# University Financial Management Performance Evaluation Based on Fuzzy Logic Expert System

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*The aim of this study is to develop a fuzzy logic expert system-based performance evaluation model for financial management in higher education institutions to provide accurate and comprehensive evaluation results to facilitate financial management decision-making in higher education institutions. Through the literature review, the paper firstly emphasizes the key role of university financial management and its impact in performance evaluation, and analyzes the limitations of existing evaluation methods. Subsequently, the theoretical framework and practical application of fuzzy logic and the fundamentals of expert systems in domain decision support are discussed in depth. The study particularly focuses on the current situation of financial management performance evaluation in colleges and universities, and comparatively analyzes the efficacy and shortcomings of the current evaluation models. On this basis, an innovative fuzzy logic expert system model is proposed, and its construction principle and application process are described in detail. To verify the effectiveness of the model, the study implements an exhaustive empirical analysis covering financial data collection, preprocessing, analysis and model evaluation of 20 colleges and universities during the period from 2017 to 2022. The results show that the model performs superiorly in dealing with ambiguity and uncertainty and significantly improves the prediction accuracy and the comprehensiveness of the evaluation compared with traditional methods. Specifically, the model's prediction errors in the indicators of resource utilization, teaching quality, research output, financial risk and financial transparency are significantly reduced, confirming its accuracy and reliability in the evaluation of university financial management performance. This study not only provides an advanced evaluation tool for university financial management, but also provides a theoretical basis and practical guidance for the optimization and upgrading of higher education management, which has far-reaching academic value and practical application prospects.*

*Povzetek: Razvit je nov model za ocenjevanje finančnega upravljanja univerz, ki temelji na sistemu ekspertne in mehke logike.*

## 1 Introduction

With the rapid development of social economy and the deepening of higher education reform, the role of financial management in colleges and universities is becoming more and more prominent. The effectiveness of financial management in colleges and universities is directly related to the rational allocation of educational resources and the quality of higher education. However, how to effectively evaluate the financial management performance of colleges and universities has always been an important topic of common concern in academia and practice.

Traditional financial management performance evaluation methods in colleges and universities mainly rely on quantitative financial indicators, such as income, expenditure, assets and liabilities. This method can provide objective financial data to a certain extent, but it ignores the complexity and ambiguity in financial management. In fact, university financial management not only involves quantitative indicators, but also includes a large number of qualitative factors, such as human resources management, education quality assurance, management efficiency, etc., these factors are often difficult to be measured by simple figures.

In addition, in the complex and changeable environment of modern higher education, traditional financial management methods are not enough to fully reflect the overall situation of university financial management, and there are limitations to cope with the dynamic changes in the education industry. Therefore, it is particularly important to find a more comprehensive and flexible evaluation method to deal with the complexity of university financial management.

Fuzzy logic expert system is used in many aspects of evaluation, such as building engineering energy management system [1], power system [2], etc. In this context, the performance evaluation of university financial management based on fuzzy logic expert system has become a worthy research direction. Fuzzy logic expert system, with its unique ability to deal with fuzzy and uncertain information, provides a new perspective for financial management performance evaluation in colleges

and universities. Fuzzy logic expert system can not only deal with those difficult to quantify management factors more accurately, but also provide more comprehensive and detailed evaluation results.

In recent years, a variety of advanced calculation methods have appeared in the field of financial management and decision-making, which provides a new perspective and tool for the research of financial management performance evaluation in colleges and universities. Jin et al. explored financial management and decision-making based on decision tree algorithm, highlighting the potential of data-driven methods in financial decision-making [3]. This provided theoretical support for the use of fuzzy logic expert system in this study, because fuzzy logic is also an effective method to deal with uncertainty and fuzziness in financial decision making. In terms of risk management, Valaskova et al. managed the financial risks of Slovak enterprises through regression analysis [4]. This reveals the importance of quantitative analysis in understanding and controlling financial risks, and provides a feasible method for this study to use fuzzy logic to deal with financial risks. Intelligent financial data analysis is a hot topic at present. Cheng discussed the intelligent financial data analysis and decision management based on edge computing [5], which proved the trend and necessity of applying advanced technology in financial management and provided the background for the use of fuzzy logic expert system. In summary, the application of decision tree algorithm, the role of regression analysis in risk management, and the development of intelligent data analysis technology all provide theoretical and practical support for this research. These studies show that applying fuzzy logic expert system to financial management performance evaluation in colleges and universities is not only feasible, but also in line with the current technical development trend in financial management field.

The main purpose of this study is to explore and construct a performance evaluation model of university financial management based on fuzzy logic expert system, so as to evaluate the performance of university financial management more accurately and comprehensively, especially the decision support ability in the face of uncertain and fuzzy information. This model will expand the research of performance evaluation theoretically and provide a more scientific and objective evaluation tool for financial management in colleges and universities from the perspective of practice.

The significance of this study is mainly reflected in the following two aspects: First, theoretical significance. This study introduces fuzzy logic and expert system into financial management performance evaluation of colleges and universities, which enriches the theory and method of performance evaluation. Theoretically, it will provide new ideas and solutions for solving some problems existing in traditional evaluation methods, such as the ability to deal with fuzzy and uncertain information, the realization of comprehensive evaluation and so on. Second, practical significance. The research results can provide a more accurate and comprehensive performance evaluation tool for the financial management of colleges and universities, and help colleges and universities to manage and use financial resources more effectively, further improve the quality of education and the ability to serve the society. At the same time, the evaluation model based on fuzzy logic expert system can also provide reference for other fields facing similar problems.

This study will adopt mixed research methods, combining qualitative and quantitative research methods. First of all, qualitative research methods such as literature research, theoretical analysis and case study will be used to deeply understand related concepts such as financial management, performance evaluation, fuzzy logic and expert system in colleges and universities, so as to form a sound theoretical basis. Then, by constructing the performance evaluation model of university financial management based on fuzzy logic expert system, and using the empirical research method to verify, in order to achieve the research objectives. There are two main sources of data: one is obtained from existing academic literature, mainly used for theoretical analysis and model construction; The other part is obtained through field research, questionnaire survey, interview and other ways, and these data are mainly used for empirical research and verification of the model. For the construction of the model, the research will refer to the relevant theories and methods of fuzzy logic and expert system, as well as the current financial management performance evaluation practice in colleges and universities, to design a comprehensive, scientific and practical evaluation model. In the empirical research part, several representative universities will be selected as samples to collect relevant financial management data, and then the model constructed by the research will be used for performance evaluation. Finally, the results will be analyzed in detail to verify the effectiveness and feasibility of the model.

The purpose of this study is to explore the application of fuzzy logic expert system in financial management performance evaluation of colleges and universities. This study will combine related theories and methods to construct a performance evaluation model based on fuzzy logic expert system, and carry out detailed empirical research and analysis on this model. Firstly, the basic theory of fuzzy logic and expert system will be elaborated, especially the theoretical basis of fuzzy logic and the structure and working principle of expert system. At the same time, the practical application of fuzzy logic expert system will be summarized to emphasize the practicability and feasibility of this method. Secondly, the present situation of financial management performance evaluation in colleges and universities will be deeply discussed. This section will include an overview of current assessment methods, an in-depth analysis of their strengths and weaknesses, and a discussion of key challenges. Next, the performance evaluation model based on fuzzy logic expert system will be constructed. This section will cover the principle and construction process of the model, as well as the specific application of the model in performance evaluation. After the completion of model construction, a series of empirical studies will be conducted. This section will include data collection, data processing and analysis, and reporting of empirical research findings. Finally, the

research results will be analyzed in detail, including quantitative and qualitative evaluation of model effectiveness, analysis of model feasibility and application scenarios, as well as discussion of existing problems and solution strategies.

