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A FUZZY MULTI-CRITERIA DECISION-MAKING MODEL FOR RANKING GRANT PROJECTS: CASE OF UKRAINIAN CIVIC ENGAGEMENT PROGRAMS

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Abstract

This paper proposes a fuzzy multi-criteria decision-making (MCDM) model for transparent and adaptive ranking of grant projects. Existing evaluation approaches in grant management often suffer from subjectivity, incomplete information, and lack of methodological validation. The proposed model integrates fuzzy set theory with a hierarchical multi-criteria structure, allowing both quantitative and qualitative indicators to be incorporated into a unified decision-support framework. The model was tested on real data from the Civic Engagement for Democratization program in Ukraine. Results demonstrate improved ranking accuracy, reduction of variance in expert assessments by 18%, and enhanced transparency compared to conventional weighted-sum and AHP methods. Sensitivity analysis confirms the stability of outcomes under varying weights and membership functions. This research contributes to the development of adaptive evaluation tools for donor organizations and provides directions for future integration with intelligent decision-support systems.

Keywords: Decision support systems, Fuzzy MCDM, Grant management, Hierarchical evaluation, Project ranking.

1. Introduction

Grant funding has become a critical instrument for supporting socio-economic, cultural, and research initiatives worldwide, and in the current context of Ukraine's development it has gained particular importance. Since 2022, the number of both international and national grant programmes aimed at supporting public administration, business, the public sector, science, education, and culture have increased significantly. In this regard, there is a pressing need to create transparent and effective mechanisms for evaluating projects submitted for competitive funding.

Despite the existence of formalised selection procedures, project evaluation remains largely subjective. Experts are often forced to base their judgments on incomplete, qualitative, or difficult-to-compare information, which reduces objectivity and complicates the justification of funding decisions. Traditional ranking methods (e.g., weighted sum, AHP, TOPSIS) also tend to overlook uncertainty and interdependencies between criteria, limiting their effectiveness in the grant evaluation context. These challenges highlight the necessity of adaptive and methodologically rigorous approaches capable of handling uncertainty, multi-criteria complexity, and subjectivity.

Recent advances in decision sciences and fuzzy systems (e.g., Applied Soft Computing, Expert Systems with Applications, Decision Support Systems, 2020-2025) demonstrate the advantages of fuzzy multi-criteria decision-making (MCDM) in addressing these issues. Fuzzy set theory and multicriteria analysis not only allow formalisation of the evaluation procedure but also enable adaptation to the specific requirements of grant programmes. The outcome of their application is a reduction of human factor influence, increased transparency, and more balanced decision-making. Nevertheless, many existing models either lack hierarchical integration of criteria, fail to validate outcomes against benchmarks, or are insufficiently tailored to grant-specific contexts.

Therefore, an urgent scientific task arises: to develop and validate an adaptive fuzzy hierarchical MCDM model for transparent grant project evaluation, tested on real data, which would address uncertainty, reflect the specifics of grant funding, and ensure transparency in the decision-making process.

2. Literature Review and Problem Statement

The problem of effective evaluation of projects submitted for grant funding is being actively studied in the context of growing competition for limited resources and the need to ensure objectivity in decision-making. Existing practices, such as those applied by the Ukrainian Cultural Foundation (UCF), typically rely on fixed expert scales. However, these methodologies often neglect both the weighting of criteria and the inter-criteria interactions, which limits transparency and methodological rigor. Kobelia-Zvir and Zvir [1] classified more than 20 grant criteria (e.g., donor type, form of support, areas of expenditure, legal status of applicants) and propose a functional systematisation, but without formalised models for integrated evaluation. Zimmermann [2] justified the use of fuzzy logic for decision-making under incomplete information, emphasising membership functions, fuzzy numbers, and the Saaty scale.

Hernández and Hidalgo [3] further demonstrated the advantages of fuzzy approaches in socio-economic project evaluation, highlighting their ability to account for subjective expert judgments. Similarly, Bredikhin and Bredikhin [4] adapted multi-criteria ranking approaches such as AHP, TOPSIS, and weighted sum analysis for small business investment projects, which are conceptually relevant for grant applications. Modern research also proposes intelligent decision support systems that combine fuzzy logic and adaptive modelling. For example, Vysochan et al. [5] presented a fuzzy-rule-based expert system for startup evaluation, potentially transferable to grant programme contexts.

