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HYBRID METHOD FOR SELECTION OF OPTIMAL SAFETY IMPROVEMENT STRATEGY IN MICRO-ENTERPRISES

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Abstract. *When assessing the impacts of the safety system, different aspects are taken into account. However, the organization's size is often overlooked. Safety, as a vital support process, requires the engagement of certain resources, which are very limited in smaller organizations. Defining priorities and optimising the process are crucial for achieving the desired effects. This paper presents a framework for improving safety based on representative strategies describing organisational priorities and drivers for improvement. Multi-attributive analysis is employed to assess the significance of indicators. The hybrid method involves determining the weights of the criteria by applying fuzzy preferences, after which the ranking of alternatives is performed using the multi-attributive border approximation area comparison. The findings indicate that the organisation's size and the scarcity of available safety resources predominantly influence the rankings of the alternatives.*

Key words: *safety, indicators, safety management, fuzzy logic, multi-attributive border approximation area comparison*

1. INTRODUCTION

Occupational safety is related to various aspects that contribute to mental and physical health and well-being in the workplace and work environment. The primary goal is to prevent work-related injuries and illnesses, primarily achieved by identifying hazards to which employees are exposed and applying procedures to prevent exposure and/or mitigate the consequences. To achieve this, an effective safety system must be in place.

The safety system has evolved through various stages of development. Initially, it was managed ad hoc, with employees responsible for their own safety. Over time, this approach evolved into a systematic and procedural methodology. Employers are now accountable for providing optimal conditions and equipment to ensure safe work environments, with

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designated personnel responsible for implementation within the organization. Furthermore, the approach to safety has shifted from individual responsibility to a collective effort and from corrective measures to preventive strategies. This evolution has given rise to risk analysis methods rooted in a systems approach, the formulation of appropriate legal regulations, and the implementation of management systems guided by a process-oriented approach and continuous improvement [1, 2]. In contemporary contexts, these procedures are formalised and precisely defined in the requirements of various system standards related to safety.

The complexity of the safety system from the socio-technical aspect of consideration is reflected in the connection between the technologies used to perform work activities, the employees who perform work activities, the organizational approach to safety and the availability of the necessary resources, as well as the influence of the environment that defines legislative obligations, standardization recommendations, and examples of good practice.

The safety system is not considered independent of other systems, so it is characterised by basic functions and principles of integration. Awareness and the exchange of experiences are two of the key success factors for safety systems. In order to identify potential problems or define priorities for the development of the safety system, it is necessary to consider performance indicators, that is, to classify and, if necessary, rank the aspects describing the characteristics of the safety system [3]. The hierarchical organisation of factors and indicators enables the application of multi-criteria analysis methods in the process of analysing the safety system. Some of those methods are presented in [4]. The application of linguistic variables makes it easier for people who are not familiar with the details of multi-criteria analysis to express their views, and these variables can be easily translated into fuzzy numbers, simply introducing uncertainty into the analysis [5-7]. Hierarchical structure is sometimes not enough to describe the problem of safety system performance evaluation, so the solution is found in the network dependence of factors and indicators, as suggested in [8].

In the process of development, the safety system went through different stages. Understanding the dangers employees face and their impact on safety and health is fundamental to any safety system. Limited organisational resources often question the possibility of application in practice. It seems that a large part of the regulation is adapted to large organisations, while smaller business entities often have to allocate certain resources by engaging external sources. The choice of approach significantly determines the necessary organisational performance, available resources, and costs [2, 3].

In previous years, small enterprises were frequent subjects of research activities [9-19]. They are characterised by their innovative nature and limited resources for functioning and development.

2. METHOD

The proposed method is shown in Figure 1. In the preparatory phase, a literature review is performed and criteria are identified. Since it is a group decision, experts are chosen, and their influence on the decision is determined based on their experience. In the first phase, experts compare individual criteria, and the consistency of that comparison is checked. Consistent comparisons are used to calculate an aggregate matrix, which is used to determine the weights of the criteria. In the second phase, identified strategies are ranked based on criteria, and priorities are determined. Finally, different scenarios during a sensitivity analysis can be considered.

