

Development of fuzzy expert system for peer review biomedical research proposals

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Article Info	ABSTRACT
Article type: Research	Introduction: The quality of review processes used to evaluate research proposals directly reflects on the soundness of the research data and the new knowledge that are disseminated to the scientific community. In today's rapidly evolving academic landscape, the peer-review process remains a cornerstone for evaluating the merit and integrity of research proposals. However, the traditional peer-review system often grapples with challenges such as reviewer bias, inconsistency, and the growing volume of submissions. To address these issues, this paper presents the development of a fuzzy expert system designed to enhance the peer-review process for biomedical research proposals.
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Keywords: Fuzzy Logic Expert System Peer Review	Material and Methods: This cross-sectional study aimed to design a fuzzy evaluation system for research proposals in four steps. Initially, a questionnaire was developed based on literature review, existing review forms, and interviews with experts. Then, this questionnaire was distributed among research council members of several universities to assign weights and rank the parameters. Each parameter was rated on a scale from 1 to 5. In the third phase, the fuzzy rule base was designed based on expert knowledge and the system was implemented in MatLab. Finally, the system was evaluated using collected review forms from research proposals. Results: The questionnaire, containing 35 items, was distributed to the research council members of Iran, Tehran and Shahid Beheshti University of Medical Sciences. A total of 27 members (response rate: 77.1%) completed and returned the questionnaire. Six factors, including cost, objectives, study type, literature review, statistical methods, and details of findings, were considered as input variables for the system, with acceptance, revision, and rejection as output results. The system had 90% accuracy and an AUC of 0.901, showing good performance. Conclusion: The fuzzy expert system enhances peer-review by reducing subjectivity, ensuring logical, transparent, consistent, accurate, and defendable biomedical proposal assessments.

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INTRODUCTION

As the volume and diversity of available information continue to expand, the potential for achieving more precise and reliable outcomes likewise increases. However, the processing of such extensive datasets demands considerable computational resources and time. Moreover, human factors—including memory lapses, misinterpretation, cognitive biases, and

preconceived assumptions—introduce substantial risks of error and subjectivity, thereby compromising the integrity of the analytical process [1–3]. The peer review of research proposals is no exception to this vulnerability.

Research proposals serve as the foundational building blocks upon which knowledge infrastructures are constructed. Consequently, the

quantity and quality of these proposals exert a direct and determinative influence on the volume and rigor of published literature across all scientific disciplines. The evaluation and scrutiny of research proposals represent one of the most critical mechanisms for ensuring the quality control of disseminated information, ultimately facilitating the accurate and valid transmission of scientific knowledge [4, 5].

Billions of dollars are invested annually in health and medical research worldwide, with funding distributed across numerous countries and sponsoring organizations [6, 7]. In this context, the meticulous appraisal of research proposals within the biomedical domain constitutes a pivotal determinant of overall research quality—one that directly shapes the trajectory of scientific and technological advancement in support of public health and societal well-being [8]. For this reason, ethical considerations occupy a position of paramount importance in medical research. It is imperative to ascertain that each proposed study not only contributes meaningfully to the existing body of knowledge and offers tangible benefits to the population but also rigorously safeguards the safety and rights of participating individuals [9].

In recent years, the most widely adopted mechanism for ensuring the quality of research proposals has been the peer review process. Within this framework, submitted manuscripts are critically assessed by one or more expert reviewers, whose primary objectives are to identify methodological and substantive weaknesses and to recommend improvements that enhance the overall quality of the work [10]. This system encompasses a structured set of procedures designed to provide robust oversight and to assure the scientific validity and ethical soundness of research prior to its execution [11].

Peer reviewers occupy a pivotal and indispensable role within the manuscript evaluation and peer review system [12]. Indeed, in the trajectory of generating and disseminating novel scientific findings, manuscripts that have undergone rigorous peer scrutiny tend to exhibit superior quality and credibility compared to those that have not [13]. The significance of this function is such that readers consistently regard information derived from peer-reviewed sources as more trustworthy and valuable.

Nevertheless, the peer review system as applied to research proposals is not without its inherent limitations [14]. The most frequently cited shortcomings include its high cost, protracted timelines, and questionable reliability; a conspicuous lack of transparency; a substantially stochastic character; and a profoundly disappointing record in detecting errors and factual inaccuracies. Moreover, evidence points to the presence of bias within the process. Additional drawbacks encompass the

influence of interpersonal relationships and human behavioral factors on review outcomes, the considerable time investment required, persistent biases and departures from impartiality, and a chronic shortage of adequately trained and specialized experts to conduct rigorous disciplinary reviews [14–16].