Recent international literature confirms a steady shift from crisp MCDM to fuzzy and hybrid models that better capture uncertainty, group disagreement, and hierarchical interdependence. Numerous studies employ hybrid fuzzy AHP-TOPSIS pipelines for weight elicitation and ranking, achieving improved stability of results and better handling of linguistic judgments across software, logistics, and healthcare domains [6-8]. Moving beyond Type-1 fuzzy sets, researchers increasingly apply interval Type-2 fuzzy sets, hesitant fuzzy sets, and integrated frameworks (e.g., DEMATEL+VIKOR) to address higher-order uncertainty and expert hesitancy, improving sensitivity to inter-criteria effects [9, 10]. Group decision-making has also received significant attention, with systematic reviews stressing transparent schemes for expert weighting, consensus building, and reproducible aggregation strategies [11, 12].

Equally important are validation and benchmarking practices. Comparative studies between fuzzy AHP, fuzzy TOPSIS, and their hybrids recommend reporting rank stability underweight perturbations, variance reduction in expert scores, and cross-method agreement as key validation metrics[13]. Evidence of application spans multiple sectors - healthcare project selection [14], supplier and partner evaluation [15], cloud/data analytics choices [16], and civil engineering planning [17]. Yet, despite this breadth, validated applications directly tailored to grant project evaluation remain scarce, especially those using real programme data and hierarchical criteria adapted to grant calls.

Identified gap and contribution. Although prior works substantiate the advantages of fuzzy MCDM in capturing uncertainty, weighting, and expert subjectivity, none provides a universal framework that simultaneously addresses multidimensionality of criteria, hierarchical integration, donor-style constraints, and transparent validation. This gap underscores the need for an adaptive fuzzy hierarchical MCDM model specifically designed for grant project evaluation. The present study addresses this by formalising a hierarchical fuzzy MCDM tailored to grant programmes, validating it against AHP and weighted-sum baselines using real Civic Engagement data, and publishing sensitivity and agreement metrics relevant for donor governance (variance reduction in expert scores, rank correlation with baselines, robustness under ±10-20% weight shocks).

3. Building a Model for Multi-Criteria Analysis of Grant Projects

The object of the study is the processes of evaluating applications submitted to grant competitions under conditions of uncertainty. The main hypothesis is that multi-criteria analysis of project applications, implemented through fuzzy mathematics, can provide more objective and transparent rankings compared to traditional approaches. Since the evaluation system typically has a hierarchical structure, the problem cannot be solved by simple aggregation methods. Building decision-making models for poorly formalised tasks requires appropriate schemes for formalising knowledge, where fuzzy sets serve as the basis for constructing models that adequately reflect the information of the subject area.

The proposed methodology is based on fuzzy sets and hierarchical aggregation of evaluation criteria. Each grant application is assessed against a two-level structure of criteria and sub-criteria, represented as membership functions. The procedure includes:

- Construction of membership functions for sub-criteria.
- Aggregation of partial criteria into higher-level evaluations.
- Application of weighting coefficients derived from expert-defined importance.
- Calculation of integrated fuzzy scores and ranking of projects.

The empirical basis of the study is real evaluation data from the Civic Engagement for Democratization program. Validation is performed through comparative analysis with AHP and weighted-sum methods, demonstrating improved consistency and stability of results. Sensitivity analysis under changes in weights and membership functions confirms the robustness of the proposed model.

3.1. Problem statement

Let a finite Problem statement be given. Let there be given a finite set of applications (projects) for the implementation of grant conditions $Z = \{z_1, z_2, \dots, z_n\} = \{z_j, j = \overline{1,n}\}$ and a goal that is evaluated by a set of unequal criteria $K = \{K^1, K^2, \dots, K^m\} = \{K^i,\ i = \overline{1,m}\}$, for which the coefficients of relative importance of these criteria are known, i.e. $\{\alpha^1, \alpha^2, \dots, \alpha^m\} = \{\alpha^i\ , i = \overline{1,m}\}$, and the degree of satisfaction of the application z_j with the criterion K^i is known, which is given by the membership function $\mu_{K^i}(z_j) \to [0,1]$, i.e. $\mu_{K^i}(z_j) \to [0,1]$.

The task of multicriteria analysis is to order the elements of the set Z according to the criteria of the set K. The best application will be the one that has the highest numerical priority in solving the problem of meeting the grant conditions, i.e. the application that is simultaneously the best by all criteria.

Let us assume that the criterion space has a two-level hierarchical system for evaluating applications. Each criterion K^i included in the set K is, in turn, characterised by a subset of partial criteria, i.e. $K^i = \{K_1^i, K_2^i, \dots, K_{m_i}^i\} = \{K_p^i,\ p = \overline{1,m_i}\}$, which are also defined by the membership function $\mu_{K_p^i}(z_j) \to [0,1]$. The task is to solve the following problem: to obtain an ordered (ranked) list of the attractiveness of applications Z^* based on the results of the evaluations.

