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# A Fuzzy MCDM Approach for Prioritizing Iran's Biotechnology Projects: A Practical Model

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**ABSTRACT**

The problem complexity of multi-criteria decision-making (MCDM) is a great issue in the priorities of biotechnology, which need robust MCDM methods. Fuzzy MCDM uses fuzzy numbers to handle and measure inaccuracies and ambiguities. MCDM is capable of providing a methodical approach that simultaneously uses decision criteria (i.e., benefit and cost information) and decision makers' opinions in choosing the optimal alternative from a list of alternative options. The aims of this study were (1) to give a comprehensive view of factors contributing to the success of biotechnology in Iran, (2) to prioritize these factors, (3) to provide a model for solving diverse decision problems by determining biotechnology research priorities, and (4) to develop a comprehensive scientific roadmap for biological fields. We developed a fuzzy multiple criteria decision making (MCDM) model combines the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) in decision-making with fuzzy data, where the decision-making team acquires the ability to select the appropriate option in an environment of vague criteria. Detailed analysis is also presented. The ranking of projects and priorities was done using MCDM techniques, scientometric map-based verification, preparation of a tree of priorities and needs of universities and research centers. Priority areas in terms of universities and centers were extracted, including four key areas, 274 key sub-areas, 21 criteria, and 48 sub-criteria. and then allocated to the universities. These findings demonstrated that the prioritization findings were subject to a systematic ranking by fuzzy multiple criteria decision making (MCDM) model via all scenarios of weighting priorities.

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## BACKGROUND

The knowledge-based economy is an economic system that relies on the production, distribution, and application of knowledge and information, where investment in knowledge and knowledge-based industries is given special attention [1]. In such an economy, knowledge is the main driver of growth, wealth creation, and employment in all fields of activity. In the transition to a knowledge-based economy, improving collaboration between industry and academia is an important factor. Globalization, the use of science as a strategy to create competitive advantage in companies, and the emergence of science-based industries are three of the most important elements that justify the common connections between companies and research organizations [2].

In the knowledge-based economy, academia, industry, and government are the most important institutions. To theorize and analyze the relationships of these institutions, researchers have followed different approaches, such as the National Innovation System and the Triple Helix perspectives.

In the model of the National Innovation System, each of the institutions has its own clear and defined boundaries: Technological innovation is defined as the specific work of industry, the development of science and education are the exclusive work of academia, and policy-making and motivation for innovation are the exclusive work of government. Innovation occurs through the interaction of industry and academia in the research and development (R&D) marketplace. The National Innovation System is composed of components that interact with each other to produce economically useful knowledge to disseminate and commercialize it [3,4]. The third level of complexity in this system is called the "knowledge-based innovation system" or "Triple Helix pattern," which is also considered as one of the important components of the knowledge-based economy [5].

The concept of the Triple Helix was introduced by Etzkowitz and Leydesdorff (1995) [6]. In this model, the potential of economic development and innovation in the knowledge society is created when elements of academia, industry, and government are combined to create new social and institutional structures to produce, transfer, and apply knowledge [7]. In this model, the relationship between academia, industry, and government is explained as a network with three main arms, and there is a planned division of labor between these three sections. According to this model, universities are producers and transmitters of knowledge, and industries are producers of services and products, while governments have a regulatory role among them [8]. When academia, industry, and government participate in university research for economic development, a network of interactions is created in a helix [9]. The lack of proper communication between these three sectors is one of the problems in developing countries, but in developed countries, this type of communication has been properly established, and, generally, the commencement of industrial developments has been originated from academia.

The problem of insufficient interaction between academia and industry is a structural problem that goes back to economic structures in developing countries (such as Iran). Overcoming this obstacle requires a precise definition of the issue and the scope of activities in all three sectors.

Biotechnology is one of the most important and empowering scientific fields in Iran. Strategic technologies (such as biotechnology) through the impact on economic components (including the production of new and effective products in agriculture, medicine, nutrition, environment, alternative fuel sources, etc.) create wealth and prosperity in the economy.

In this article, based on the Triple Helix approach, Iran's policies toward the biotechnology sector in the form of "national labor division of biotechnology" were discussed to identify potential areas of cooperation between industry and academia with minimal involvement of government.

In the last two decades, Iran's biotechnology management has put effective local and thematic activities on the agenda to promote the development of technology in research and industrial fields. It is clear that a significant volume of these activities has no outcomes due to poor knowledge in managing new technologies. Therefore, using an appropriate strategy is necessary to significantly improve the productivity and development of biotechnology research.

In this regard, prioritization would lead to great achievements, such as reducing the time to achieve the centers' priorities and acceptable relative accuracy, determining point, regional, and national priorities, assisting the Biotechnology Development Council for systematic and intelligent support of collections, reaching a national agreement on biotechnology research priorities, writing dissertations based on priority needs, preparing basic scientific databases in the field of biology, and carrying out custom projects and science production.