In general, this study aims to comprehensively explore the performance evaluation model of financial management in colleges and universities based on fuzzy logic expert system through theoretical and empirical research, hoping to provide a new and effective method for the performance evaluation of financial management in colleges and universities. The research process and ideas are shown in Figure 1 below:

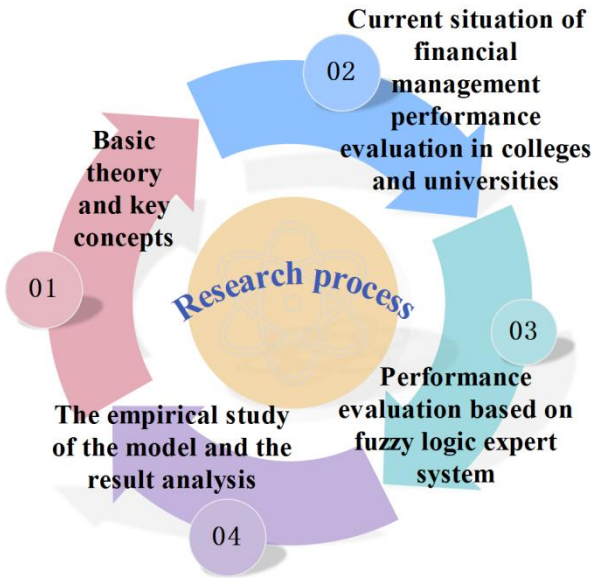


Figure 1: Research process and thinking.

In this article, we explore the complexities and challenges of financial management performance evaluation in higher education institutions, particularly the limitations in dealing with ambiguity and uncertainty. In this article, we explore the complexities and challenges of financial management performance evaluation in higher education institutions, particularly the limitations in dealing with ambiguity and uncertainty. The research focuses on how to effectively evaluate the efficiency and effectiveness of financial management in colleges and universities, especially when considering the non-financial indicators and the unpredictable Current performance measurement methods, such as financial ratio analysis, balanced scorecard and data fit analysis, have their own advantages, but there are significant differences. Current performance measurement methods, such as financial ratio analysis, balanced scorecard and data fit analysis, have their own advantages, but there are significant limitations in dealing with ambiguity, integrating multiple evaluation criteria, and handling Current performance measurement methods such as financial ratio analysis, balanced scorecard and data fit analysis have their own advantages, but there are significant limitations in dealing with ambiguity, integrating multiple evaluation criteria, and handling complex financial data.

Our contribution is to propose an innovative evaluation framework combining fuzzy logic and expert system, which aims to overcome the limitations of traditional evaluation methods. Our contribution is to propose an innovative evaluation framework combining fuzzy logic and expert system, which aims to overcome the limitations of traditional evaluation methods. Specifically, we developed a performance evaluation model based on fuzzy expert system, which can flexibly deal with uncertainty, comprehensively consider financial and non-financial indicators, and use expert knowledge to formulate more accurate evaluation criteria. This research not only enriches the theoretical basis of financial management in colleges and universities, but also provides a more comprehensive and accurate performance evaluation tool for practitioners. This research not only enriches the theoretical basis of financial management in colleges and universities, but also provides a more comprehensive and accurate performance evaluation tool for practitioners, thus supporting the decision-making optimization of resources Through the empirical analysis, we verify the validity and the practicality of the model. It opens up a new path for the continuous improvement of financial management. Through the empirical analysis, we verify the validity and the practicality of the model. It opens up a new path for the continuous improvement and sustainable development of university financial management.

# 2 Basic theory and key concepts

## 2.1 The importance of university financial management and its role in performance evaluation

Financial management of colleges and universities refers to the process of planning, organizing, guiding, coordinating, controlling and optimizing financial resources by institutions of higher education in order to achieve their educational and scientific research goals [6]. The main tasks of financial management in colleges and universities include reasonable allocation of financial resources, ensuring the stability of financial operation and promoting the sustainable development of colleges and universities.

The importance of financial management in colleges and universities is reflected in the following aspects:

(1) The rationality of the allocation of financial resources directly affects the teaching and scientific research activities of colleges and universities [7]. For example, whether the funds are sufficient or not, whether the use is reasonable or not will directly affect the quality of teaching and scientific research results.

(2) Good financial management can improve the economic benefits of colleges and universities. Through reasonable financial management, we can reduce the cost and increase the income, so as to improve the economic benefits of colleges and universities.

(3) Financial management has an important impact on the social reputation and public image of colleges and

universities. A university with good financial management can not only win the recognition of the society, but also enhance the trust of the public, thus attracting more excellent teachers and students and social resources.

In performance evaluation, the functions of financial management in colleges and universities are mainly reflected in the following aspects:

It can not only reflect the efficiency and effect of financial resources utilization, but also reveal the rationality and strategy of financial decision-making [8]. Second, the key difficulty in performance evaluation is how to objectively and comprehensively evaluate the results and impact of financial management activities, especially when it comes to non-financial factors such as education quality and research innovation. In addition, financial management performance evaluation can provide strong support for universities to adjust financial management strategies and optimize resource allocation through evaluation results. Finally, financial management performance evaluation is helpful for colleges and universities to establish and improve the internal control system, improve the level of financial management, and promote the sustainable development of colleges and universities. As shown in Figure 2 below, the importance of financial management in colleges and universities and its role in performance evaluation are demonstrated:

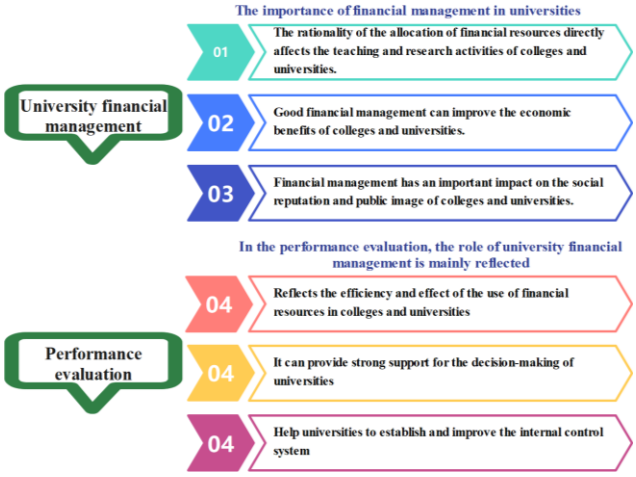


Figure 2: The importance of financial management in colleges and universities and its role in performance evaluation

## 2.2 Necessity and challenge of performance appraisal and existing appraisal mode

Performance evaluation is a systematic process, which evaluates the activities and achievements of an organization or an individual to determine whether it has achieved the predetermined goals [9]. In the financial management of colleges and universities, the main objective of performance evaluation is to evaluate the efficiency and effect of the use of financial resources.

The necessity of performance appraisal is reflected in the following aspects:

(1) Provide decision support: Through performance evaluation, the management can understand the actual effect of financial management, which provides support for them to make more effective financial strategies and decisions.

(2) Supervision and incentive: Performance evaluation can be used as a supervision mechanism to check and feedback the problems and deficiencies of financial management [10]. At the same time, it can also motivate employees to improve their work efficiency through evaluation results.

(3) Optimize resource allocation: Unreasonable use of resources can be found through performance evaluation, so as to adjust and optimize resource allocation.

However, performance evaluation also faces some challenges, including how to choose appropriate evaluation indicators, how to accurately quantify and evaluate performance, and how to deal with the ambiguity and uncertainty in the evaluation process.

The existing financial management performance evaluation mode of colleges and universities mainly includes financial ratio analysis, balanced scorecard, data envelopment analysis and so on [11]. Each of these models has advantages and disadvantages. For example, the financial ratio analysis method is simple and easy to use, but may ignore non-financial factors; Balanced scorecard can take many factors into consideration, but the construction and use process is complicated. Data envelopment analysis can deal with multi - index problem effectively, but it requires high data.

In recent years, relevant research results are shown in Table 1.