3.2. The general scheme for solving the problem

The general scheme for solving the problem can be presented as follows. Consider the problem when the criterion space has a two-level hierarchical structure. Let $\{\mu_{K_p^i}(z_j),\ p = \overline{1,m_i},\ i = \overline{1,m}, j = \overline{1,n}\}$ be the membership functions of the alternative z_j to the partial criteria $\{K_1^i, K_2^i, \dots, K_{m_i}^i\} = \{K_p^i,\ p = \overline{1,m_i}\}$, for which the coefficients of relative importance of these criteria are known, i.e. $\{\alpha_1^i, \alpha_2^i, \dots, \alpha_{m_i}^i\} = \{\alpha_p^i\ , p = \overline{1,m_i}\}$. The generalised solution algorithm can be written as follows:

Step 1. Let $\{\mu_{K_p}(z_j), p = \overline{1, m_{m_i}}\}$ be numbers in the range [0;1] that characterise the level of evaluation of the application z_j according to the criterion $\{K_p^i,\ p = \overline{1, m_i}\}$. The higher the number, the higher the score.

Let's represent the criteria $\{K_p^i,\ p = \overline{1, m_i}\}$ in the form of fuzzy sets $\{\widetilde{K}_p^i,\ p = \overline{1, m_i}\}$ on the universal set $Z = \{z_1, z_2, \ldots, z_n\} = \{z_j, j = \overline{1, n}\}$:

$$\widetilde{K}_p^i = \{\frac{\mu_{K_p^i}(z_1)}{z_1}, \frac{\mu_{K_p^i}(z_2)}{z_2}, \ldots, \frac{\mu_{K_p^i}(z_n)}{z_n}\} \quad (1)$$

Step 2. By aggregating the partial criteria (indicators) of the lower level, each criterion of the upper level of the hierarchy is evaluated, i.e., based on the construction of convolutions of partial criteria $\{K_1^i, K_2^i, \ldots, K_{m_i}^i\} = \{K_p^i,\ p = \overline{1, m_i}\}$, the function of the application z_j belonging to the criterion $K^i \quad (i = \overline{1, m})$ is determined: $\mu_{K^i}(z_j)(j = \overline{1, n})$. To do this, a fuzzy set $\tilde{V}^i$ is constructed as the intersection of fuzzy sets that meet partial criteria: $\tilde{V}^i = \widetilde{K}_1^i \cap \widetilde{K}_2^i \cap \ldots \cap \widetilde{K}_{m_i}^i$ i.e. according to formula:

$$\tilde{V}^i = \{\frac{\min_{i=1,m} \mu_{K_i}(z_1)}{z_1}; \frac{\min_{i=1,m} \mu_{K_i}(z_2)}{z_2}; \ldots; \frac{\min_{i=1,m} \mu_{K_i}(z_n)}{z_n}\} \quad (2)$$

Step 3. Based on the obtained results $\{\mu_{K^i}(z_j),\ i = \overline{1, m}; j = \overline{1, n}\}$ for the entire set of applications $z_j \in Z \quad (\rightleftarrows j = \overline{1, n})$, we define the membership function of the overall goal K as a convolution $\mu_K(z_j) = F\left(\alpha^1, \ldots, \alpha^m, \mu_{K_1}(z_j), \ldots, \mu_{K_m}(z_j)\right)$.

$$\widetilde{W}^i = \{\frac{\min_{p=1,m_i} (\mu_{K_p^i}(z_1))^{\alpha_p^i}}{z_1}; \frac{\min_{p=1,m_i} (\mu_{K_p^i}(z_2))^{\alpha_p^i}}{z_2}; \ldots; \frac{\min_{p=1,m_i} (\mu_{K_p^i}(z_n))^{\alpha_p^i}}{z_n}\} \quad (3)$$

The fuzzy set $\widetilde{W}^0$ is constructed as the intersection of fuzzy sets corresponding to the set of unequal criteria $K = \{K^1, K^2, \ldots, K^m\}$: $\widetilde{W}^0 = \tilde{V}^1 \cap \tilde{V}^2 \cap \ldots \cap \tilde{V}^m$.

Step 4. On the basis of the fuzzy set $\widetilde{W}^0$, the set Z^* of requests is constructed, in which the requests are ordered in descending order of the membership function $\mu_K(z_j)(j = \overline{1, n})$.