A substantial proportion of the terminology and conceptual frameworks employed in the evaluation of research proposals are characterized by imprecision, relativity, and a hybrid of subjective and objective elements. Decision-making frequently rests upon reviewers' personal judgments, which are inherently susceptible to variability and may not consistently reflect objective merit. Furthermore, it is methodologically untenable to assign meaningful value to scholarly manuscripts solely on the basis of a binary acceptance-rejection scale; such an approach tends to yield evaluative outcomes that are predominantly formalistic and impressionistic rather than substantively grounded [17]. This concern is corroborated by a body of empirical evidence indicating that assessment practices often lean toward superficial and linguistically mediated criteria, which can significantly distort the final evaluation results [4, 5, 18, 19].

The evaluation of research proposals for grant allocation constitutes a profoundly complex problem, characterized by imprecise and often incomplete information. Consequently, current assessment methodologies appear to be inadequately suited to the task, and effective decision-making in this context necessitates the development of multi-criteria models capable of accommodating and processing uncertainty. Emerging approaches to mathematical decision-making and evaluation under conditions of indeterminacy—such as fuzzy logic—offer a promising avenue for addressing this challenge [20].

Fuzzy logic has been established as a robust and effective tool for decision support systems operating in environments marked by uncertainty [21]. In recent years, its application has garnered increasing attention as an innovative framework for the design of intelligent decision-aid systems [22]. As a branch of artificial intelligence, fuzzy logic possesses the unique capacity to model human cognitive processes and to articulate vague, imprecise, or inherently uncertain concepts in a mathematically tractable manner [23]. For these reasons, it is particularly well-suited to the evaluation of research proposals, which typically involve a constellation of interrelated causal factors characterized by complexity, ambiguity, and non-deterministic properties [8].

Fuzzy systems are generally characterized as knowledge-based or rule-based systems, founded upon a corpus of if-then production rules. These rules are typically elicited from the expertise of domain specialists and subsequently stored within

the system's knowledge base. Fuzzy systems afford a more precise and nuanced articulation of conditional reasoning, thereby enabling a clearer and more rigorous analysis of if-then relationships. As a multi-valued logic, fuzzy logic bears a strong resemblance to human reasoning and interpretative processes, and is commonly employed to represent qualitative descriptors such as weak, moderate, good, very good, and similar gradations. Importantly, this logic possesses the inherent potential to integrate human heuristics and inferential patterns into computer-based decision support systems [22]. In contexts where less experienced reviewers are involved, this novel approach can serve as a valuable adjunct to facilitate more accurate and consistent evaluation and adjudication. A key distinguishing feature of fuzzy-based peer review, as compared with conventional review practices, lies in its departure from absolute binary outcomes of unconditional acceptance or rejection. Instead, the fuzzy paradigm accommodates conditional acceptance contingent upon specified revisions and amendments. This nuanced framework enables reviewers to render judgments regarding acceptance, rejection, or revision with greater confidence, precision, and deliberative rigor [5].

Taken together, there exists a compelling imperative to develop a comprehensive and standardized methodology for the peer review of research proposals within the biomedical sciences, with the overarching aim of enhancing both the quality and uniformity of the evaluation process. The deployment of expert systems in this domain holds considerable promise as a facilitative and supportive instrument. It is for this reason that the present study was undertaken with the objective of designing a fuzzy logic-based decision support system for the peer review of medical research proposals. It is anticipated that the findings of this investigation will provide a foundational framework for the development of an appropriate and robust model for the review process.

Moreover, it is hoped that the design and implementation of such a system will assist journals in achieving more precise, consistent, and equitable evaluations of submitted proposals. The distinctive contribution of the proposed system resides in its capacity to enhance the accuracy, productivity, and overall efficiency of research proposal assessment.

In a study conducted by Ayoobi Ardakan and colleagues, which aimed to examine the impact and necessity of the peer review process in monitoring the quality of published scientific works, the findings indicated that two criteria—namely, "the originality and novelty of the research" and "the relevance of the topic to the journal's thematic scope"—exerted a significant influence on manuscript acceptance. Furthermore, the editorial board was found to play a

more pivotal role in the review process than other evaluative criteria [4].

