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An FCM-Based Scenario Analysis for Improving the Global Ranking of a Turkish University

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Abstract

Despite the increasing international success of Turkish universities, shortcomings in this area remain evident. Several factors are considered when determining the world ranking of universities, including academic publication performance, financial status, success in world rankings, number of international faculty members, number of international students, student-faculty member ratio, size of the university, quality of teaching, and ratio of faculty members with a doctorate. This study aims to highlight this issue and achieve tangible success by identifying these factors and conducting an application with the staff of a model university. A fuzzy cognitive mapping (FCM) study was conducted to identify administrative steps to improve the world rankings of Turkish universities. In the model university where the application was conducted, a cognitive map structure was created from evaluations conducted with decision-makers at various levels. In this context, the factors causing the current situation and their status in various scenarios were examined. The FCM model was developed using the Delphi technique, based on the opinions of five academics representing different areas of expertise. Three different scenarios were analyzed on the model, which was enhanced by combining individual cognitive maps, and it was determined that budget increases, increasing the number of national and international students, and increasing the number of faculty members had positive effects on university performance. Thus, the study offers a cognitive support model for evaluating the factors affecting university rankings using a systems approach. When the examined scenarios are evaluated together, it has become clear that increasing the university budget will contribute to the university in every way and bring about positive effects; however, increasing the Number of National and International Students has had a negative impact.

Keywords
Fuzzy Cognitive Mapping (FCM), University Ranking, Fuzzy Logic, Cognitive Modeling, Scenario Analysis.

1. Introduction

The main purpose of this study is to determine the priority factors that will improve the global ranking of Turkish universities. Various factors affecting university rankings will be identified and analyzed through a literature review, and the most effective strategies to improve them will be determined. Many factors affect university rankings, such as academic performance, financial status, international recognition and industry. These factors are interrelated, and understanding their interactions is crucial for effective decision-making.

This study introduces a Fuzzy Cognitive Map (FCM) to model the relationships among factors influencing university rankings. The FCM will help visualize the impact of the identified factors on the university's performance metrics and evaluate different scenarios. This study will assist university administration in their decision-making processes and enable them to make the right decisions to improve their global standing.

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1.1 Elements of the Decision Problem

Global university rankings are compiled by various organizations based on numerous factors. Before deciding on these factors, the literature was reviewed, and various performance factors used by institutions were identified, taking into account the situation of the university where the study was completed. These factors are listed below for use in the FCM application (Saka & Yaman, 2011).

- **Academic Publication Performance:** It reflects the overall quality of research output produced by the university's faculty and researchers.
  Sub-factors;
  - **Number of Highly Cited Studies**: Studies that are frequently cited in other research studies, showing their impact on the academic community.
  - **Number of Studies Published in Reputable Journals:** This refers to the number of studies published in certain journals; these journals may vary from institute to institute, as they are considered the most competent in their field.
  - **Number of Studies Published in High-Impact Journals: Articles published in these journals receive high citation counts; therefore, it was used** as a criterion.
  - **Number of International Patents:** Internationally patented innovations and inventions reflecting the university's contribution to global technological developments (Konan & Yılmaz, 2017).

- **Financial Status:** The university's research budget expresses the status of resources such as faculty salaries, infrastructure, industrial support, and research centers.
- **Success in World Rankings:** The university's current position in well-known global ranking systems such as the QS World University Rankings, the Times Higher Education (THE) World University Rankings, and the Academic Ranking of World Universities (ARWU).
- **Number of International Faculty Members:** The number of faculty members from different countries, reflecting the university's multinationalism and globality.
- **Number of International Students:** The number of international students enrolled in the university.
- **Number of Faculty Members per Student (Student-Faculty Member Ratio):** The faculty-to-student ratio affects the quality of education and the individual attention each student receives.
- **Size of the University:** It refers to factors such as the university's infrastructure and number of employees, and indicates the quality of service.
- **Quality of Teaching:** It indicates the quality of teaching; this factor has a complex structure that emerges from the combination of many sub-factors.
- **Percentage of Faculty Members with a Doctorate Degree:** The percentage of faculty members with a doctorate (Bozoğlu, 2022).

Understanding and optimizing these factors with the Fuzzy Cognitive Mapping approach will help develop strategies in university management. FCM is well-suited to capturing interactions among multiple factors and modeling complex systems. Since the problem of improving the ranking of Turkish universities involves many interconnected factors, Fuzzy Cognitive Mapping is a suitable choice.