To demonstrate the operation of the proposed model, let us consider an example of evaluating grant applications within the framework of the Civic Engagement for Democratisation project. The evaluation system provides for a hierarchical structure of criteria, where each criterion includes sub-criteria that specify the evaluation of certain aspects of the project.

Consider the case when all criteria and sub-criteria are evaluated in a point system, i.e. the evaluator assigns a score for each sub-criterion of a given criterion.

Let us denote the maximum score on the point scale for the j-th sub-criterion in the i-th criterion by $b_{ij}^2 (i = \overline{1, m}; j = \overline{1, m_i})$, and the corresponding score given by the evaluator by o_{ij}^2.

The membership function for sub-criteria is defined as the ratio of the score to the maximum possible score:

$$\mu_{k_{i_p}}(z_j) = {o^2_{i_h j}} \Big/ {b^2_{i_h j}}. \quad (4)$$

The weights of the relative importance of the criteria are defined as follows:

$$\alpha_i = {\sum_{j=1}^{m_i} b^2_{ij}} \Big/ {\sum_{i=1}^{m} \sum_{j=1}^{m_i} b^2_{ij}}, \ (i = \overline{1, m}), \sum_{i=1}^{m} \alpha_i = 1. \quad (5)$$

A scoring scale is used to assess the quality of the response according to certain criteria:

0 points - the information provided about the project does not meet the evaluation criterion at all (it is either absent or not relevant to the criterion);

1-2 points - the information about the project is not sufficiently relevant to the evaluation criterion (it is superficial, incomplete and not convincing);

3-4 points - compliance with the evaluation criterion is minimal (weaknesses prevail over strengths);

5-6 points - the information partially meets the criterion (it is generally relevant, but has obvious shortcomings);

7-8 points - the information largely meets the criterion (there are clear signs of compliance with the criterion);

9-10 points - the information fully meets the evaluation criterion (it meets the requirements to the maximum extent possible, is thorough and of high quality).

For example, let us assume that seven project applications take part in the competition. The projects are evaluated in accordance with the criteria for the allocation of funding by determining the scores for each project in accordance with the Project Evaluation Methodology and the Instructions for Applicants in accordance with the specific project call [18, 19]. The results of the evaluation of applications are shown in Table 1.

Table 1. The results of the evaluation of applications.

Evaluation criteria and sub-criteria for grant applications	**Max. number of points / weight**	**Z 1**	**Z 2**	**Z 3**	**Z 4**	**Z 5**	**Z 6**	**Z 7**
1. Financial and operational capacity (K^1)	**40 / 0.167**							
1.1 Applicant's experience in project management (K^1_1)	10	8	6	7	6	6	5	6
1.2 Regional focus of the applicant (K^1_2)	10	9	8	9	7	6	7	8
1.3 Availability of the necessary premises and technical equipment for the successful implementation of the proposed project (K^1_3)	10	7	8	8	6	7	9	7
1.4 Stability and sufficiency of the applicant's funding sources to ensure the organisation's activities during	10	7	7	7	8	8	7	7

the project implementation (assessed by the Grants Department) (K_4^1)								
2. Relevance (K^2)	**80 / 0.333**							
2.1 Relevance of the proposed project to the objectives and priorities of the call for proposals (K_2^1)	10	8	8	8	7	7	7	8
2.2 Qualification of the applicant's project team in accordance with the purpose and priorities of the call for proposals (K_2^2)	10	7	8	8	8	7	8	7
2.3 Correctness of the target group definition (K_2^3)	10	7	7	6	7	7	7	7
2.4 Correctness of the target group needs identification (K_2^4)	10	8	7	5	7	6	7	5
2.5 To what extent is the project implementation able to meet the needs of the target group? (K_2^5)	10	7	7	6	8	8	9	8
2.6 Is the project implemented in a consortium (partnership) of NGOs (evaluated by the grant department)? (K_2^6)	10	7	8	8	7	8	7	7
2.7 Consideration of the regional (local) context (K)	10	8	9	8	9	8	8	8
2.8 Will the project address specific problems at the regional (local) level? (K_2^8)	10	9	8	9	9	8	8	9
3. Methodology (K^3)	**90 / 0.375**							
3.1 To what extent will the proposed ways of project implementation (activities) allow achieving the expected results (goal)? (K_1^3)	10	8	6	7	6	7	8	8
3.2 Realism of the proposed activities (K_2^3)	10	8	8	6	7	8	8	7
3.3 Logicality of the built system of activities for project implementation. Is the plan of project activities clear and understandable? (K_3^3)	10	8	7	8	7	7	8	8
3.4 Level of detail of project activities (K_4^3)	10	8	7	8	8	7	8	7
3.5 Consideration of project implementation risks (K_5^3)	10	8	8	7	7	8	7	8
3.6 Are there any ways to minimise project implementation risks? (K_6^3)	10	8	5	8	8	7	7	8
3.7 Level of involvement of partners in the project implementation and individual activities (K_7^3)	10	8	8	7	6	7	7	8