Vazirinejad and colleagues, in their investigation into the accuracy of reviewers in identifying requisite revisions within a given manuscript, reported that the process, structure, and inherent nature of peer review are in need of substantial improvement and enhancement. Their findings further suggested that the adoption of novel methodologies in this context could prove effective in addressing these deficiencies [18].

In a separate study, Montazer sought to identify salient qualitative concepts and translate them into quantifiable, measurable indicators for the evaluation and peer review of scientific books. To this end, he developed a structured and mechanized system grounded in the principles of multivariate analysis and, ultimately, logical inferential reasoning. By applying validated inputs to this system and assigning numerical values to each parameter, it became possible to determine the relative value of a given book and to conduct its peer review in a systematic and automated manner [5].

Khorshid and colleagues developed a multi-objective fuzzy mathematical model for the optimization of research project portfolios. Owing to the application of mathematical modeling, the consideration of diverse objectives, as well as organizational constraints, was facilitated with relative ease within this framework. Ultimately, the model was solved using a genetic algorithm [24]. Jafarinejad and colleagues designed a decision support model for the evaluation of scientific-research articles in the field of management. In this model, evaluation indicators were weighted using the analytic hierarchy process (AHP) in conjunction with the opinions of university faculty members, and project selection was subsequently performed through zero-one programming [25]. Friedman, in an examination of the peer review process for scientific articles, identified reviewer expertise and experience as two critical determinants—both objective and subjective—in the accurate assessment of manuscripts [26]. Khalili and colleagues employed the TOPSIS method in combination with fuzzy goal programming for the selection of multi-objective projects (MOPS) within a multi-period planning horizon (MPPH) [27]. Tavana and colleagues utilized data envelopment analysis (DEA) and multi-objective fuzzy linear programming for projects involving advanced technology [28]. Chang and colleagues applied fuzzy analytic hierarchy process (fuzzy AHP) and fuzzy data envelopment analysis (fuzzy DEA) for the ranking and selection of new product development (NPD) projects [29].

MATERIAL AND METHODS

This retrospective, cross-sectional study was conducted with the aim of designing a fuzzy evaluation and decision support system for the peer review of research proposals.

In the first phase, a comprehensive questionnaire comprising indicators and parameters relevant to the evaluation of research proposals was developed. This instrument was constructed through an extensive review of reputable scientific literature, adherence to the APA [30] and CAPRS-CS [31] guidelines, and analysis of existing review forms utilized at the Faculties of Paramedical Sciences of Tehran University of Medical Sciences and Shahid Beheshti University of Medical Sciences, as well as the Faculty of Management and Medical Informatics of Iran University of Medical Sciences.

In the second phase, the questionnaire developed in the preceding step was distributed among members of the Research Councils of the aforementioned faculties, with the objective of determining the weight and ranking of each parameter within the review process. Each parameter was assigned a score on a 5-point Likert-type scale, ranging from 1 (least important) to 5 (very important). It should be noted that, owing to the small size of the target population, the sample size was considered equivalent to the entire statistical population—namely, all Research Council members of the respective faculties—and consequently, no sampling procedure was performed. Questionnaires were administered via electronic mail.

In the third phase, the knowledge base of the system was populated with a set of if-then production rules derived from the expertise of seasoned peer reviewers, specifically two members of the Research Council of Iran University of Medical Sciences. The Mamdani inference method, which represents the most widely employed approach in fuzzy system development [32], was adopted for fuzzy inference. Based on the final set of parameters extracted from the preceding stages, the system's inputs and the corresponding output—categorized as acceptance, revision, or rejection—were defined. Membership functions were correspondingly established using Gaussian functions. System implementation was carried out in the MATLAB environment, version 2018a.

In the fourth phase, system evaluation was performed to calculate accuracy and the area under the curve (AUC) using a collection of review forms obtained from previously evaluated research proposals at the aforementioned faculties. Specifically, ten review forms—complete with their final outcomes—were gathered from each faculty, yielding a total of 30 forms. System testing was conducted by comparing its outputs against the

results recorded on these review forms.

RESULTS

In the first phase, a questionnaire comprising indicators and parameters relevant to the peer review of research proposals was developed through an extensive review of reputable scientific literature [21–23], adherence to the APA and CAPRS-CS guidelines, and analysis of existing review forms.