University performance metrics can be affected by uncertainty; integrating fuzzy logic to address it enables more realistic modeling of the problem. The ability of Fuzzy Cognitive Mapping to visualize relationships between factors and experiment with different scenarios by adjusting their weights was a significant factor in its selection, particularly for this problem. Given the complexity of the problem and the factors involved, Fuzzy Cognitive Mapping is a suitable decision-making technique. The resulting Fuzzy Cognitive Mapping will be a powerful tool for improving the university's global standing.

2. Literature Review

Many modern systems today are defined as increasingly complex dynamic systems. These systems are generally high-dimensional, comprising numerous variables and factors. Therefore, while traditional methods offer significant insights into the modeling and analysis of such systems, they are insufficient in various aspects. Fuzzy Cognitive Maps, which utilize the knowledge and experience of experts to represent the dynamics of such complex systems, reveal causal relationships between concepts and analyze system behavior, and are widely used as a knowledge representation and modeling tool. Consisting of concepts that represent different aspects of a system's behavior and

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interact with each other, FCMs reveal the dynamics of the system while symbolically expressing complex system behaviors (Groumpos, 2010)

Nowadays, Fuzzy Cognitive Maps (FCM) are preferred for many scientific research problems, such as modeling the relationships between factors affecting learning, identifying causal relationships in school educational management, analyzing stress symptoms in university students, and designing Learning Management Systems (Mansouri et al., 2021).

In their study, Perivolaris and Stylianakis (2023) aimed to create a holistic evaluation system by modeling the causal relationships between factors affecting university performance. To assess the quality of service (HEI-QoS) of higher education institutions, they initially examined commonly used university ranking systems in the literature (QS World University Rankings, Times Higher Education Rankings, and Academic Ranking of World Universities), analyzing prominent indicators and identifying eight key indicators with high representational power: funding, educational opportunities, cultural opportunities, administrative services, faculty effectiveness, laboratory infrastructure, student performance, and university location. Causal relationships, relationship directions, and strengths between these indicators were determined, resulting in an FCM network that reveals inter-conceptual relationships. The obtained relationships were weighted to create the model's linkage matrix. When the model was run, the interactions between concepts were calculated iteratively, and the output value obtained when the system reached a certain equilibrium state was presented as the university's overall performance level. The created model was tested under different scenarios, and the impact of various changes on the university's overall quality indicator was examined. Thus, the system's behavior under different conditions and which factors are more decisive in determining the outcome were analyzed.

Karasan et al. (2023), in their work on globally important issues such as campus sustainability and combating climate change, developed a ranking system to reveal the current state of green campuses and sustainability among universities worldwide. The ranking system proposed in this study uses 6 main criteria, 39 sub-criteria, and a numerical scoring system to evaluate universities. To overcome the operational difficulties encountered in collecting numerical data, decision-makers need a system that utilizes human judgment. To this end, this study presents a novel fuzzy ranking system based on a multi-stage decision-making model incorporating multi-criteria decision-making methods and FCM. The proposed method was applied to determine the green index of universities, thus demonstrating the applicability of the method

Infante-Moro et al. (2021) examined the use of FCM methodology in scientific research, primarily in the social sciences, and presented a comprehensive literature review on the subject. The study explored the applicability of the method within the social sciences, while also addressing potential key problems that might be encountered. It emphasized the critical importance of steps such as defining the concepts within the system, selecting experts, and determining the coefficients/weights representing the experts' knowledge levels, and offered crucial recommendations for more reliable handling of these fundamental stages

Ketipi et al. (2020), in their study, emphasized the general independence of criteria in traditional decision-making methods, but noted that this is different in real-life problems, highlighting the necessity of considering complex relationships between criteria. To address this gap, they developed a dynamic decision-making model based on FCM that examines and considers the relationships between criteria. Initially, fuzzy evaluation opinions on the importance levels of the criteria were obtained from experts, and initial criterion weights were calculated. Subsequently, causal relationships between the criteria were defined, and a Fuzzy Cognitive Map was created. Thus, by considering the initial weights of the criteria, their interactions, and their mechanisms of influence, updates are made to determine the level of significance of the criteria, evaluating both expert opinions and inter-criterion relationships. In addition to this evaluation, a performance score for the relevant alternative is obtained from the output node structure added to the system, and the alternatives are ranked according to these scores, with the highest-scoring alternative identified as the most suitable option. In this way, causal relationships among criteria are integrated into the decision model, enabling a more realistic evaluation and ranking of alternatives.