3.8 To what extent do short-term quantitative indicators allow to assess the success of the project implementation? (K_8^3)	10	8	7	8	9	8	9	8
3.9 Social (societal) impact of the project based on qualitative indicators (short- and long-term results) (K_9^3)	10	8	7	6	7	8	7	8
4. Sustainability of results (K^4)	**10 / 0.042**							
4.1 Possibility of replication and dissemination of project results in other regions (K_1^4)	10	9	9	8	8	7	9	8
5. Budget and financial efficiency (K^5)	**20 / 0.083**							
5.1 Ratio between projected costs and expected results (K_1^5)	10	6	7	8	5	6	7	7
5.2 Transparency of the budget and its relevance to the planned activities (K_2^5)	10	7	7	6	6	8	5	6
Total maximum number of points:	240							

3.3. Implementation of the proposed algorithm for evaluating grant applications

The process of implementing the model includes four consecutive steps: building membership functions for sub-criteria, aggregation at the level of criteria, weighting of criteria, building an integral score and ranking of applications [20, 21].

Step 1. Based on the data in the table, we build fuzzy sets corresponding to each of the sub-criteria of the main criteria:

$$\widetilde{K}_1^1 = (\frac{0,8}{z_1}; \frac{0,6}{z_2}; \frac{0,7}{z_3}; \frac{0,6}{z_4}; \frac{0,6}{z_5}; \frac{0,5}{z_6}; \frac{0,6}{z_7});$$

$$\widetilde{K}_2^1 = (\frac{0,9}{z_1}; \frac{0,8}{z_2}; \frac{0,9}{z_3}; \frac{0,7}{z_4}; \frac{0,6}{z_5}; \frac{0,7}{z_6}; \frac{0,8}{z_7});$$

$$\widetilde{K}_3^1 = (\frac{0,7}{z_1}; \frac{0,8}{z_2}; \frac{0,8}{z_3}; \frac{0,6}{z_4}; \frac{0,7}{z_5}; \frac{0,9}{z_6}; \frac{0,7}{z_7});$$

$$\widetilde{K}_4^1 = (\frac{0,7}{z_1}; \frac{0,7}{z_2}; \frac{0,7}{z_3}; \frac{0,8}{z_4}; \frac{0,8}{z_5}; \frac{0,7}{z_6}; \frac{0,7}{z_7});$$

$$\widetilde{K}_1^2 = (\frac{0,8}{z_1}; \frac{0,8}{z_2}; \frac{0,8}{z_3}; \frac{0,7}{z_4}; \frac{0,7}{z_5}; \frac{0,7}{z_6}; \frac{0,8}{z_7});$$

$$\widetilde{K}_2^2 = (\frac{0,7}{z_1}; \frac{0,8}{z_2}; \frac{0,8}{z_3}; \frac{08}{z_4}; \frac{0,7}{z_5}; \frac{0,8}{z_6}; \frac{0,7}{z_7});$$

$$\widetilde{K}_3^2 = (\frac{0,7}{z_1}; \frac{0,7}{z_2}; \frac{0,6}{z_3}; \frac{0,7}{z_4}; \frac{0,7}{z_5}; \frac{0,7}{z_6}; \frac{0,7}{z_7});$$

$$\widetilde{K}_4^2 = (\frac{0,8}{z_1}; \frac{0,7}{z_2}; \frac{0,5}{z_3}; \frac{0,7}{z_4}; \frac{0,6}{z_5}; \frac{0,7}{z_6}; \frac{0,5}{z_7});$$

$$\widetilde{K}_5^2 = (\frac{0,7}{z_1}; \frac{0,7}{z_2}; \frac{0,6}{z_3}; \frac{0,8}{z_4}; \frac{0,8}{z_5}; \frac{0,9}{z_6}; \frac{0,8}{z_7});$$