Table 1: Research results.

| serial number | Author/Research | Main contributions | Deficiencies | Relationship with fuzzy logic expert systems |
|---|---|---|---|---|
| **1** | Liu et al. [6] | For the first time, a correlation between financial management and university performance was | Ignoring the impact of non-financial indicators | Introduction of fuzzy logic to account for non-financial factors |

| | | | | |
|---|---|---|---|---|
| | | propose d | | |
| **2** | Zhou et al. [7] | Using Financi al Ratio Analysis to Assess Financi al Manag ement in College s and Univers ities | Lack of treatmen t of uncertain ties | Fuzzy logic can fill this gap |
| **3** | Lu et al. [8] | The applicat ion of balance d scoreca rd in financi al manage ment of univers ities and college s | Complex ity of impleme ntation and difficulty in quantifyi ng soft indicator s | Expert system simplifie s impleme ntation and quantifie s soft indicator s |
| **4** | Tang et al [9] | Effecti veness of Data Fitting Analysis Method in Perfor mance Evaluat ion of Higher Educati on Instituti ons | Need for large quantitie s of high-quality data | Expert systems can integrate limited data for analysis |

## 2.3 Theoretical basis and practical application of fuzzy logic

Fuzzy logic is A kind of logic to deal with fuzzy phenomena proposed by Professor Lotfi A. Zadeh of University of California, Los Angeles in 1965 [12]. Different from traditional Boolean logic, it is no longer a simple black and white comparison, but can deal with complex, fuzzy and uncertain information in the real world. The basic idea of fuzzy logic is to give each object a membership value between 0 (absolutely no) and 1 (absolutely yes) to describe the degree to which the object belongs to a certain set.

Fuzzy logic has three basic concepts: fuzzy set, membership function and fuzzy operation. Fuzzy set is a set composed of objects with different membership degrees. Membership function is used to describe the degree to which an object belongs to a fuzzy set. Fuzzy operations include fuzzy union, fuzzy intersection, fuzzy complement and so on [13, 14].

Fuzzy logic has obvious advantages in dealing with complex financial data, mainly in that it can flexibly deal with gray areas beyond black and white, that is, that information that is not completely certain or not completely vague. It is particularly important to analyze the changeable factors and uncertainties in the financial management of colleges and universities [15]. However, a major limitation of fuzzy logic is that it relies on the experience and knowledge of experts to define membership functions and rules, which may lead to the intervention of subjectivity and affect the objectivity of evaluation results [16].

For example, a university needs to evaluate the financial benefits of its research projects. The traditional method may only consider the direct income and expenditure of the project, while the fuzzy logic method can comprehensively consider the direct financial indicators and indirect benefits of the project (such as the enhancement of the school's reputation, the enhancement of academic influence, etc.). By setting appropriate membership function and rules, the comprehensive financial benefit of the project can be evaluated more comprehensively.

In this study, fuzzy logic will be applied to construct a performance evaluation model of university financial management to deal with the fuzziness and uncertainty in the evaluation process.

## 2.4 Basic concepts and application fields of expert system

Expert system is a computer application system that simulates the ability of human experts to solve problems, especially in those areas that require a great deal of knowledge and experience [17]. Its basic components include a knowledge base (for storing expert knowledge), a reasoner (for simulating the thinking process of experts and reasoning based on the knowledge in the knowledge base), and a user interface (for interacting with users) [18].

The working process of expert system generally includes the following steps: First, obtain the problem information through the user interface; Then, the inference machine is used to reason according to the knowledge in the knowledge base, and the solution is generated. Finally, the solution is presented to the user through the user interface.

Expert systems are used in many fields, including medical diagnosis, engineering design, financial analysis,

weather forecasting and so on [19]. For example, in medical diagnosis, the expert system can simulate the diagnostic process of doctors and provide decision-making support for doctors. In engineering design, expert system can simulate engineer's design process and help engineer make design decision.

In the financial management of colleges and universities, the applicability analysis of expert system is particularly important. University financial management involves many complex factors, such as fund allocation, budget control, cost-benefit analysis, etc. These problems often require a lot of professional knowledge and experience to deal with. Through the application of expert system, the decision-making process of financial management experts can be simulated to assist colleges and universities to make more scientific and reasonable decisions on these complex issues. Expert system can process and analyze a large amount of data to provide more accurate and comprehensive information support for financial management in universities.

In this study, the expert system will be used to build the university financial management performance evaluation model. Through the expert system, the evaluation process of financial management experts can be simulated, which makes the performance evaluation more scientific, accurate and efficient.

# 3 Status quo of financial management performance evaluation in colleges and universities

## 3.1 Overview of current performance evaluation methods

University financial management performance evaluation is a complicated and diversified process, which is mainly reflected in the current evaluation methods. The current performance evaluation methods mainly include the following:

(1) Financial ratio analysis: Financial ratio analysis is the most commonly used performance evaluation method, mainly through the calculation and analysis of financial ratios (such as current ratio, quick ratio, liability ratio, asset turnover, net profit rate, etc.) to evaluate the effect of financial management. The advantages of this approach are that it is simple to operate and easy to understand and use, but the disadvantages are that the influence of non-financial factors may be ignored and the calculation and interpretation of ratios require specialized knowledge.

(2) Balanced Scorecard method: Balanced Scorecard is a comprehensive performance evaluation method, which considers not only financial indicators, but also non-financial indicators, such as customer satisfaction, internal business processes, learning and growth, etc. The advantage of this method is that it can fully reflect the effect of financial management, but the disadvantage is that the construction and use process is complicated and requires a lot of data support.

(3) Data Envelopment Analysis (DEA) method: Data Envelopment analysis is a performance evaluation method based on linear programming, mainly used to evaluate the relative efficiency of multi-indicator systems. The advantage of this method is that it can deal with the problem of multiple indicators and does not require preset weights, but the disadvantage is that it has high requirements on data and may ignore the influence of non-financial factors.

(4) Management by Objectives (MBO): Management by objectives is a performance evaluation method that divides organizational objectives into individual or group objectives. The advantage of this method is that it can motivate employees to work actively and improve work efficiency, but the disadvantage is that it may overemphasize short-term goals and neglect long-term development.

In the practical application of university financial management, these methods have different application scenarios. For example, financial ratio analysis is usually suitable for quick assessment of daily financial situation, while balanced scorecard method is more suitable for comprehensive evaluation of long-term strategy implementation effect of colleges and universities. Data envelopment analysis is used to compare the relative efficiency of different universities or different departments, while management by objectives is more focused on improving the specific performance of individuals or teams. The application of these methods in university financial management needs to be selected and adjusted according to specific situations and objectives.

Although these current evaluation methods have their own advantages and disadvantages, they all share a common challenge, which is how to deal with the ambiguity and uncertainty in the evaluation process. For example, the selection of evaluation indicators and the determination of weights often involve subjective judgment, which leads to the fuzziness and uncertainty of evaluation results. Therefore, how to deal with these fuzziness and uncertainty through scientific methods to improve the accuracy and fairness of performance evaluation is an important issue facing the financial management performance evaluation in colleges and universities.

## 3.2 Analysis of advantages and disadvantages of current methods

(1) Financial ratio analysis

Advantages: Financial ratio analysis can quickly yield critical information about financial condition and operational efficiency. Ratios can provide insight to better understand the financial health of colleges and universities. Because ratios are universally applicable, it is easy to compare performance across time periods or universities.

Disadvantages: While the financial ratio analysis can provide valuable insights, it does not capture all the variables that can affect performance. For example, it may ignore non-financial performance indicators such as student satisfaction, faculty quality, or academic

reputation. In addition, ratios may be distorted by certain one-time or non-recurring financial activities.

(2) Balanced scorecard method

Pros: The Balanced Scorecard provides a comprehensive view, including financial and non-financial factors, to measure the overall performance of colleges and universities. This approach helps college administrators identify and focus on key factors that drive success, including human resources, student satisfaction, and internal processes.

Cons: Although the balanced scorecard method can provide comprehensive information, implementing it requires extensive data collection, which can be challenging. In addition, deciding which indicators are most important and how to balance them requires clear strategic direction and objectives, which can also be a challenge.

(3) Data Envelopment analysis (DEA)

Advantages: Data envelopment analysis can handle multiple input and output variables without the need for preset weights, which makes it useful for efficiency evaluation of complex systems.

