight into the importance of individual KPIs, which facilitated the management of activities and the adoption of measures for the organization's operations improvement. Future research is to focus on monitoring the state of application of the model and its further improvement.

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