Recent literature indicates that global university rankings such as QS, Times Higher Education (THE), and ARWU are not common performance measures but rather algorithmic evaluation frameworks that use different sets of indicators, weightings, and data sources (Liu et al., 2004).

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Indeed, some studies highlight that methodological differences between these systems create inconsistencies in university placements, that rankings fail to adequately reflect specific institutional missions, regional contexts, and academic diversity, and that they cannot even be used alone in research evaluation. While transparency appears relatively strong, significant weaknesses are reported in the dimension of "what matters to communities"; additionally, survey-based indicators and subjective expert selections have been shown to generate subjectivity and bias (Herrera-Viedma et al., 2024)

In this context, the reliability, representativeness, and undesirable outcomes of ranking systems should be addressed not merely as a methodological detail, but as a fundamental problem area in terms of higher education policy and institutional strategy (Latifis et al., 2024).

This study differs from the FCM-based university performance model proposed by Perivolaris and Stylianakis in several important respects. While their study presents a generic model for evaluating overall university performance through endogenous variables and scenario analysis (Perivolaris & Stylianakis, 2023), the present study develops a context-specific FCM model based on the judgments of decision-makers from a single model university. Rather than providing a generalized institutional performance framework, this study focuses on identifying the factors influencing world university rankings within a specific organizational setting. Furthermore, the cognitive map was constructed using the Delphi technique with experts from different disciplines, enabling the model to reflect the characteristics and priorities of the selected institution. Consequently, the proposed model provides institution-specific managerial insights for improving international university rankings, rather than a general assessment of university performance.

3. Methodology

The cognitive mapping method, whose foundations were laid by Axelrod (1976), began to make inferences about how groups perceive cognitive activities. Subsequently, Kosko (1986) integrated fuzzy methods into this method, developing the Fuzzy Cognitive Mapping method. Thanks to these studies, the ways in which groups perceive systems have been revealed, and experts' cognitive knowledge has been mathematically modeled and made easier to understand. Thanks to the application-oriented steps developed by Özesmi and Özesmi (2004), the FCM methodology has reached a stable form. The methodology used in the study is presented step by step in Figure 1.

The Fuzzy Cognitive Map (FCM) used in this study was developed using expert opinions and the Delphi technique. Five academics, selected using purposive sampling, participated. All were experts with relevant academic and administrative experience. The group consisted of two professors, two associate professors, and one assistant professor; two of whom were department heads and one a vice dean; and they possessed expertise in business, management, artificial intelligence, decision-making, and statistics. The experts were selected based on their academic expertise in the research topic, relevant scientific publications, positions in higher education, and decision-making experience.

The Delphi method was applied in two rounds during the creation of the FCM. In the first round, experts were asked to independently identify the underlying factors and their causal relationships. In the second round, the anonymized results were shared for re-evaluation. Since the expert opinions remained consistent, consensus was reached, and the process was completed. The commonly identified causal relationships were grouped into a single neighborhood matrix, and equal weight was given to all expert opinions. No weighting was applied based on academic titles or years of experience of the experts.

Causal relationships were assigned weights between -1 and +1; negative values indicate blocking, and positive values indicate support. Figure 1 shows the direction using only -1, 0, and +1. Intermediate values such as 0.4, 0.5, 0.6, and 0.8 in the adjacency matrix represent normalized weights reflecting both the direction and relative strength of the relationships accepted by the experts. FCM simulations were performed using Mental Modeler software. System behavior was analyzed with the standard FCM update algorithm. In scenario analyses, only the initial activation levels of the targeted concepts were changed, while other variables remained constant. Results were compared to the baseline scenario to assess the impact of each intervention.

The primary objective of the model in this study is to evaluate the potential impacts of various policy and governance scenarios. Sensitivity, robustness, and uncertainty analyses were not performed; this is a methodological limitation. Future studies are encouraged to support the model results with additional analyses.