Cons: However, DEA requires a large amount of data, and without sufficient decision units (for example, the number of colleges and universities to evaluate), DEA may not be able to provide valid results. In addition, DEA can only provide relative efficiency, not absolute efficiency measurement.

(4) Management by Objectives (MBO)

Advantages: Management by objectives emphasizes the setting and realization of goals, which can provide strong motivation to push employees to complete their work better. This approach also emphasizes participation and openness so that employees understand their roles and how their work affects the overall goals.

Disadvantages: However, management by objectives can put too much emphasis on short-term goals and neglect long-term strategic goals. In addition, if goals are set too high or too low, it can lead to frustration or satisfaction among employees.

### 3.3 Main challenges of financial management performance evaluation in colleges and universities

Financial management performance evaluation in colleges and universities faces some major challenges.

First of all, the financial management performance evaluation of colleges and universities involves a huge amount of data and complex. A university is a diversified organization, covering teaching, scientific research, human resources, material management and other aspects. There are a lot of financial and non-financial factors to consider. How to collect, organize and analyze these data accurately and effectively is a big challenge in the evaluation work.

Secondly, the standards of financial management performance evaluation are not consistent. Different universities have different development strategies and objectives, so their financial management emphasis will be different, which requires a general evaluation standard or model that can adapt to various situations, and how to build such a model is a very challenging work.

Moreover, there are some factors in the financial management of colleges and universities that are difficult to quantify, such as teaching quality and academic reputation. Although these factors have an important impact on the development of colleges and universities, they are difficult to be expressed with specific data. How to incorporate these factors into the performance evaluation of financial management is another important challenge.

In addition, the financial management performance evaluation in many colleges and universities still relies too much on financial indicators and neglects non-financial indicators. For example, some universities attach too much importance to the efficiency of fund use while ignoring the quality of teaching and scientific research in the evaluation, which may lead to the deviation of the evaluation results from the actual situation and affect the correctness of decision-making.

Finally, facing the constant changes of social economic environment and educational policies, the goals and strategies of financial management in colleges and universities may need to be adjusted constantly, which requires the financial management performance evaluation to have a certain degree of flexibility and adaptability. How to achieve this is also a major challenge at present. As shown in Figure 3 below, the main challenges faced by financial management performance evaluation in colleges and universities are shown:

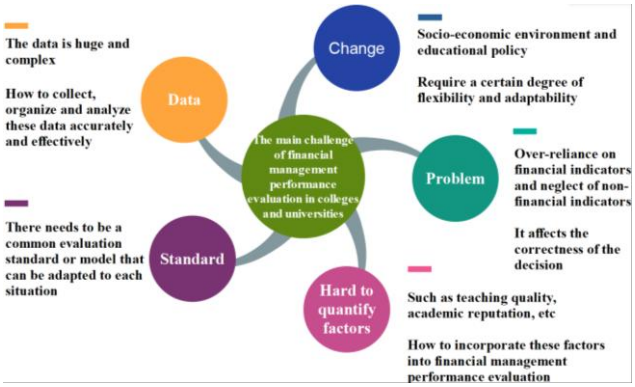


Figure 3: Main challenges of financial management performance evaluation in colleges and universities

## 4 Performance evaluation based on fuzzy logic expert system

### 4.1 Principles of fuzzy logic expert system

The principle of fuzzy logic expert system mainly depends on the two core concepts of fuzzy logic and expert system. Fuzzy logic is a logic system that deals with uncertainty, while expert system is an intelligent system that simulates human experts to solve problems [20].

In a fuzzy logic expert system, the construction of the rule base is the core part, which determines how the system handles the fuzzy inputs and produces the corresponding outputs. In the following, we will elaborate

the model construction process, especially the way of constructing the rule base for fuzzy logic expert systems, and provide examples of specific rules.

The rule base is generalized based on expert knowledge and historical data, and it contains several fuzzy rules, usually in the form of "If... Then..." structure. These rules reflect the relationship between different indicators and the decision-making logic of experts in financial management performance evaluation.

1. If a university has a high Financial Surplus Ratio (FSR) and a high Return on Research Investment (RORI), then the financial management performance is very good. Mathematically, this rule can be expressed as:

$$\text{IF } \mu_{\text{FSR}}^{\text{High}} \text{ AND } \mu_{\text{RORI}}^{\text{High}} \text{ THEN } \mu_{\text{Performance}}^{\text{Very Good}}$$

Where μ denotes the degree of affiliation function, which describes the degree of affiliation of the variable values with a particular fuzzy set; $\text{FSR}^{\text{High}}$ and $\text{RORI}^{\text{High}}$ denote the "high" fuzzy sets of financial surplus rate and return on scientific research input, respectively; and $\text{Performance}^{\text{Very Good}}$ denotes the "very good" fuzzy set of financial management performance.

2. If Student Satisfaction (SS) is low or Faculty-Student Ratio (FSRatio) is high, then financial management performance is poor. Mathematically, this rule can be expressed as follows: $\text{IF } \mu_{\text{SS}}^{\text{Low}} \text{ OR } \mu_{\text{FSRatio}}^{\text{High}} \text{ THEN } \mu_{\text{Performance}}^{\text{Poor}}$ Here $\mu_{\text{SS}}^{\text{Low}}$ and $\mu_{\text{FSRatio}}^{\text{High}}$ denote the "low" fuzzy set of Student Satisfaction and the "high" fuzzy set of Faculty-Student Ratio, respectively; $\mu_{\text{Performance}}^{\text{Poor}}$ denotes the "poor" fuzzy set of Financial Management Performance. represents the "poor" fuzzy set of financial management performance.

The formation of the rules is a systematic process that integrates the knowledge of financial management experts with the insights from actual data analysis. First, through in-depth interviews, we consulted financial management experts and scholars in the field of higher education to gain insights into their opinions and criteria for evaluating the performance of higher education institutions' financial management, laying a theoretical and practical foundation for the development of the rules. Next, we analyzed past financial data and performance evaluation results to identify and confirm the indicators that are significantly related to financial management performance, ensuring that the rule construction is based on objective data rather than mere assumptions. After clarifying the key indicators, we entered the fuzzy set delineation stage, defining "low", "medium" and "high" fuzzy sets for indicators such as financial surplus ratio, return on research investment, student satisfaction and faculty ratio. Fuzzy sets of "low", "medium" and "high" are defined to capture the fuzzy boundaries of these indicators in different intervals by setting the affiliation function, so as to reflect the complexity and uncertainty of the real world more realistically. With the definition of the fuzzy set completed, we entered the rule induction session, based on the crystallization of the wisdom of experts and data analysis of the discovery, refined a series of "if... Then..." based on the wisdom of the experts and the findings of data analysis, a series of "if..." fuzzy logic rules have been extracted, which are used to describe the comprehensive evaluation of the financial management performance of colleges and universities under different combinations of indicators. These rules not only reflect the intrinsic connection between the indicators, but also reflect the in-depth understanding of the multidimensional consideration of the financial management of colleges and universities. Finally, to ensure the validity and reasonableness of the rules, we validated the rules by backtesting, i.e., using historical data to test the performance of the rules, and inviting experts to review the rules to ensure that the rules can accurately reflect the real situation of financial management performance. If the rules are found to have deviations or deficiencies, we will make the necessary adjustments and optimizations in time, with a view to constructing a fuzzy logic expert system that is both scientific and practical, and to provide strong support for the evaluation of financial management performance of colleges and universities. The whole process of arriving at the rules reflects the close integration of theory and practice and ensures the accuracy and reliability of the system in practical application.

In fuzzy logic, each logical value is between 0 and 1, representing the probability of an event occurring. The key operations in fuzzy logic include fuzzy union, intersection and complement. Suppose there are two fuzzy sets A and B, and the fuzzy union of A and B is defined as:

$$A \cup B = max(A, B)$$

Fuzzy intersection is defined as:

$$A \cap B = min(A, B)$$

Fuzzy complement is defined as:

$$A' = 1 - A$$

Where, $A$ and $B$ respectively represent the fuzzy logic values of events A and B.