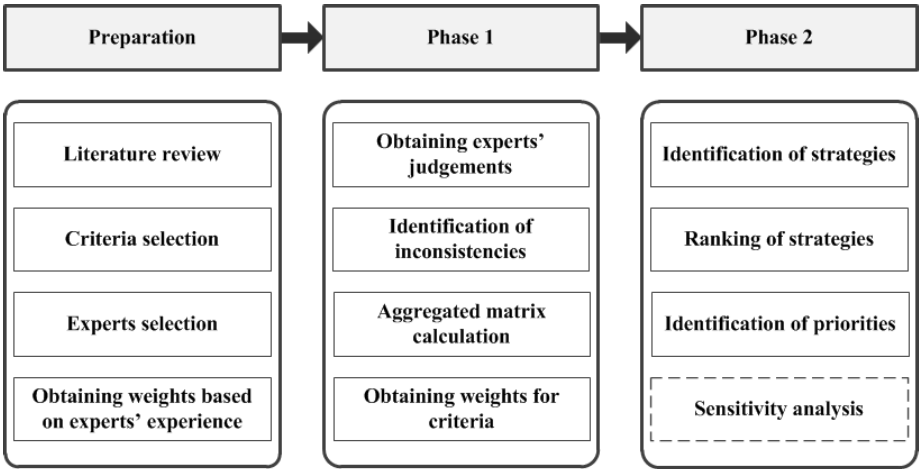

Fig. 1 The structure of the method.

Taking into consideration national regulations on occupational safety in Serbia as well as contemporary research in this area [7-20], for the previously mentioned processes and quality elements of occupational safety management, the following criteria are defined, as shown in Table 1.

Table 1 Proposed criteria affecting occupational safety decisions at the organisational level.

Criterion	Description
Human factor (K_1)	▪ human resources necessary for the implementation of changes, with certain skills, education, and the desire for changes in the work environment and the application of innovative safety measures
Financial resources (K_2)	▪ the basis for the implementation of any organisational change, especially in the field of safety, as a supporting process in which appropriate training of employees is necessary
Management (K_3)	▪ an appropriate management style has a positive influence on the development of all activities and encourages the development of ideas and their implementation in the work environment
Technology (K_4)	▪ the level of applied technology, in itself, defines a certain level of protection and requires compliance with special work procedures and the technical skills of employees
Environment (K_5)	▪ the business environment encourages the need to implement solutions that are defined by regulations and market requirements or initiated by the exchange of experiences with related organisations
Organisational context (K_6)	▪ the way the organisation functions, which encourages teamwork and interpersonal exchange of experiences, enables organisational learning as well as the application of modern or innovative solutions

The human factor is an unavoidable factor in the creation of innovations. It affects the creation of a healthy organisational climate and shapes an environment where the drive for improvement and change is cultivated. Positive effects can be stimulated by the educational level of the employer, the tertiary education of the employees, the knowledge of at least one foreign language, or the special engagement of one of the employees in innovative activities.

The financial aspect is particularly important due to the very limited possibilities for using funds outside the core activities of micro-enterprises. That is why the possibility of using different sources of funding outside of the internal budget intended for development in the field of occupational safety is significant. The introduction of new technologies can indirectly affect safety, requiring additional training for employees or introducing a higher level of protection.

Planning in micro-enterprises is a limiting factor because it is often not aimed at improvement and development but at maintaining the existing level of functioning. The capacity for adequate control, with the aim of identifying potential problems and achieving the necessary level of quality, is limited by the absence of a strategic plan and inadequate management of ideas.

The external environment dictates legal obligations, and standard procedures are determined in collaboration with customers, suppliers, and other stakeholders. Collaborating with similar organisations within a knowledge community or a community of practice can provide valuable ideas and examples of best practices. The organisational context allows for the establishment of a suitable organisational structure and culture. It promotes teamwork, knowledge exchange, and experience sharing while motivating the development and implementation of innovative measures.

For the purposes of identifying the optimal strategy, the aforementioned criteria are ranked using the group fuzzy analytic hierarchy process (FAHP). This method was chosen due to the simplicity of the procedure and the possibility of checking consistency. A group of *m* experts, with certain experience in the field of safety and innovations, participates in determining the weight of the criteria based on the θ_k coefficient, which describes the influence of an individual expert as follows:

$$\theta_k = \frac{d_k \cdot e_k \cdot f_k}{\sum_{k=1}^{m} d_k \cdot e_k \cdot f_k}, \tag{1}$$

where d_k represents the total professional experience of the expert, e_k describes experience in safety, and f_k describes experience with innovation management, where d_k, e_k, $f_k \in \{1,2,3\}$. Here, 1 represents basic experience (3 to 5 years), 2 represents moderate experience (6 to 9 years), and 3 represents extensive experience (10+ years).