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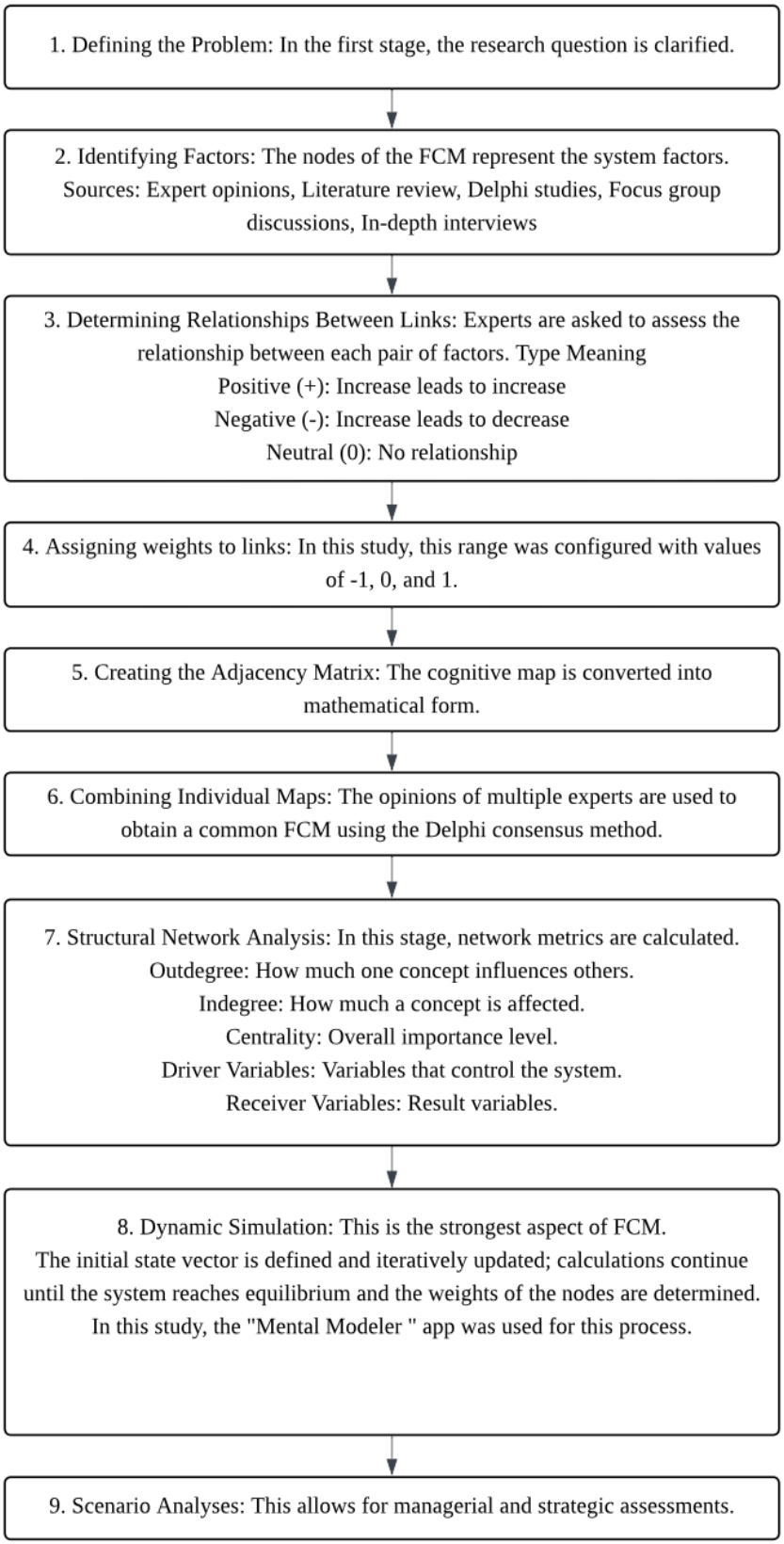

Figure 1. Methodology Steps (Jetter & Kok, 2014; Barbrook-Johnson & Penn, 2022)

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4. Proposed Decision Model

In the defined model, Fuzzy Cognitive Mapping was used to analyze and optimize the key factors affecting the university's worldwide ranking. Using FCM, it will be easier to visualize the relationships between the factors and determine effective strategies for improvement.

First, the basic factors for the study were determined. Then, the relationships among the determined factors were created using the “Mental Modeler" app. For example, a strong relationship was found between "Financial Status" and "Academic Publication Performance". The factors were shown on the map using the " Mental Modeler" app. Weights, determined by the research, were assigned to each relationship according to its strength and direction. Various scenarios were tested using Fuzzy cognitive mapping, and key points were identified on the map. Strategic plans will be proposed depending on these results.

3.1 Decision Makers and Data Collectıon

In this study, data and criteria were determined together at this stage. The ratios mentioned in the studies "Ranking Indicators and Recommendations for Universities in Türkiye", "University Ranking Systems; Criteria and Criticism" and "Measuring Service Quality in the Education Sector: The Example of the Student Affairs Unit" were used as references (Konan & Yılmaz, 2017; Saka & Yaman, 2011; Tosun & Başgöze, 2015).