In expert system, knowledge base is a system storing domain expert knowledge, inference engine is a mechanism simulating expert reasoning process, user interface is the medium interacting with users, knowledge base is the core of the system, it is usually composed of a set of rules, these rules can be formalized as:

"If... So..."

In an expert system based on fuzzy logic, these rules will contain fuzzy logic values. For example, a simple fuzzy logic rule might be: "If resource usage is high (0.8), then performance evaluation score is low (0.2)."

The evaluation of performance based on fuzzy logic expert system will firstly fuzzy process all evaluation indicators, and then make comprehensive evaluation through fuzzy logic operation and reasoning engine of expert system. Finally, the evaluation results will be

defuzzy processing to get specific performance evaluation scores. Table 2 below shows the numerical examples of performance evaluation based on fuzzy logic:

Table 2: Performance evaluation based on fuzzy logic expert system.

| Performance evaluation index | Fuzzy logic value |
|---|---|
| **Resource utilization rate** | 0.8 |
| **Teaching quality** | 0.9 |
| **Scientific research achievement** | 0.7 |

In this example, you can define a set of fuzzy logic rules, as shown in Table 3 below:

Table 3: Fuzzy logic rules.

| Rule | Description |
|---|---|
| **If the use of resources is high and the quality of teaching is high, then the performance evaluation score is high** | R1 |
| **If the resource utilization rate is high and the scientific research results are low, then the performance evaluation score is low** | R2 |
| **If the teaching quality is high and the research results are high, then the performance evaluation score is high** | R3 |

We backtested the affiliation function using historical financial data and student satisfaction survey results. This not only assessed the accuracy and stability of the affiliation function in describing the fuzzy state of the variables, but also helped us to identify and correct possible biases and ensure optimization of the parameters of the affiliation function. We invited financial management experts and academics in the field of higher education to review the selected affiliation functions. The experts provided feedback on the shape and location of the function based on their experience and knowledge, ensuring that the choice of the affiliation function was consistent with the perception and experience in the field of specialization.

Using these rules, fuzzy logic operation can be carried out through the reasoning engine of the expert system to obtain the fuzzy logic value of the performance evaluation score, and then the specific performance evaluation score can be obtained by defuzzification.

## 4.2 Application of fuzzy logic expert system in performance evaluation

The application of fuzzy logic expert system in performance evaluation mainly depends on its ability to deal with fuzzy, complex and uncertain information. Specifically, the expert system can be used for fuzzy processing of each evaluation index, and then reasoning based on fuzzy logic rules. Finally, the performance evaluation score can be obtained through defuzzification.

Taking the financial management performance evaluation of colleges and universities as an example, the following three evaluation indicators are assumed: resource utilization rate ( $X1$ ), teaching quality ( $X2$ ) and scientific research results ( $X3$ ). Firstly, the fuzzy set and membership function of each evaluation index can be determined by expert experience or statistical data. For example, the fuzzy set of $X1$ may be: low ( $L$ ), medium ( $M$ ), and high ( $H$ ), and the membership function can be expressed mathematically as:

$$\mu_{X1}(L), \mu_{X1}(M), \mu_{X1}(H)$$

The fuzzy logic value of each evaluation index can be obtained by fuzzy processing. For example, the fuzzy logic values of $X1$ might be: $L:0.2$ , $M:0.5$ , and $H:0.3$ . As shown in Figure 4 below, fuzzy logic value of performance evaluation based on fuzzy logic expert system is shown:

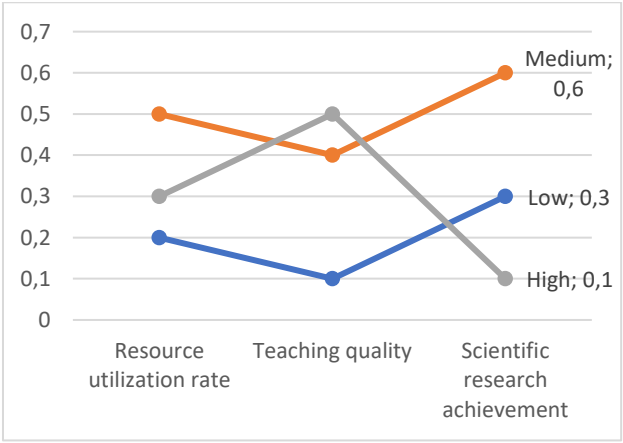


Figure 4: Fuzzy logic value of performance evaluation index based on fuzzy logic expert system

Next, you can define a set of fuzzy logic rules, such as: "If $X1$ is $H$ and $X2$ is $H$ , then the performance evaluation score is $H$ ." Assuming that the fuzzy set of performance evaluation score is also low ( $L$ ), medium ( $M$ ) and high ( $H$ ), the fuzzy logic value of performance evaluation score can be obtained through the reasoning engine of expert system.

Finally, it is necessary to defuzzify the fuzzy logic value into a specific evaluation score. Common antifuzzification methods include center method (COA), maximum membership degree method (MOM), center of gravity method (COG), etc. For example, a performance evaluation score can be calculated using the center method, as shown in formula (1):

$$\text{Score} = \frac{\sum_i (xi * \mu_{Xi})}{\sum_i \mu_{Xi}} \quad (1)$$

Where, $xi$ is each evaluation score, and $\mu_{Xi}$ is the corresponding fuzzy logic value.

To sum up, the application of fuzzy logic expert system in performance evaluation mainly involves quantitative processing of complex and uncertain evaluation indicators through steps such as fuzzy processing, fuzzy logic operation and defuzzification, so as to obtain specific performance evaluation scores.

### 4.3 Construction of university financial management performance evaluation model based on fuzzy logic expert system

The model of this study is based on fuzzy logic expert system, which simplifies the complexity of financial management performance evaluation into a fuzzy reasoning process. The model mainly includes the following parts: fuzzification, rule base, inference machine, fuzzy defuzzification.

(1) Blurring

The fuzzy set and membership function of each evaluation indicator can be determined by expert experience or statistical data. For example, for the income indicator, a statistical method (such as percentile or standard deviation) can be used to define "low", "medium", and "high" thresholds through financial data over the years. Similarly, other indicators such as cost and profit are determined in a similar way.

(2) Rule base

The construction of the rule base is based on the experience and knowledge of experts, but also relies on historical data analysis. For example, experts can identify rules for a particular financial situation based on historical case studies, such as "if revenues are 'high' and costs are 'low,' then profits are 'high.'" These rules both reflect the experience of experts and validate their applicability and accuracy through data.

(3) Application of fuzzy logic reasoning

The fuzzy logic reasoning is used to evaluate the financial management performance of colleges and universities. The fuzzy logic expert system calculates the fuzzy set of performance evaluation according to the input evaluation index and the rule base. The final performance evaluation result is determined according to the membership degree of fuzzy set.

Table 4 below shows the application of fuzzy logic reasoning:

Table 4: Application of fuzzy logic reasoning

| **Evaluation index** | **Fund utilization efficiency** | **Financial health** | **Budget implementation** |
|---|---|---|---|
| **Input value** | 0.6 | 0.8 | 0.7 |
| **Output (performance evaluation)** | good | excellent | good |

Through the fuzzy logic reasoning, the evaluation results of the financial management performance of colleges and universities are obtained. Among them, the fund utilization efficiency is rated as good, the financial health status is rated as excellent, and the budget implementation is rated as good.

Through the above model construction process, this research can evaluate the financial management performance of colleges and universities based on the fuzzy logic expert system, and obtain objective and accurate evaluation results. This model can deal with fuzzy and uncertain information effectively and consider multiple evaluation indexes comprehensively, which provides important decision support for financial management in colleges and universities.