Using the comparison matrix $A^{(k)}$ from individual expert *k*, with dimensions *n*x*n*, the elements a_{ij} of the aggregate matrix are determined as follows:

$$a_{ij} = \prod_{k=1}^{m} (a_{ij}^{k})^{\theta_k}, \tag{2}$$

where *m* represents the total number of experts whose individual ratings are aggregated. The cyclic consistency index (CCI) is used to assess the consistency of the obtained aggregate matrix [21]. Defuzzification, which determines the crips value, is performed using the following expression:

$$A = \frac{(a_3 - a_1) + (a_2 - a_1)}{3} + a_1, \tag{3}$$

where (a_1,a_2,a_3) represents a fuzzy number, an element of the fuzzy aggregate matrix.

After determining the weights, the alternatives are ranked using the MABAC (Multi-attributive border approximation area comparison) method. This method employs a criterion function to assess the differences between the observed alternatives and the border approximation area [22]. The initial matrix for *n* criteria and *m* alternatives consists of evaluation vectors, representing the alternatives' performance according to each criterion. Normalising this matrix by criteria (columns) is crucial, taking into account whether the criterion follows a cost-type (lower values are better) or benefit-type (higher values are better) logic. This normalisation process results in a standardised matrix. The components of the weight matrix are calculated using the following formula [22]:

$$v_{ij} = w_i \cdot (n_{ij} + 1), \tag{4}$$

where w_i presents the weight of the criteria *i*, while n_{ij} presents an element of the normalized matrix. Using these values, a border approximation area (BAA) is determined for each criterion, calculated as the geometric mean of the values v_{ij}:

$$b_i = \left(\prod_{j=1}^{m} v_{ij} \right)^{1/m}, \tag{5}$$

where *m* represents the number of alternatives. The values b_i for all *n* criteria form the border approximation area vector $B=[b_1\ b_2\ \dots\ b_n]$. It is used to calculate the distance of the alternative d_{ij} in relation to the border approximation area as

$$d_{ij} = v_{ij} - b_j, \tag{6}$$

forming the matrix D_{mxn} for *n* decision criteria and *m* alternatives. A positive value of d_{ij} defines that the alternative is in the upper border approximation area (B^+), closer to the ideal alternative, while a negative value defines belonging to the lower border approximation area (B^-), closer to the anti-ideal alternative [22]. The ranking of alternatives is performed using the following criterion function:

$$F_i = \sum_{j=1}^{n} d_{ij}, \tag{7}$$

for the alternative *i*, based on the *n* criteria used.

3. Results and Discussion

In 2021, there were 612 large enterprises in Serbia, with 408.36 thousand entrepreneurial, micro-, small-, and medium-sized enterprises. According to the number of employees, 546.17 thousand employees worked in large enterprises, while 989.46 thousand employees worked in other enterprises [23]. This means that smaller companies were more numerous (99.85%) and had a higher percentage of employees (64.4%). Numerous other indicators favour smaller companies, but an important aspect that should be highlighted is safety. According to the

Law on Occupational Safety and Health (2023) in the Republic of Serbia, an employer can perform occupational health and safety tasks after passing a professional exam if the enterprise has up to 20 employees, and this is primarily applicable in certain service activities. Often, external experts are hired for safety services. Due to limited resources, especially in the smallest companies, the focus is on the economic survival and development of the core business activity, while supporting activities such as safety remain in the background.

During the analysis, microenterprises were considered. Ten experts, specialising in safety and health at work and innovation activities, participated in defining the weights of the criteria. Their θ_k values are represented by the following vector: Θ={0.11;0.07;0.17;0.11;0.17;0.07;0.17;0.04;0.06;0.04}. As the ranking criteria are descriptive, the experts used fuzzy linguistic descriptors during the ranking. Each criterion is described by one of five descriptors with corresponding fuzzy numbers: I - insignificant impact (1,1,2); II - small impact (1,2,3); III - medium impact (2,3,4); IV - significant impact (3,4,5); V - dominant impact (4,5,5). Based on the comparison matrices of individual experts and their associated θ_k values, an aggregate matrix was determined using Eq. (2), and its element values are shown in Table 2.

Table 2 Aggregate matrix for decision criteria (CCI=0.01) and corresponding weights.