Subsequently, these ratios were updated for the university where the work was conducted, and opinions were obtained from 5 academic staff members. The profiles of the staff members who were interviewed are summarized below in two categories.

1. University Administration: These decision-makers are the most important in this issue because they can reshape everything in the university. They can push the faculty to conduct more research and secure funding for new projects:

- Vice Chancellor
- Deans of Faculties
- Heads of Departments, etc.

2. Academicians and Research Assistants: Their research performance affects everything. For example, if a professor wins the Nobel Prize, the university ranking increases rapidly.

3.2 Fuzzy Cognitive Map

When creating the FCM, it is critical to first assess the scope of the problem. In this context, all possible scenarios that would define the scope of the problem were evaluated. Based on feedback from decision-makers, the FCM shown in Figure 2 was created. Weights were determined between -1 and +1. A complex structure consisting of positive, negative, and bidirectional relationships emerged. When the resulting structure is examined in detail, it is seen that the 15 factors, along with the sub-factors, determined as a result of common opinions determined within the framework of the Delphi consensus, mostly affect the quality of education.

For example, it is seen that the high number of academic staff with doctoral degrees positively affects the quality of education. Similarly, an increase in the number of international faculty members provides diversity in education, thus having a positive effect. In addition, it was revealed that the financial situation of the university is quite effective in determining the overall performance, as shown in the map.

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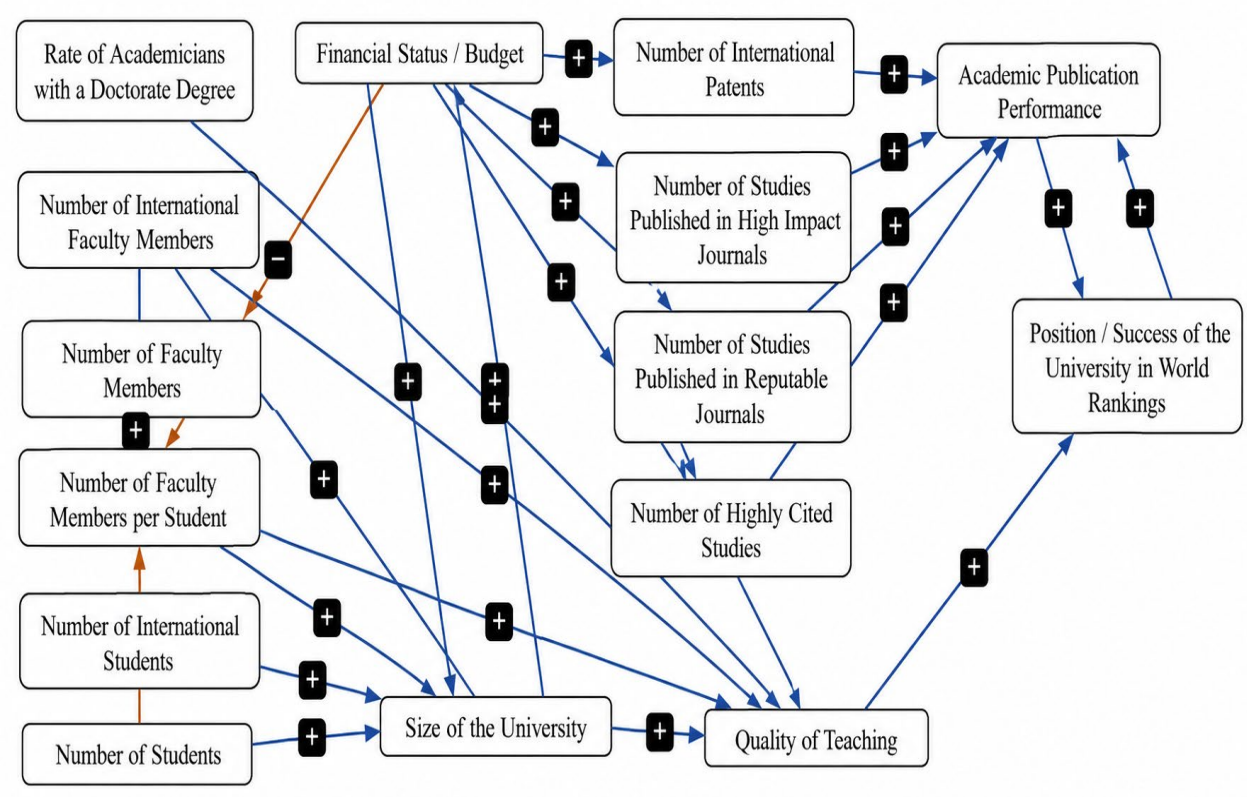

Figure 2. Fuzzy Cognitive Map

Abbreviations in Figure 3 will be used in the fuzzy cognitive mapping study.