In the second phase, the questionnaire was distributed via email to 35 members of the Research Councils of Iran University of Medical Sciences, Tehran University of Medical Sciences, and Shahid Beheshti University of Medical Sciences. A follow-up reminder was sent one week later. Ultimately, 27 individuals completed and returned the questionnaire, yielding a response rate of 77.1%. The questionnaire employed a 5-point Likert-type scale, and respondents were requested to assign a score to each criterion ranging from 1 (low importance) to 5 (high importance). Table 1 presents the demographic and professional characteristics of the expert participants in this stage of the study.

Table 1: Demographic and Professional Characteristics of Expert Participants in the Second Phase of the Study

Variable		N (%)
Gender	Male	18 (66.6)
	Female	9 (33.3)
Years of Experience	< 10	5 (18.5)
	10-20	19 (70.4)
	>20	3 (11.1)
Academic Rank	Instructor	3 (11.1)
	Assistant Professor	12 (44.5)
	Associate Professor	9 (33.3)
	Professor	3 (11.1)

Criteria with a mean score exceeding 3.5 were retained for inclusion in the study. These comprised cost, objectives, study novelty, literature review, statistical methods, and details of findings. Subsequently, in consultation with two members of the Research Council of Iran University of Medical Sciences—specializing in medical informatics and library and information sciences—membership functions for the system parameters and output, as well as the fuzzy inference rules, were determined. Fig 1 and 2 illustrate the output membership functions and a sample of the rules defined within the MATLAB environment, respectively.

To evaluate system performance, three independent reviewers assessed a total of 30 research proposals. In order to minimize bias, the consensus of their evaluations was compared against the system's output. The results demonstrated that the system achieved an accuracy of 90%. In other words, the system's output matched the consensus evaluation of the three reviewers for 27 out of 30 proposals,

indicating robust system performance.

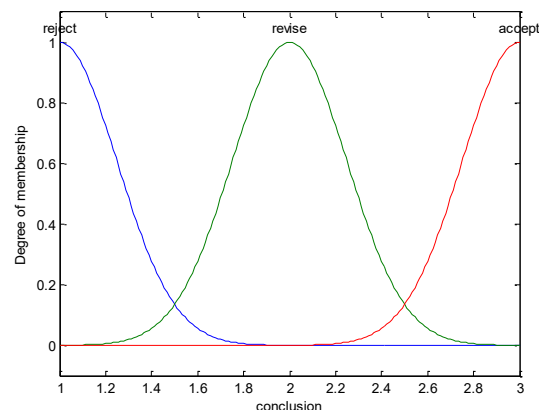


Fig 1: Membership functions of the output variable for the research proposal peer review system.

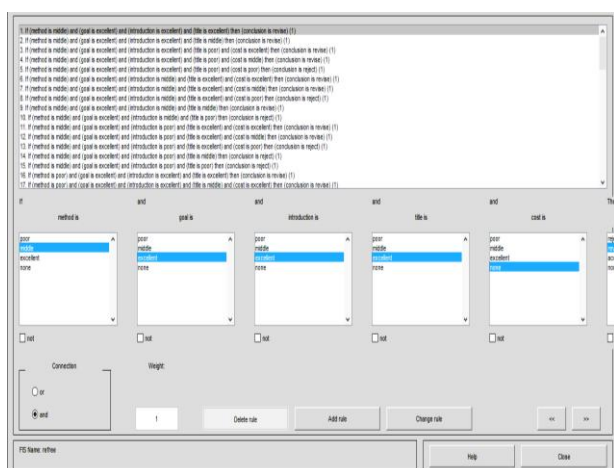


Fig 2: Sample rules employed in the research proposal peer review system.

The receiver operating characteristic (ROC) curve depicts sensitivity plotted against 1-specificity. A curve positioned higher above the diagonal, equivalently, a larger AUC indicates superior system performance. For the proposed system, the AUC was calculated as 0.901. Fig 3 presents the ROC curve for the fuzzy expert system.

DISCUSSION

Previous studies on the ranking and evaluation of research proposals have employed techniques such as network analysis, balanced scorecards, and grey theory [25, 33, 34]. However, these investigations are subject to several limitations, including a high number of criterion scales, insufficient elaboration of the criteria themselves, the absence of a dedicated decision support system, and a lack of computer-based implementation or the use of relevant software. These shortcomings may be considered notable weaknesses when compared with the present study.