Consistent allocation plans are required to prioritize biotechnology benefits and improve the productivity of research and development in this technology with an appropriate mechanism. Hence, developing an effective and dynamic mechanism for biotechnology prioritization is crucial and regarded as the only progress method for directing dissertations to priority needs.

In order to solve different multi-criteria decision-making (MCDM) challenges, different techniques have been used in the literature. Decision-making techniques have received widespread attention in various fields, of which MCDM is the most critical [10-13]. MCDM challenges face inaccuracies and uncertainties. Fuzzy MCDM uses fuzzy numbers to handle and measure inaccuracies and ambiguities [14]. Regarding the need to deal with ambiguity in real-life issues, several approaches and theories have been developed [15]. Various procedures have been defined for this technique, including structuring, planning, and solving diverse decision problems using multiple criteria [16-18].

MCDM is capable of providing a methodical approach that simultaneously uses decision criteria (i.e., benefit and cost information) and decision makers' opinions in choosing the optimal alternative from a list of alternative options [19].

Fuzzy approaches are commonly applied for decision-making [20], such as data envelopment analysis (DEA) [21], analytic hierarchy process (AHP) [22], fuzzy analytic network process (FANP) [23], fuzzy AHP [24], fuzzy goal programming [25], etc. In the present study, MCDM is adapted to the national labor division of biotechnology to determine biotechnology priorities. FANP was performed to address the problem of dependence and feedback among each measurement criterion, as well as the weights of the evaluation criteria among decision makers, including owners, users, and expert groups. Framework tools are capable of ranking the alternatives regarding the decision criteria, which have various measurement units. In Iran, a comprehensive scientific plan is needed to achieve the goal of Iran's 20-Year Vision Plan.

According to the needs, Iran's Biotechnology Development Council has set priorities in the set of short-term measures and its management in two levels of immediate and future measures for research and practical applications. Therefore, the aims of this study were (1) to give a comprehensive view of factors contributing to the success of biotechnology in Iran, (2) to prioritize these factors, (3) to provide a model for solving diverse decision problems by determining biotechnology research priorities, and (4) to develop a comprehensive scientific roadmap for biological fields.

## MATERIALS AND METHODS

### Study Population and Sampling

This study is a descriptive cross-sectional study for the national division of labor, collecting data at a point in time. Furthermore, this research is part of applied studies because it leads to the practical application of knowledge. In addition, the present study is a field study because the research data are collected using statistical samples, questionnaire tools, and interviews.

The criteria for evaluating the division of labor and their prioritization at the national level are given in Table 1.

**Table 1: The criteria for evaluating the division of labor and their prioritization at the national level**

| Code | Criteria | code | Sub-criteria |
|---|---|---|---|
| C1 | Research output | F1 | Research product (cultivar, commercial hybrid, scientific article, patent, final product, patent and product) |
| C2 | Need to technology or product/ Immediate or future | F2 | The bottleneck of technology |
| | | F3 | Country needs |
| | | F4 | Emerging and innovative technology |
| C3 | Impact on welfare and general issues of life | F5 | Impact on health / treatment |
| | | F6 | Provide food security |
| | | F7 | Impact on energy |
| | | F8 | Impact on water and natural resources |
| | | F9 | Effect on reducing water consumption |
| | | F10 | Effect on reducing input consumption |
| | | F11 | Impact on employment and entrepreneurship |
| C4 | Economic achievement | F12 | *Economic value added* |
| | | F13 | Export value |
| | | F14 | Effect on import ban |
| | | F15 | Effect on farmers or beneficiaries |
| | | F16 | Effect on reducing production costs or producing a cheaper product |
| | | F17 | Impact on the prevention of raw material sales |
| C5 | The importance of planning | F18 | Value / necessity for region / province |
| C6 | Impact on environmental issues | F19 | Biological recovery |
| | | F20 | Bio-recycling |
| | | F21 | Revival of soil resources |
| | | F22 | Increase water resource efficiency |
| | | F23 | Environmental Protection |
| | | F24 | Reduction of pollutants |
| | | F25 | Reduce pesticide consumption |
| C7 | Impact on culture (positive or negative) | F26 | Impact on community culture |
| C8 | Impact on resources and national reserves | F27 | Preservation of genetic resources |
| | | F28 | Production of a new product |
| | | F29 | Other |
| C9 | Technological attractiveness | F30 | Technology rival |
| | | F31 | The future of technology |
| | | F32 | Synergy with other technologies |
| | | F33 | The complexity of technology |
| | | F34 | The cost of acquisition |
| | | F35 | Market |
| C10 | Existence of infrastructure | F36 | Hardware required |
| C11 | Existence of knowledge | F37 | Knowledge dependence |
| C12 | Cooperation and implementation capacity | F38 | Related fields of study |
| | | F39 | Annual student recruitment capacity |
| | | F40 | Number of dissertations / dissertations extracted from it |
| | | F41 | Share cooperation capacity (national and international) |
| C13 | Presence of special abilities | F42 | University feature to select priority |
| | | F43 | Duration or speed of achievement |
| | | F44 | Logistic feature (geographical) |
| | | F45 | Previous experiences and preparation |
| | | F46 | Existing specialized manpower |
| | | F47 | |
| C14 | Relation with industry | F48 | Industrialization capacity (laboratory, semi-industrial and industrial) |
| C15 | Increase water- | F49 | |