Academic Publication Performance	APP
Financial Status / Budget	FSB
Number of Studies Published in High Impact Journals	NSPHIJ
Number of International Patents	NIP
Position / Success of the University in World Rankings	PSUWR
Number of International Faculty Members	NIFM
Number of International Students	NIS
Number of Faculty Members per Student	NFMS
Size of the University	SU
Quality of Teaching	QT
Rate of Academicians with a Doctorate Degree	RADD
Number of Highly Cited Studies	NHCS
Number of Students	NS
Number of Faculty Members	NFM
Number of Studies Published in Reputable Journals	NSPRJ

Figure 3. Abbreviations

The adjacency matrix in Figure 4 shows both positive and negative causal influence between all factors. In this context, for example, a negative causal relationship of -0.2 was determined between financial status and the ratio of academics per student. The number of international students and the number of faculty members per student also show a negative causal influence of -0.4 with the ratio of academics per student (Table 1)

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Table 1. Adjacency Matrix

	APP	FSB	NSPHIJ	NIP	PSUWR	NIFM	NIS	NFMS	SU	QT	RADD	NHCS	NS	NFM	NSPRJ
APP					0.8										
FSB			0.4	0.6			-0.2	0.5	0.6		0.4			0.4	
NSPHIJ	0.4														
NIP	0.4														
PSUWR	0.8														
NIFM							0.8	0.4	0.4						
NIS							-0.4	0.5							
NFMS								0.4	0.8						
SU		0.5							0.4						
QT					0.8										
RADD									0.3						
NHCS	0.6														
NS							-0.4	0.8							
NFM							0.8								
NSPRJ	0.4														

A high outdegree indicates that the node has a strong influence on many other nodes in the system. Nodes with high outdegree are often considered influential in the system. Nodes with high indegree indicate that they are strongly influenced by many other nodes in the system. Nodes with high indegree are often viewed as dependent factors that are affected by changes in the system. The number of Faculty Members is a key driver influencing other factors. The quality of Teaching is highly dependent on improvements in Academic Publications, etc. Figure 4 shows the degrees of all factors in detail (Table 2)

Table 2. Component Type

COMPONENT	INDEGREE	OUTDEGREE	CENTRALITY	TYPE
APP	2,6	0,8	3,4	ordinary
FS	0,5	3,1	3,6	ordinary
NFM	0,0	0,8	0,8	driver
NFMS	2,6	1,2	3,8	ordinary
NHCS	0,4	0,6	1,0	ordinary
NIFM	0,0	1,6	1,6	driver
NIP	0,6	0,4	1,0	ordinary
NIS	0,0	0,9	0,9	driver
NS	0,0	1,2	1,2	driver
NSPHIJ	0,4	0,4	0,8	ordinary
NSPRJ	0,4	0,4	0,8	ordinary
PSUWR	1,6	0,8	2,4	ordinary

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QT	2,5	0,8	3,3	ordinary
RADD	0,0	0,3	0,3	driver
SU	2,6	0,9	3,5	ordinary

4. Results and Discussion

This section examines the model's performance in different scenarios and provides examples of the scenarios tested. The three different scenarios examined are presented below, along with their interpretations.