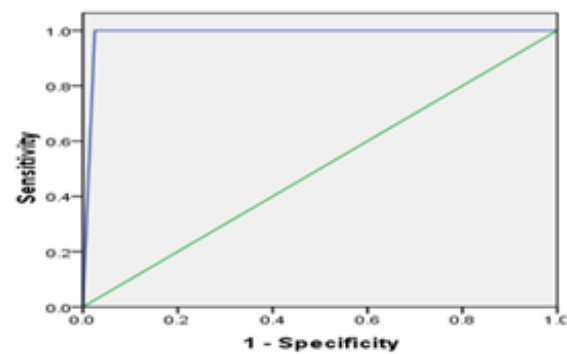


Fig 3: ROC curve for the research proposal peer review system.

In a study [35], a decision support system was designed for the evaluation and prioritization of research projects, wherein the Utastare method was employed to determine the final utility function of the problem. A significant drawback of that study was the absence of fuzzy logic to incorporate the judgments of expert reviewers. In contrast, the present study accords a pivotal role to expert opinions in the prioritization and weighting of parameters, as well as in determining their respective influences on the review outcome.

Several studies [29, 36–39] have predominantly focused on the cost parameter—reflecting the economic dimension—in the evaluation and peer review of research proposals. By contrast, the current study employs a comprehensive prioritization and weighting framework for all parameters, explicitly delineating the interrelationships among them and the relative importance of each within the review process. This feature may be regarded as a significant strength of the present work.

In other comparable studies [40, 41], performance metrics such as accuracy, sensitivity, and precision were not fully reported with respect to system testing. Consequently, it is difficult to draw meaningful conclusions regarding the performance of those systems. An examination of the proposals misclassified by our system revealed that two cases, despite their adequate quality, were rejected owing to high costs, while one case was rejected on the grounds of substantial deficiencies in the presentation of the study methodology—yet was categorized by the system as requiring revision.

Like any other investigation, the present study was subject to certain limitations. The system was evaluated using research proposals that had been previously peer-reviewed at the three universities upon whose Research Council members' opinions the system had been originally designed. Evaluation of the system using proposals from other universities and across a broader range of study types could yield more comprehensive and generalizable results.

CONCLUSION

In the present study, a fuzzy logic-based approach was employed for the peer review of research proposals in the medical sciences. The proposed system is capable of evaluating and adjudicating proposals by classifying them into three categories: acceptance, revision, or rejection. Ultimately, this framework facilitates the prioritization of proposals, enables more effective resource allocation, and contributes to significant time savings.

The rationale for employing fuzzy logic in the proposed expert system lies in its capacity to utilize quantitative and measurable indicators in contrast to qualitative, subjective, and objective concepts—thereby rendering the review process more systematic and transparent. Furthermore, the system's output can serve as a valuable decision support tool to augment the logical reasoning of journal editorial boards. Additionally, reviewers are likely to find the system more intuitive and acceptable in terms of interaction and usability.

The system proposed in this study demonstrated favorable levels of accuracy, precision, and sensitivity in its discriminatory performance, indicating that it can be employed with a high degree of confidence in practical settings.

In continuation of the present study, several recommendations are proposed for the further development and enhancement of fuzzy expert systems in the peer review process, with the aim of improving the evaluation of research proposals.

Given the existence of organizational and cultural variations, the fuzzy expert system could be implemented and validated across diverse institutional settings to assess its robustness and generalizability. Furthermore, the system could be augmented through integration with other artificial intelligence approaches—such as machine learning and deep learning—to potentially achieve superior performance outcomes.

Although the present study was specifically designed

for the evaluation of research proposals in the biomedical domain, the proposed framework is adaptable to other scientific disciplines. Future investigations may also consider comparing system outputs directly with human peer review judgments to further establish its validity and utility.

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AUTHOR'S CONTRIBUTION

All authors contributed to the literature review, design, data collection, drafting the manuscript, read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this study.

ETHICAL APPROVAL

This study was approved by the Research Ethics Committee of Iran University of Medical Sciences (Ethical Code: IR.IUMS.REC.1394.26907).

FINANCIAL DISCLOSURE

No financial interests related to the material of this manuscript have been declared.

AI USAGE

Artificial intelligence tools were used exclusively for grammar correction and language polishing. No AI was used for data analysis, interpretation, or content generation. The authors assume full responsibility for the final manuscript.

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