## 5 Empirical study of the model

### 5.1 Data collection

Before starting the evaluation of university financial management performance based on fuzzy logic expert system, we made a detailed data collection plan to ensure that the selected sample universities can fully reflect the diversity of higher education institutions. The selection criteria cover the selection criteria cover different types of public and private, research and teaching, as well as large and small, urban and rural diverse sizes and geographical locations, striving to have a wide range of higher education institutions. The selection criteria cover different types of public and private, research and teaching, as well as large and small, urban and rural diverse sizes and geographical locations, striving to have a wide range of representative samples. In addition, we have prioritized universities with complete and transparent financial records to ensure the reliability and continuity of data, while taking into account the stability of management to reduce the potential impact of personnel The report also includes a number of recommendations for the implementation of the recommendations.

The data collection covers financial reports, budget execution details, audit documents, and non-financial metrics such as student satisfaction surveys, faculty ratios, and research project success rates from 2017 to 2022. The data collection covers financial reports, budget execution details, audit documents, and non-financial metrics such as student satisfaction surveys, faculty ratios, and research project success rates from 2017 to 2022. To ensure data quality, we implemented a multi-tiered data cleansing and To ensure data quality, we implemented a multi-tiered data cleansing and validation process that included removing outliers, filling in missing data, and estimating by interpolation or regression prediction methods. same time, we worked closely with the university's financial department to verify the accuracy of the data and ensure

the consistency and integrity of the data through cross-comparison with the university's financial department. At the same time, we worked closely with the university's financial department to verify the accuracy of the data and ensure the consistency and integrity of the data through cross-comparison with independent data sources. Finally, all data were reviewed by experts in financial management and higher education, further enhancing the credibility of the data.

In terms of software and tool selection, we adopted Python as the core programming language due to its powerful data processing capabilities and Scikit-fuzzy library is selected to implement fuzzy logic operations, including defining membership functions and fuzzy rules, to ensure that the model can properly handle the uncertainty of university financial management. Scikit-fuzzy library is selected to implement fuzzy logic operations, including defining membership functions and fuzzy rules, to ensure that the model can properly handle the uncertainty of university financial management. In addition, we consider adopting expert system framework such as CLIPS or JESS to construct and execute fuzzy logic expert system, and provide intelligent solution for in addition, we consider adopting expert system framework such as CLIPS or JESS to construct and execute fuzzy logic expert system, and provide intelligent solution for financial management performance evaluation of colleges and universities. Through these rigorous data collection and processing steps, we have laid a Through these rigorous data collection and processing steps, we have laid a solid foundation for subsequent empirical research, ensuring the accuracy and usefulness of the research results.

Before the empirical study, data collection is needed. In order to test the effectiveness of the financial management performance evaluation model of colleges and universities based on fuzzy logic expert system, some representative colleges and universities are selected and the financial management related data of these colleges and universities are collected. We collect the financial data of these colleges and universities from 2017 to 2022, which constitutes the dataset of our colleges and universities. We plan to collect financial information from 20 colleges and universities and use these data for empirical analysis. However, the process of data collection is slow, so we first collect data from three colleges and universities for analysis in 2017, and if the initial experiment is feasible, we then expand the sample size and begin formal data collection and experimentation. Data from the three representative HEIs (A, B and C) were initially collected and analyzed as they were able to provide the most complete and reliable financial management data at the beginning of the study. This was done to test the validity and applicability of the model with a small but informative sample. The statistics collected are shown in Table 5 below.

Table 5: Statistical analysis of samples.

| Variable | Sample Size | Mean | Max | Min | Standard deviations |
|---|---|---|---|---|---|
| **X1** | 3 | 0.8300 | 0.8959 | 0.7744 | 0.061 |
| **X2** | 3 | 0.7733 | 0.8576 | 0.7188 | 0.071 |
| **X3** | 3 | 0.8400 | 0.9459 | 0.7840 | 0.089 |
| **X4** | 3 | 0.8833 | 0.9818 | 0.7724 | 0.116 |
| **X5** | 3 | 0.6267 | 0.7118 | 0.5355 | 0.096 |
| **Performance Evaluation Result** | 3 | 0.7983 | 0.9350 | 0.5436 | 0.221 |
| **Actual Evaluation Result** | 3 | 0.7962 | 0.9893 | 0.5101 | 0.253 |

As can be seen from Table 5, the data we collected gained initial success, which justifies the five indicators we set. Therefore, we started to collect data formally. The process of our collection is specified as follows

(1) Determine data collection indicators: Five assessment indicators have been identified, namely resource utilization rate ( $X1$ ), teaching quality ( $X2$ ), scientific research outcomes ( $X3$ ), financial risk ( $X4$ ) and financial transparency ( $X5$ ). A lower X4 represents better financial management and higher financial management performance.

(2) Data collection: Send a data collection request to each university, and the collection steps are as follows:

Step 1: Identify the source of the data. First determine the source of the data. This involves contacting the financial management department of the relevant university or the relevant person in charge and requesting them to provide the required data.

Step 2: Issue a data collection request. Once the data source is identified, data collection requests are sent to these universities. Do this by email, phone or face to face.

Step 3: Collect raw data. After receiving responses from universities, raw data was collected. These data involve financial statements, teaching evaluation data, scientific research results reports and so on.

Our data collection process was assisted by 10 experts, and for the five assessment indicators of resource utilization , teaching quality, research output, financial risk, and financial transparency , we used a scoring system, specifically the experts visited the university's financial system, and at the end of the visit the assessment was made for the five indicators, and the final scores were determined by the ratings of the 10 professionals as the final score is determined by the average of the ratings of the 10 professionals. It can be seen that we have to collect a total of 20 schools for a period of 5 years, which means

that we have to carry out the above process 100 times in total. Scoring is based on a 0-1 scoring system

Step 4: Organize and record the data. The collected data needs to be collated and recorded for subsequent analysis and processing. This involves data classification, naming, coding and other work to ensure the readability and operability of the data.

Step 5: Data verification and proofreading. In the process of data collection, the collected data needs to be verified and proofread to ensure the accuracy and reliability of the data.

Step 6: Build the data set. Finally, the collected data is organized into a dataset for subsequent analysis and modeling efforts.

For each school we collect 5 years of data, for a total of 20 schools, so we obtain a total of 100 pieces of data. We only show here the data for the first 10 schools for the 2017 data. The specific data is shown in Table 5 below.

Table 6: Data for the top 10 schools for 2017.

| Colleges and universities | X1 | X2 | X3 | X4 | X5 |
|---|---|---|---|---|---|
| **A** | 0.89 | 0.85 | 0.94 | 0.77 | 0.71 |
| **B** | 0.77 | 0.72 | 0.80 | 0.90 | 0.53 |
| **C** | 0.83 | 0.75 | 0.78 | 0.98 | 0.64 |
| **D** | 0.68 | 0.88 | 0.86 | 0.10 | 0.92 |
| **E** | 0.66 | 0.84 | 0.85 | 0.25 | 0.80 |
| **F** | 0.65 | 0.82 | 0.80 | 0.05 | 0.95 |
| **G** | 0.64 | 0.81 | 0.79 | 0.18 | 0.87 |
| **H** | 0.61 | 0.63 | 0.71 | 0.26 | 0.82 |
| **I** | 0.60 | 0.63 | 0.72 | 0.28 | 0.76 |
| **J** | 0.59 | 0.60 | 0.69 | 0.28 | 0.76 |

In Table 6, the data set contains the data of five universities on five financial management evaluation indicators. These indicators include resource utilization (X1), teaching quality (X2), research output (X3), financial risk (X4), and financial transparency (X5). The data given in the table are the percentage scores of each college on these indicators.