Scenario 1: Increasing Number of National and International Students

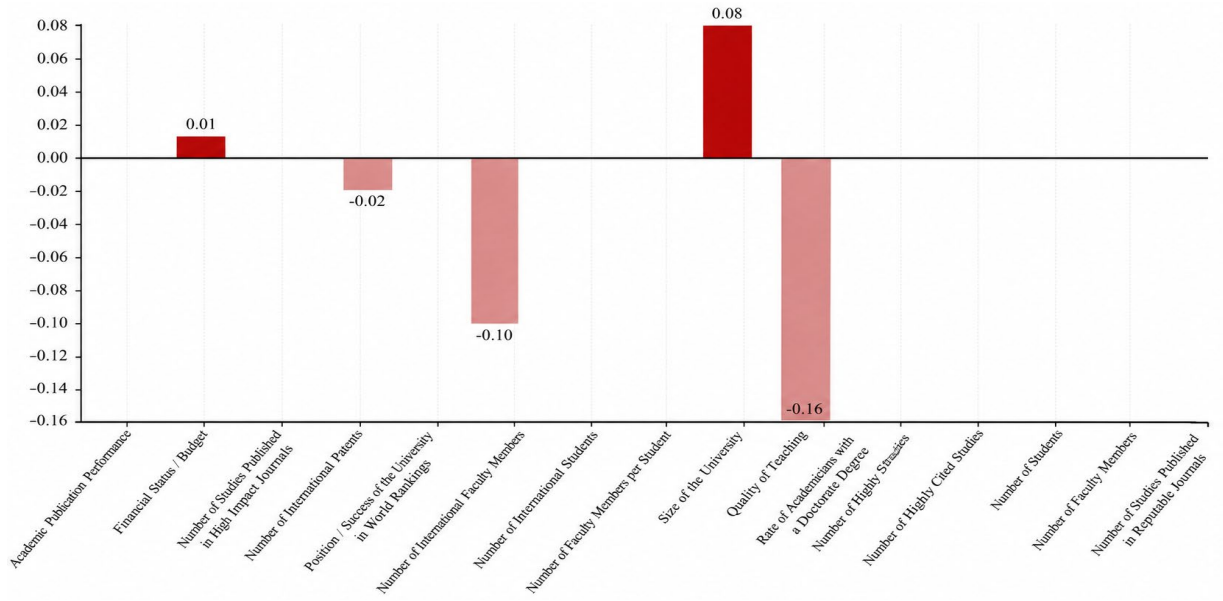

Figure 4. Scenario-1

In this case, the quality of teaching will decline significantly, the number of faculty members will be insufficient, and the University's position in world rankings will decline. In this case, it can be assumed that having more students negatively affects the current situation. It is shown in Figure 4.

Scenario 2: Budget Increase

It is expected that academic studies will increase with the provision of sufficient budget. Therefore, as seen in the table, the articles related to article writing, which are the most important factors for rankings, show a serious increase in this scenario. If the increase in the budget is driven by an increase in the number of students, as shown in FCM, this may lead to an inadequacy of the teaching staff and negatively affect this factor. It is shown in Figure 5.

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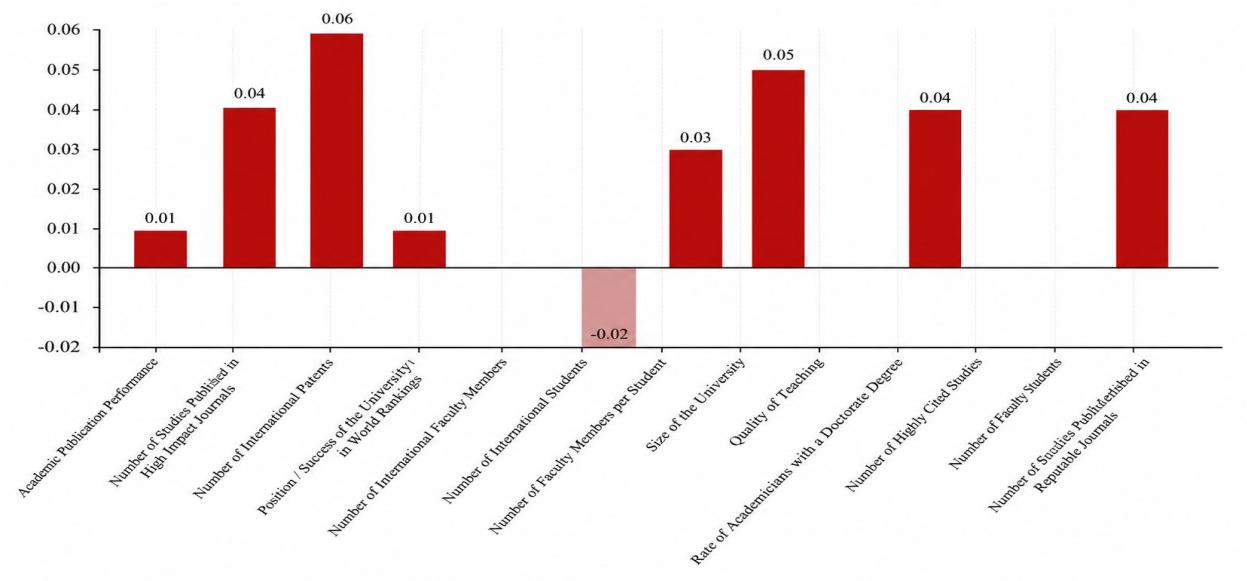

Figure 5. Scenario-2

Scenario 3: Increasing The Number of Faculty Members

It is understood from the table that increasing the number of faculty members and faculty members with doctoral degrees has a very positive impact on both the quality of education and the university's global ranking. It is shown in Figure 6.