	K_1	K_2	K_3	K_4	K_5	K_6
K_1	(1,1,1)	(0.68,1.38,1.77)	(0.58,1.04,1.53)	(0.8,1.37,2.25)	(1.13,1.89,2.97)	(1.04,2.09,2.99)
K_2	(0.56,0.72,1.47)	(1,1,1)	(0.58,0.89,1.53)	(0.85,1.14,2.26)	(0.92,1.84,2.59)	(0.89,1.83,2.56)
K_3	(0.65,0.96,1.73)	(0.66,1.12,1.73)	(1,1,1)	(0.71,1.25,1.95)	(0.75,1.41,2.02)	(0.96,1.54,2.76)
K_4	(0.45,0.73,1.25)	(0.44,0.88,1.18)	(0.51,0.8,1.41)	(1,1,1)	(0.74,1.26,2.15)	(0.61,1.14,1.69)
K_5	(0.34,0.53,0.89)	(0.39,0.54,1.08)	(0.49,0.71,1.33)	(0.46,0.8,1.36)	(1,1,1)	(0.67,0.93,1.77)
K_6	(0.33,0.48,0.96)	(0.39,0.55,1.13)	(0.36,0.65,1.04)	(0.59,0.88,1.63)	(0.57,1.08,1.5)	(1,1,1)
w_{Ki}	0.214	0.192	0.193	0.151	0.126	0.125

Through defuzzification using Eq. (3), the crisp weights of the criteria w_{Ki} were determined. These values are represented by the weight vector $W=\{w_{Ki}, i=1,6\}$. Criterion K_1 (w_{K1}=0.214) carries the highest weight, whereas the criterion K_6 (w_{K6}=0.125) holds the least significance.

The next step is the ranking alternatives to improve the safety system in microenterprises based on previously defined weights. Considering potential improvements in safety systems for microenterprises, experts proposed the following approaches: (A_1) extensive safety training focused on individual employees, with periodic performance checks; (A_2) precise definition (formalisation) of safety protocols and strict adherence to rules in practice; (A_3) collaboration with other organisations in the same field, involving the exchange of knowledge and experience in safety; (A_4) application of safety labels and signs, active participation of employees, with appropriate rewards; (A_5) utilisation of the best possible work equipment, regular monitoring, and technological improvement. The primary decision matrix is formed through the defuzzification of linguistic descriptors based on criteria. Further, the rule applicable to benefit-type criteria is applied. This results in the creation of the normalized matrix

$$N = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccccc} K_1 & K_2 & K_3 & K_4 & K_5 & K_6 \end{array} \\ \begin{bmatrix} 1.00 & 0.75 & 0.75 & 1.00 & 0.67 & 0.00 \\ 0.25 & 0.25 & 1.00 & 0.67 & 1.00 & 0.67 \\ 0.50 & 0.50 & 0.50 & 0.00 & 0.33 & 1.00 \\ 0.00 & 0.00 & 0.25 & 0.33 & 0.00 & 0.67 \\ 0.25 & 1.00 & 0.00 & 1.00 & 1.00 & 0.33 \end{bmatrix} \end{array}, \quad (8)$$

which serves as the basis for determining the weighted matrix V based on Eq. (4):

$$V = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccccc} K_1 & K_2 & K_3 & K_4 & K_5 & K_6 \end{array} \\ \begin{bmatrix} 0.428 & 0.335 & 0.337 & 0.302 & 0.210 & 0.125 \\ 0.267 & 0.240 & 0.385 & 0.252 & 0.253 & 0.208 \\ 0.321 & 0.288 & 0.289 & 0.151 & 0.168 & 0.249 \\ 0.214 & 0.192 & 0.240 & 0.201 & 0.126 & 0.208 \\ 0.267 & 0.383 & 0.192 & 0.302 & 0.253 & 0.166 \end{bmatrix} \end{array}. \quad (9)$$

Based on Eq. (5), the vector of boundary approximate areas is determined, which is of the form B=[0.291 0.279 0.280 0.234 0.195 0.186]. Based on Eq. (6), the distance matrix of alternatives is determined:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccccc} K_1 & K_2 & K_3 & K_4 & K_5 & K_6 \end{array} \\ \begin{bmatrix} 0.136 & 0.056 & 0.056 & 0.068 & 0.015 & -0.06 \\ -0.02 & -0.04 & 0.104 & 0.018 & 0.057 & 0.208 \\ 0.029 & 0.008 & 0.008 & -0.08 & -0.03 & 0.249 \\ -0.08 & -0.08 & -0.04 & -0.03 & -0.07 & 0.208 \\ -0.02 & 0.104 & -0.09 & 0.683 & 0.057 & 0.166 \end{bmatrix} \end{array}. \quad (10)$$