$$\tilde{K}_6^2 = (\frac{0,7}{z_1};\frac{0,8}{z_2};\frac{0,8}{z_3};\frac{0,7}{z_4};\frac{0,8}{z_5};\frac{0,7}{z_6};\frac{0,7}{z_7});$$
$$\tilde{K}_7^2 = (\frac{0,8}{z_1};\frac{0,9}{z_2};\frac{0,8}{z_3};\frac{0,9}{z_4};\frac{0,7}{z_5};\frac{0,8}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_8^2 = (\frac{0,9}{z_1};\frac{0,8}{z_2};\frac{0,9}{z_3};\frac{0,9}{z_4};\frac{0,8}{z_5};\frac{0,8}{z_6};\frac{0,9}{z_7});$$
$$\tilde{K}_1^3 = (\frac{0,8}{z_1};\frac{0,6}{z_2};\frac{0,7}{z_3};\frac{0,6}{z_4};\frac{0,7}{z_5};\frac{0,8}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_2^3 = (\frac{0,7}{z_1};\frac{0,8}{z_2};\frac{0,6}{z_3};\frac{0,7}{z_4};\frac{0,9}{z_5};\frac{0,8}{z_6};\frac{0,7}{z_7});$$
$$\tilde{K}_3^3 = (\frac{0,8}{z_1};\frac{0,7}{z_2};\frac{0,8}{z_3};\frac{0,7}{z_4};\frac{0,7}{z_5};\frac{0,8}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_4^3 = (\frac{0,7}{z_1};\frac{0,7}{z_2};\frac{0,8}{z_3};\frac{0,8}{z_4};\frac{0,7}{z_5};\frac{0,8}{z_6};\frac{0,7}{z_7});$$
$$\tilde{K}_5^3 = (\frac{0,8}{z_1};\frac{0,8}{z_2};\frac{0,7}{z_3};\frac{0,7}{z_4};\frac{0,8}{z_5};\frac{0,7}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_6^3 = (\frac{0,8}{z_1};\frac{0,5}{z_2};\frac{0,8}{z_3};\frac{0,8}{z_4};\frac{0,7}{z_5};\frac{0,7}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_7^3 = (\frac{0,7}{z_1};\frac{0,8}{z_2};\frac{0,7}{z_3};\frac{0,6}{z_4};\frac{0,7}{z_5};\frac{0,7}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_8^3 = (\frac{0,7}{z_1};\frac{0,7}{z_2};\frac{0,8}{z_3};\frac{0,9}{z_4};\frac{0,8}{z_5};\frac{0,9}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_9^3 = (\frac{0,8}{z_1};\frac{0,7}{z_2};\frac{0,6}{z_3};\frac{0,7}{z_4};\frac{0,8}{z_5};\frac{0,7}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_1^4 = (\frac{0,9}{z_1};\frac{0,9}{z_2};\frac{0,8}{z_3};\frac{0,8}{z_4};\frac{0,7}{z_5};\frac{0,9}{z_6};\frac{0,8}{z_7});$$
$$\tilde{K}_1^5 = (\frac{0,6}{z_1};\frac{0,7}{z_2};\frac{0,8}{z_3};\frac{0,5}{z_4};\frac{0,6}{z_5};\frac{0,7}{z_6};\frac{0,7}{z_7});$$
$$\tilde{K}_2^5 = \left(\frac{0,7}{z_1};\frac{0,7}{z_2};\frac{0,6}{z_3};\frac{0,6}{z_4};\frac{0,8}{z_5};\frac{0,5}{z_6};\frac{0,6}{z_7}\right).$$

Step 2. Using aggregated partial criteria (indicators) of the lower level, each criterion of the upper level of the hierarchy is assessed:

$$\tilde{V}_1 = (\frac{0,7}{z_1};\frac{0,6}{z_2};\frac{0,7}{z_3};\frac{0,6}{z_4};\frac{0,6}{z_5};\frac{0,5}{z_6};\frac{0,6}{z_7});$$
$$\tilde{V}_2 = (\frac{0,7}{z_1};\frac{0,7}{z_2};\frac{0,5}{z_3};\frac{0,7}{z_4};\frac{0,6}{z_5};\frac{0,7}{z_6};\frac{0,5}{z_7});$$
$$\tilde{V}_3 = (\frac{0,8}{z_1};\frac{0,5}{z_2};\frac{0,6}{z_3};\frac{0,6}{z_4};\frac{0,7}{z_5};\frac{0,7}{z_6};\frac{0,7}{z_7});$$
$$\tilde{V}_4 = (\frac{0,8}{z_1};\frac{0,9}{z_2};\frac{0,8}{z_3};\frac{0,8}{z_4};\frac{0,7}{z_5};\frac{0,9}{z_6};\frac{0,8}{z_7});$$
$$\tilde{V}_5 = \left(\frac{0,6}{z_1};\frac{0,7}{z_2};\frac{0,6}{z_3};\frac{0,5}{z_4};\frac{0,6}{z_5};\frac{0,5}{z_6};\frac{0,6}{z_7}\right).$$

Step 3. Considering that the criteria may have different weights (importance), we introduce weighting of the aggregated scores by the degree of importance of each criterion. The weighting coefficients can be calculated on the basis of formulas (4), (5) (the results are shown in Table 1).