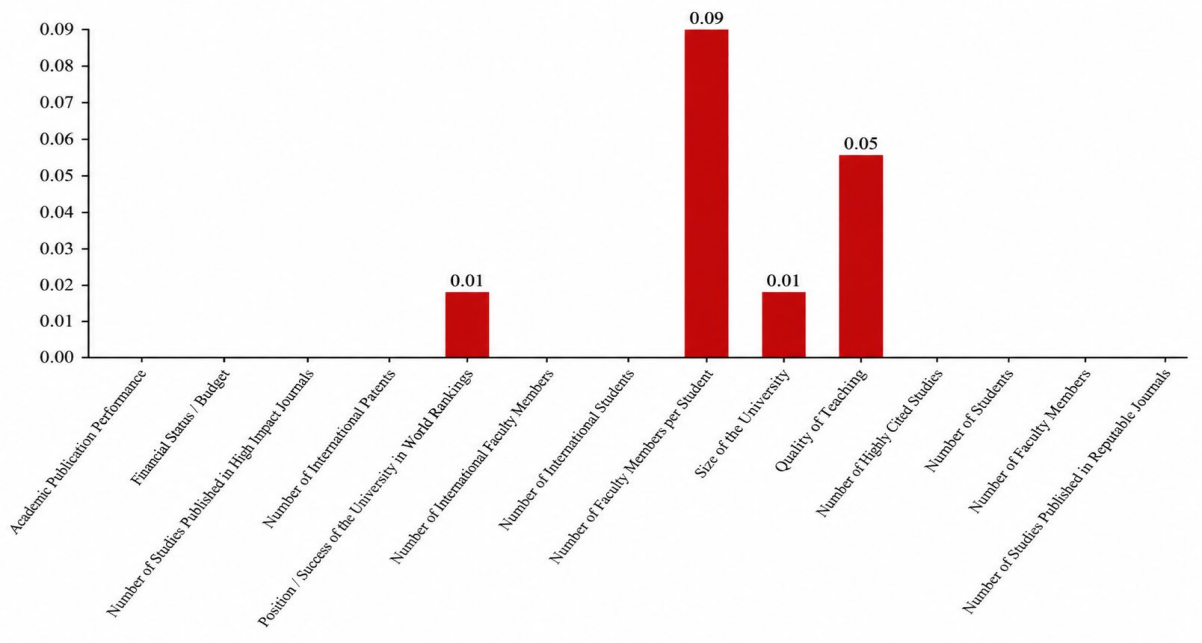

Figure 6. Scenario-3

5. Conclusion

Based on the scenario analysis using Fuzzy Cognitive Mapping (FCM), the following conclusions can be drawn regarding strategies to improve a university's global ranking: Increasing the number of national and international students without significant improvements in faculty and resources results in a decrease in teaching quality. The student-faculty ratio becomes unbalanced, leading to a decrease in the university's global ranking.

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An increase in the university's budget leads to a significant improvement in academic publications and research quality. However, if the budget increase is achieved by increasing student enrollment, it may result in an insufficient number of faculty and negatively affect teaching quality. Care should be taken not to reduce teaching quality while improving the financial situation. Therefore, budget improvements can be accompanied by strategic investments in faculty recruitment and infrastructure to maintain educational standards.

Increasing the number of faculty members, especially those with doctoral degrees, has a positive impact on both the quality of education and the university's global ranking. Investing in the recruitment of highly qualified faculty members is a highly effective strategy to improve both the quality of education and global rankings. This approach enables the university to provide high-quality teaching while increasing its research activities. It is important to make conscious decisions that strategically balance resources, faculty and student numbers while raising the university to world standards, thus ensuring continuous excellence in education and research.

This study has some limitations. The model was developed specifically for a single university, based solely on the opinions of five academic experts; the linkage weights were determined by expert assessments, and no external validation was performed with an independent dataset. Furthermore, because sensitivity and uncertainty analyses were not performed, testing the findings under different conditions is an important area for future research. Nevertheless, the proposed FCM model contributes to a holistic assessment of the factors influencing university rankings and supports strategic decision-making processes.

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Biographies

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