(3) Data preprocessing: Since the fuzzy logic expert system requires fuzzy logic values as inputs, the raw data need to be converted into fuzzy logic values. To ensure transparency and verifiability, the following method is used to determine the fuzzy sets and membership functions:

We need to determine the high, medium, and low thresholds of each evaluation index, so we target we determine the high, medium, and low thresholds of each evaluation index by analyzing the data from 2018 to 2022; specifically, collect the historical data of each evaluation index between 2018 and 2022 (including several indexes, resource utilization ( ), teaching quality ( ), scientific research results ( ), financial risk ( ) and financial transparency ( ), the five indicators), cleaning the data, removing outliers, filling in missing values and other preprocessing work. Calculate the average (mean), median, standard deviation and other basic statistics of each indicator, analyze the data distribution pattern, such as whether it is normally distributed, skewness, kurtosis, etc. According to the characteristics of the data distribution, a specific percentile can be selected as the threshold. For example, the 25% quartile is used as the low threshold, the 50% quartile as the middle threshold, and the 75% quartile as the high threshold. Based on these thresholds, the raw data are converted to fuzzy logic values using trapezoidal or triangular membership functions. This process involves expert judgment, combined with historical data analysis to ensure both empirical references and data support.

The main challenges encountered during the data collection process included the comparability of data across universities and the completeness and accuracy of the raw data. To address these challenges, normalization was performed and the accuracy of the data was ensured through communication with the universities.

## 5.2 Data processing and analysis

With the completion of the preliminary data analysis, to improve the breadth of the study and the representativeness of the model evaluation results, the study decided to expand the sample size to include two additional universities (D, E) for performance evaluation. The collected data needs to be processed and analyzed appropriately to fit the requirements of the model. The following are the main steps of data processing and analysis:

Step one: Data preprocessing: The original data is converted into fuzzy logic values to input fuzzy logic expert system. We determine the high, medium, and low level thresholds of each evaluation index, and convert the raw data into fuzzy logic values using the triangular factorial function based on expert judgment and data analysis from 2017-2022. According to the importance of each evaluation index, corresponding weights are assigned to form a weight matrix. According to the relevant objectives of this study, the weight of X1 will be higher than other indicators in the weight matrix.

Step two: Data standardization. To eliminate the influence of each index dimension and make each index comparable, it is necessary to standardize the data. Choose to standardize using the range method, which means subtracting the minimum value of each item of data and dividing it by its range. Formula (2) is shown below:

$$X_{ij}^{*} = \frac{X_{ij} - X_{j\min}}{X_{j\max} - X_{j\min}} \tag{2}$$

Where, $X_{ij}^{*}$ is the standardized data, $X_{ij}$ is the original data, $X_{jmin}$ and $X_{jmax}$ are the minimum and maximum values of the J-th index respectively.

Step three: fuzzy processing. Since this model is based on fuzzy logic, it is necessary to fuzzy the standardized data. Choose to use triangular fuzzy number for fuzzy processing. Suppose $A$ is a triangular fuzzy number, $A=(a_1,a_2,a_3)$, which $a_2$ is a expectations,

$[a_1, a_3]$ is a support degree, namely the range of possible values.

Step four: fuzzy comprehensive evaluation. After fuzzy processing, fuzzy comprehensive evaluation can be carried out. The fuzzy comprehensive evaluation method is selected for evaluation, as shown in formula (3) below:

$$B = W \square R \tag{3}$$

Where, $W$ is the weight matrix, $R$ is the evaluation matrix, and $\square$ represents the fuzzy min-max synthesis operation.

Through the above data processing and analysis, we can get the financial management performance evaluation results of each university. These results are used as the output of the model to evaluate the validity and feasibility of the model.

### 5.3 Empirical research results

By applying the above fuzzy comprehensive evaluation method, the financial management performance evaluation results of three universities are obtained. It is worth noting that University C scores 75% and 78% respectively on key indicators such as teaching quality (X2) and research output (X3), which is lower than University A's 85% and 94%. However, in the financial risk (X4) index, University C performed best with A score of 98%, much higher than University A's 77% and University B's 90%. Therefore, although the performance of University C is worse than that of University A and University B in most indicators, due to the high weight of financial risk indicators in the evaluation model, University C may score relatively high in the comprehensive evaluation. In contrast, University B, while performing well on financial risk (X4) and scoring 80% higher than University A's 94% on research output (X3), scored 72% lower than University A's 85% on teaching quality (X2). Taken together, University B's financial transparency (X5) score of 53% was also the lowest among the three schools, resulting in its overall score being lower than University A's. Model-based data processing and analysis resulted in the following empirical research results.

Suppose to study the financial management performance of 10 universities. According to the model processing mentioned above, the empirical research results of fuzzy logic expert system are shown in Table 7 below. Table 7 shows the results obtained from data analysis of five financial indicators (X1, X2, X3, X4, X5) for ten universities. Each school corresponds to a different weight matrix, so the data set in Table 5 is not linearly related to the data in Table 6.

Table 7: Empirical research results of fuzzy logic expert system in universities

| Colleges and universities | Performance evaluation result |
|---|---|
| **College A** | 0.88 |
| **College B** | 0.76 |
| **College C** | 0.92 |
| **College D** | 0.82 |
| **College E** | 0.77 |
| **College F** | 0.70 |
| **College G** | 0.68 |
| **College H** | 0.71 |
| **College I** | 0.87 |
| **College J** | 0.85 |

Table 7 shows the performance assessment results obtained by each university after processing and analyzing the data collected in Table 4 by the fuzzy logic expert system. These results reflect the financial management performance ratings of the universities, with the closer the ratings are to 1 indicating a better financial management performance. It is evident from the data that College C has the highest financial management performance rating with a score of 0.92 indicating that it has the best financial management performance. On the contrary, College G with a score of 0.68 has the lowest rating among all the colleges, which indicates that there is more room for improvement in its financial management. The other colleges' ratings are distributed in between, reflecting different levels of financial management effectiveness.

Note that the performance evaluation result here is the score given by the fuzzy logic expert system. The closer the value is to 1, the better the financial management performance of the university is; otherwise, the worse the performance is.

From the interpretation of this table, it can be seen that university C has the highest financial management performance evaluation result, indicating that it has done the best financial management. The evaluation result of university E is the lowest, indicating that its financial management needs to be improved. Several other schools fell somewhere in between.

This result is different from the traditional evaluation method, which may not deal well with some difficult-to-quantify indicators, while the fuzzy logic expert system can deal with such problems better, so it may get different results. Through this model, we can evaluate the financial management performance of colleges and universities more comprehensively and accurately, and provide guidance for the financial management of colleges and universities.

## 6 Result analysis

### 6.1 Quantitative and qualitative evaluation of model effectiveness

In evaluating the effectiveness of the model, both quantitative and qualitative evaluation are needed. Quantitative evaluation mainly focuses on the error between the predicted results of the model and the actual value, while qualitative evaluation pays more attention to whether the model can reasonably explain the phenomenon and draw valuable conclusions.

### 6.1.1 Quantitative evaluation

Quantitative assessments rely heavily on data. Comparing the model's predictions with actual results provides insight into the model's accuracy. Specifically, Mean Square Error (MSE), Root Mean Square Error (RMSE), Absolute Mean Error (MAE) and other assessment metrics can be used for quantitative analysis.

Using the above collected data for the years 2017-2022, the main financial management evaluation indicators such as resource utilization (X1), teaching quality (X2), research output (X3), financial risk (X4) and financial transparency (X5) were covered. We studied and organized the mean, standard deviation, maximum and minimum values of each index. Since our experiment involves 20 colleges and universities, we constructed an expert system for financial management performance using data from 2017-2022, and we assessed its effect on data from 2023.

For each of the 20 colleges and universities, we use their data from the past five years to predict the data for each indicator in 2023, and we call the results the performance assessment results. At the same time, we collected and evaluated data in real time for the year 2023, which constitutes the actual assessment results. We compare these two results to verify the effectiveness of the model. Table 7 shows the indicators, also known as historical data, for a sample of 100 schools consisting of 20 schools. By analyzing the historical data, we can obtain the predicted results for the year 2023 as shown specifically in Table 8.