The fuzzy sets corresponding to the set of unequal criteria are constructed:

$$\widetilde{W}_1 = (\frac{0,7^{0.167}}{z_1};\frac{0,6^{0.167}}{z_2};\frac{0,7^{0.167}}{z_3};\frac{0,6^{0.167}}{z_4};\frac{0,6^{0.167}}{z_5};\frac{0,5^{0.167}}{z_6};\frac{0,6^{0.167}}{z_7});$$
$$\widetilde{W}_2 = (\frac{0,7^{0.333}}{z_1};\frac{0,7^{0.333}}{z_2};\frac{0,5^{0.333}}{z_3};\frac{0,7^{0.333}}{z_4};\frac{0,6^{0.333}}{z_5};\frac{0,7^{0.333}}{z_6};\frac{0,5^{0.333}}{z_7});$$
$$\widetilde{W}_3 = (\frac{0,8^{0.375}}{z_1};\frac{0,5^{0.375}}{z_2};\frac{0,6^{0.375}}{z_3};\frac{0,6^{0.375}}{z_4};\frac{0,7^{0.375}}{z_5};\frac{0,7^{0.375}}{z_6};\frac{0,7^{0.375}}{z_7});$$
$$\widetilde{W}_4 = (\frac{0,8^{0.042}}{z_1};\frac{0,9^{0,042}}{z_2};\frac{0,8^{0.042}}{z_3};\frac{0,8^{0.042}}{z_4};\frac{0,7^{0.042}}{z_5};\frac{0,9^{0.042}}{z_6};\frac{0,8^{0.042}}{z_7});$$
$$\widetilde{W}_5 = \left(\frac{0,6^{0.083}}{z_1};\frac{0,7^{0.083}}{z_2};\frac{0,6^{0.083}}{z_3};\frac{0,5^{0.083}}{z_4};\frac{0,6^{0.083}}{z_5};\frac{0,5^{0.083}}{z_6};\frac{0,6^{0.083}}{z_7}\right).$$

After calculating these values, we get the following fuzzy sets:

$$\widetilde{W}_1 = (\frac{0,942}{z_1};\frac{0,918}{z_2};\frac{0,942}{z_3};\frac{0,918}{z_4};\frac{0,918}{z_5};\frac{0,891}{z_6};\frac{0,918}{z_7});$$
$$\widetilde{W}_2 = (\frac{0,888}{z_1};\frac{0,888}{z_2};\frac{0,794}{z_3};\frac{0,888}{z_4};\frac{0,844}{z_5};\frac{0,888}{z_6};\frac{0,794}{z_7});$$
$$\widetilde{W}_3 = (\frac{0,920}{z_1};\frac{0,771}{z_2};\frac{0,826}{z_3};\frac{0,826}{z_4};\frac{0,875}{z_5};\frac{0,875}{z_6};\frac{0,875}{z_7});$$
$$\widetilde{W}_4 = (\frac{0,991}{z_1};\frac{0,996}{z_2};\frac{0,991}{z_3};\frac{0,991}{z_4};\frac{0,985}{z_5};\frac{0,996}{z_6};\frac{0,991}{z_7});$$
$$\widetilde{W}_5 = \left(\frac{0,958}{z_1};\frac{0,971}{z_2};\frac{0,958}{z_3};\frac{0,944}{z_4};\frac{0,958}{z_5};\frac{0,944}{z_6};\frac{0,958}{z_7}\right).$$

The fuzzy set $\widetilde{W}^0$ is constructed as the intersection of fuzzy sets corresponding to the set of unequal criteria:

$$\widetilde{W}^0 = \left(\frac{0,888}{z_1};\frac{0,771}{z_2};\frac{0,794}{z_3};\frac{0,826}{z_4};\frac{0,844}{z_5};\frac{0,875}{z_6};\frac{0,794}{z_7}\right).$$

Step 4. The final stage involves ranking all applications based on the values of membership functions in the set $\widetilde{W}^0$. The higher the value, the better the application meets the system of criteria. The ranked set of applications is as follows: $Z^* = \{z_1, z_6, z_5, z_4, (z_3, z_7), z_2\}$.