Eqs. (7) and (10) are used to determine the ranks of the alternatives based on the F_i values shown in Table 3. According to the value of F_i, it follows that alternative A_2 is the preferred (F_{A2}=0.3236), while alternative A_4 is ranked last (F_{A4}=-0.0986). The choice of alternative strategies by the experts indicated the importance of human resource development and the accumulation of organisational knowledge, as well as the clear definition and observance of work or safety procedures (processes). Maintenance of work equipment is something that is most often taken for granted because it is required by law. A solution to insufficient experience has been found in networking related businesses into communities of knowledge or practice.

Table 3 Final ranks of the alternatives.

Alternative	F_i	Rank
A_1	0.2709	3
A_2	0.3236	1
A_3	0.1856	4
A_4	-0.0986	5
A_5	0.2839	2

During the sensitivity analysis, the following four scenarios were considered: (X_1) development of human resources W=(0.5;0.1;0.1;0.1;0.1;0.1); (X_2) development of organisational climate and management W=(0.1;0.1;0.3;0.1;0.1;0.3); (X_3) financial improvement and technological development W=(0.1;0.3;0.1;0.3;0.1;0.1); (X_4) positive environment and organisational context W=(0.1;0.1;0.1;0.1;0.3;0.3). The ranks obtained for previous scenarios are shown in Table 4.

Table 4 Ranks of alternatives and corresponding F_i values for different scenarios.

	X_1		X_2		X_3		X_4	
Alternative	F_i	Rank	F_i	Rank	F_i	Rank	F_i	Rank
A_1	0.3854	1	0.0904	5	0.2793	2	0.0555	5
A_2	0.2013	3	0.6881	1	0.2285	3	0.6699	1
A_3	0.2013	2	0.5548	2	0.0452	4	0.5032	3
A_4	-0.1570	5	0.2798	4	-0.1465	5	0.2116	4
A_5	0.1763	4	0.3965	3	0.4202	1	0.5782	2

When considering different strategies, it is challenging to draw general conclusions applicable to all situations. Therefore, it is essential to focus the research on specific organisations or activities with distinct hazards and potential safety improvements. By elaborating on the criteria and establishing a hierarchical structure of indicators, a more detailed analysis of potential opportunities to enhance the existing occupational safety system becomes feasible.

4. Conclusion

The safety system is often analysed without considering the size of the organization. However, the organisation's size significantly influences the availability of resources required for implementing the safety system, especially if some of these resources need to be allocated to core business activities. Consequently, larger organisations enjoy a significant advantage over smaller ones. Even in large organisations, during crises, efforts are made to cut costs in supporting processes. This puts additional pressure on safety measures in terms of efficient resource utilization. The defined priorities for strategies to improve the safety system in microenterprises underscore this challenge.

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HIBRIDNI METOD ZA IZBOR STRATEGIJE ZA UNAPREĐENJE ZAŠTITE U MIKRO PREDUZEĆIMA

Prilikom razmatranja efekata sistema zaštite uzimaju se u obzir različiti aspekti, ali se najčešće ne razmatra veličina organizacije. Zaštita kao podržavajući proces zahteva angažovanje određenih resursa, koji su u manjim organizacijama veoma ograničeni. Zato je veoma značajno definisanje prioriteta i optimizacija procesa, kako bi se postigli željeni efekti. Ovaj rad prikazuje okvir za poboljšanje zaštite, zasnovan na reprezentativnim strategijama koje opisuju organizacione prioritete i drajvere za poboljšanje. Za utvrđivanje značajnosti indikatora koristi se višeatributivna analiza. Hibridni metod je zasnovan na određivanju težina kriterijuma primenom fazi preferencija, nakon čega se pristupa rangiranju alternativa pomoću višeatributivnog poređenja graničnih aproksimativnih oblasti. Rezultati pokazuju da su rangovi alternativa uzrokovani veličinom organizacije i ograničenim raspoloživim resursima zaštite.

Ključne reči: *zaštita, indikatori, upravljanje zaštitom, fazi logika, višeatributivno poređenje graničnih aproksimativnih oblasti*