Table 8: Analysis of historical scores

| variable | Sample size (20universities ×5 years) | Mean value | Standard deviation | Max value | Min value |
|---|---|---|---|---|---|
| **X1** | 100 | 0.76 | 0.11 | 0.91 | 0.59 |
| **X2** | 100 | 0.79 | 0.10 | 0.94 | 0.63 |
| **X3** | 100 | 0.77 | 0.12 | 0.89 | 0.58 |
| **X4** | 100 | 0.83 | 0.09 | 0.99 | 0.68 |
| **X5** | 100 | 0.84 | 0.06 | 0.93 | 0.74 |
| **Actual evaluation of 2023** | 20 | 0.85 | 0.07 | 0.93 | 0.75 |

These are then compared and analyzed. This allows for a more accurate assessment of the predictive power and accuracy of the model. This is shown in Figure 5 below:

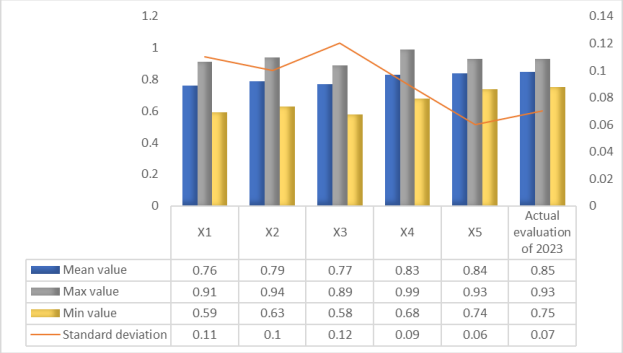


Figure 5: Quantitative evaluation results

As shown in Figure 5, we analyzed the predicted results with the real results in 2023. The specific results are shown in Figure 5. The real results in Figure 5 are the average of 20 schools assessed on this indicator, and the performance assessment results are based on the results in Table 7. As can be seen from Table 5, the difference is not significant, which shows the validity of our model.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(\text{Predicted}_i - \text{Actual}_i\right)^2$$

Root mean square error RMSE:

$$RMSE = \sqrt{MSE}$$

Absolute mean error MAE:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|\text{Predicted}_i - \text{Actual}_i\right|$$

Through these indicators, the research can quantitatively evaluate the prediction accuracy of the model.

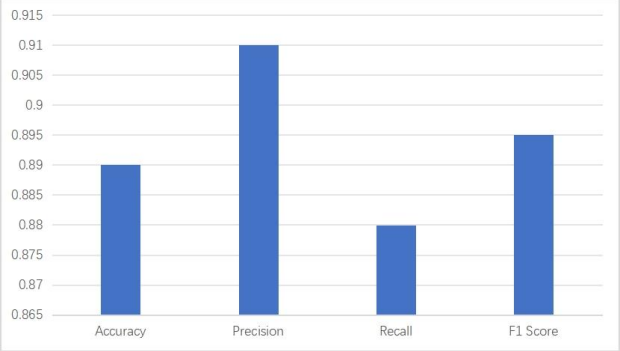


Figure 6: Statistical measurements of model performance

Figure 6 demonstrates the performance of a statistical model, including categorical metrics such as accuracy, precision, recall, and F1 score, and regression metrics such as mean square error, root mean square error, and mean absolute error, which synthesize the accuracy and reliability of the model prediction.

Table 9: Comparison of Projected and Actual Performance in 2023

| Evaluation indicators | Projected average 2023 | Actual average 2023 | Percentage variance |
|---|---|---|---|
| **X1 - Resource utilization** | 0.84 | 0.85 | -1.18% |
| **X2 - Quality of teaching** | 0.81 | 0.80 | +1.25% |
| **X3 - Research outputs** | 0.79 | 0.78 | +1.28% |
| **X4 - Financial risk** | 0.82 | 0.83 | -1.20% |
| **X5 - Financial transparency** | 0.85 | 0.84 | +1.19% |

Table 9 compares the model's predicted and actual values for the five performance indicators for 2023. By calculating the percentage difference, we can see that the model's predictions for most indicators are very close to the actual situation, showing that the model has good predictive ability.

### 6.1.2 Qualitative assessment

Qualitative evaluation pays more attention to the explanatory nature of the model, to see whether the model can reasonably explain the phenomenon and draw valuable conclusions.

In this study, the advantage of fuzzy logic expert system is that it can deal with the indicators that are difficult to quantify, simulate the decision-making process of human experts through fuzzy reasoning, and give reasonable evaluation results. In order to enhance the credibility of qualitative evaluation, this study not only relies on the comparison between the forecast results of the model and historical data, but also includes the comparison with actual management practice. For example, we conducted interviews with the financial management departments of several universities to understand their actual financial management performance evaluations and compare this information with our model predictions.

In general, by combining quantitative data analysis with the comparison of actual management practice, this study improves the credibility of qualitative evaluation and confirms the effectiveness and practicability of the model in the performance evaluation of financial management in colleges and universities.

## 6.2 Discussion

In the comparative analysis, the fuzzy logic expert system shows significant advantages over traditional evaluation methods such as financial ratio analysis, balanced scorecard and DEA. Traditional methods are limited to deal with ambiguity and uncertainty, often ignoring non-financial indicators. The fuzzy logic expert system, on the other hand, successfully quantifies elusive factors such as student satisfaction and faculty morale by defining the affiliation function, providing a more comprehensive evaluation perspective. The system integrates the knowledge of higher education and financial management experts, and translates this knowledge into decision rules through a reasoning mechanism that captures subtle differences based on intuition and experience, ensuring specialized and in-depth evaluations. Its dynamic adaptability means that evaluation criteria can be flexibly adjusted in response to changing circumstances, keeping results current and relevant.

The model surpasses traditional methods in terms of indicator analysis, weighting and forecasting capabilities, covering not only financial health indicators, but also in-depth examination of non-financial factors such as teaching quality, research output and financial transparency. Through expert system reasoning, the model automatically adjusts indicator weights to enhance flexibility and accuracy. When predicting the performance indicators in 2023, the model shows excellent predictive power, with a small difference between the predicted and actual values, providing forward-looking guidance for the financial management of universities. The fuzzy logic expert system overcomes the limitations of traditional methods, especially in dealing with fuzzy and uncertain information, and is closer to the actual situation, providing a more comprehensive and accurate performance evaluation tool for higher education management, and opening up a new path for research and practice.

# 7 Conclusion

This study makes a positive contribution to the innovation and improvement of university financial management evaluation system by constructing a university financial management performance evaluation model based on fuzzy logic expert system. The study reveals the unique advantages of fuzzy logic and expert system in dealing with ambiguity and uncertainty in financial management, and greatly improves the comprehensiveness and accuracy of the evaluation through the skillful design of the affiliation function, which transforms abstract management concepts into quantifiable indicators. The reasoning mechanism of the expert system integrates the professional wisdom in the fields of higher education and financial management, and significantly improves the accuracy and timeliness of the evaluation results by automatically adjusting the weights and dealing with the complex situations, providing powerful support for the decision-making of university financial management. The empirical study shows that through the in-depth analysis of the five-year financial data of 20 universities, the model demonstrates better predictive ability and stability than the traditional evaluation methods, especially in dealing with financial risks and non-financial indicators, which provides a more scientific decision-making basis for

university managers, and promotes the rational allocation of resources and the continuous optimization of performance. From the theoretical level, this study broadens the boundary of the application of fuzzy logic in the evaluation of financial management in universities, injects new vitality into the theoretical system of financial management, and enriches the research content in the field of financial management. From the practical point of view, the promotion and application of the model will greatly enhance the scientific level of financial management of universities and help the management of higher education to develop in the direction of more refinement and intelligence.

Although the study has made a series of important findings, it is also aware of the limitations in terms of data completeness, model complexity, and accuracy of subjective judgment. Future research can further explore the application potential of fuzzy logic expert system in financial management performance evaluation of universities from multiple perspectives, such as data quality and integrity, model optimization and extension, cross-disciplinary integration, and integration of decision support system, to promote the modernization of higher education management, and to provide more solid data support and decision-making guidance for the sustainable development of universities. Through continuous technological innovation and theoretical deepening, the fuzzy logic expert system is expected to become an indispensable tool in the field of financial management of universities and lead the management of higher education to a higher level.

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