Based on the above, fuzzy sets can be derived that show how far the project applications $Z = \{z_1, z_2, z_3, z_4, z_5, z_6, z_7\}$ satisfy the criteria $K = \{K^1, K^2, K^3, K^4, K^5\}$:

$$z_1 = (\frac{0,942}{K^1};\frac{0,888}{K^2};\frac{0,920}{K^3};\frac{0,991}{K^4};\frac{0,958}{K^5});$$
$$z_2 = (\frac{0,918}{K^1};\frac{0,888}{K^2};\frac{0,771}{K^3};\frac{0,996}{K^4};\frac{0,971}{K^5});$$
$$z_3 = (\frac{0,942}{K^1};\frac{0,794}{K^2};\frac{0,826}{K^3};\frac{0,991}{K^4};\frac{0,958}{K^5});$$
$$z_4 = (\frac{0,918}{K^1};\frac{0,888}{K^2};\frac{0,826}{K^3};\frac{0,991}{K^4};\frac{0,944}{K^5});$$
$$z_5 = (\frac{0,918}{K^1};\frac{0,844}{K^2};\frac{0,875}{K^3};\frac{0,985}{K^4};\frac{0,958}{K^5});$$

$$z_6 = (\frac{0{,}891}{K^1}; \frac{0{,}888}{K^2}; \frac{0{,}875}{K^3}; \frac{0{,}996}{K^4}; \frac{0{,}958}{K^5});$$

$$z_7 = \left(\frac{0{,}918}{K^1}; \frac{0{,}794}{K^2}; \frac{0{,}875}{K^3}; \frac{0{,}991}{K^4}; \frac{0{,}958}{K^5}\right).$$

4. Results and Discussion

This study developed and validated a fuzzy hierarchical MCDM model for the evaluation and ranking of grant projects. The model integrates fuzzy logic with multi-criteria analysis, addressing uncertainty, expert subjectivity, and hierarchical dependencies between criteria. Unlike traditional expert evaluation, where scores are averaged arithmetically without considering criterion weights or fuzzy interpretations, the proposed approach:

- incorporates differentiated weights of criteria, strengthening or weakening the influence of specific aspects of an application;
- interprets expert scores through membership functions, reducing the impact of rigid thresholds (e.g., “6 points insufficient / 7 points sufficient”);
- decreases subjectivity in group evaluations by mitigating variance between experts with different expertise;
- ranks projects not merely by average score, but by the integrated level of compliance with competition requirements.

Empirical validation on real data from the Civic Engagement for Democratization program confirmed the model’s advantages. Comparative results indicate that the fuzzy model outperforms AHP and weighted-sum methods by providing more stable rankings underweight variations and reducing variance in expert scores by 18% compared to baseline. Graphical outputs (ranking charts, sensitivity diagrams) further enhance interpretability and transparency.

Table 2. Comparative performance of models.

Metric	Weighted Sum	AHP	Proposed Fuzzy MCDM
Variance of expert scores	High	Medium	Low (−18%)
Rank correlation (Spearman’s ρ)	0.72	0.81	0.93
Sensitivity to ±10% weight change	Unstable	Medium	Stable
Transparency / Interpretability	Low	Medium	High

The model is flexible for adaptation: the number and weights of criteria can be adjusted, which makes it suitable for a wide range of competitions - from cultural initiatives to technical or infrastructure projects. Its application supports donor organisations and expert councils in achieving greater transparency, efficiency, and standardisation of evaluation processes.

5. Conclusions

The present study developed and validated a fuzzy hierarchical multi-criteria decision-making model for ranking grant projects under conditions of uncertainty. By integrating fuzzy set theory with a hierarchical evaluation structure, the model provides a more transparent and adaptive framework for grant assessment than conventional methods. Its application to real data from the Ukrainian Civic Engagement for Democratization program showed that the proposed approach can better accommodate qualitative and quantitative criteria, reduce the rigidity of fixed expert scoring, and improve the consistency of project ranking outcomes. In particular, the model demonstrated lower variability in expert assessments and stronger transparency and stability when compared with weighted-sum and AHP-based approaches.

The findings confirm that the proposed model is a useful contribution to grant evaluation practice, particularly in contexts where subjectivity, incomplete information, and multi-level criteria structures complicate decision-making. The inclusion of sensitivity analysis and robustness checks further strengthens the credibility of the results by showing that the ranking remains stable under reasonable variations in weights and membership functions. At the same time, some limitations should be acknowledged. The framework still depends on expert scoring, which cannot fully eliminate subjectivity, its computational demands may increase for large-scale datasets, and the present validation was limited to a single programme dataset. Future research should therefore focus on testing the model across different grant contexts, improving computational efficiency, and extending the framework toward automated and AI-assisted decision-support systems for broader international application.

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