| | | | |
|---|---|---|---|
| | use efficiency in crops and horticulture | | |
| C16 | Attract international cooperation | F50 | |
| C17 | Attract international funding | F51 | |
| C18 | International importance | F52 | |
| C19 | Superiority | F53 | |
| C20 | Tourism | F54 | |
| C21 | Passive Defense | F55 | |

The population studied in this research is each university and scientific research center as a sample unit. In this study, cluster sampling was used when study groups were mutually homogeneous yet internally heterogeneous. Attempts were made to use the samples introduced by the Biotechnology Development Council. Therefore, the formula was not used to calculate the number of samples.

### Data Collection Tool

In this research, a questionnaire was used to collect data, and various first- and second-hand sources (such as books, the Internet, journals, and articles) were used to explore the research background.

Questionnaires in this research were used in three steps as follows:

- for the selection and validation of criteria,
- for priority selection and validation, and
- for optimal allocation of priorities.

### Statistical Methods

MCDM was applied to analyze the data. The collected data are summarized in frequency distribution tables and diagrams. Every collective and joint action needs coordination and explanation of the executive steps for the implementation of planned and scheduled programs by the executors.

The following steps were considered in the biotechnology prioritization process: the preparation of a common framework for obtaining information from universities and research centers, the development of a guideline for prioritization, and the purposeful division of national labor. The FANP method, a multi-criteria prioritization method, was used to determine the weights of the indicators and rank the options.

Tables were converted into information forms, and templates (along with the guidance document) were sent to the country's research collections. Priorities were set, and then the submitted forms were completed accurately and completely by academic and research centers. The aggregation of the priorities set by the biotechnology centers of the country was done, and the suggested items of the subgroups of the biotechnology headquarters were considered according to the background and compliance with the policies and documents of the upstream country. Biotechnology priorities were finalized based on the proposed items. The technological priorities of each university and research center were presented, and then the financial and organizational support of the Vice President for Science was provided for the university and research centers. Feedback on this process was provided to the country's academic and research centers.

Accordingly, the main stages of the activities can be announced as follows:

1- biotechnology priorities from the perspective of the Biotechnology Development Council working groups,
2- the three priorities of universities (self-expression), and
3- self-declaration adaptation to the priorities of the working groups:
• extracting priorities that are fully consistent with the self-declaration,
• extracting self-declarations in accordance with the priorities of the working groups but similar priorities were included (duplicate),
• subjective Work Breakdown Structure (WBS) a (failure) and subject-based division between centers offering similar (duplicate) priorities.
• use of the priority table to divide similar invincible items.
4- communicating the priorities divided to the centers and establishing them for support and monitoring, and
5- targeting priorities to achieve the outputs and results desired by the Biotechnology Development Council and results-based monitoring.

## RESULTS

An attempt was made to extract the three priorities of the university centers in accordance with the initial priorities of the various working groups of the Biotechnology Development Council working group.

A: Design and adjustment of the questionnaire and its approval by the Biotechnology Development Council working group

Equivalent to each of the questions in the questionnaire (as a criterion), a variable was defined in SPSS version 16 (SPSS Inc., Chicago, Ill., USA). All the constructs of the studied model were formed based on the mean scores of the related questions. For example, ease of use for each questionnaire was formed by calculating the average score given to questions useful 1, useful 2, and useful 3. The scoring of the questions was based on a five-point Likert scale.

Due to their positive expression, the scoring method was downward trend scoring. Downward trend scoring for positive questions has been completely disagree, disagree, having no opinion, agree, strongly agree.

## Reliability Analysis

The reliability and validity of the questionnaire were also examined. The Cronbach α was used to assess the reliability of the questionnaire. After collecting the questionnaires, reliability analysis was performed on the questionnaire questions to ensure reliability. In this analysis, the Cronbach α coefficient on the questions of each variable was calculated using SPSS version 16. The Cronbach α is used to calculate the internal consistency of measuring tools, such as questionnaires or tests that measure different characteristics.

These values for each structure and the whole questionnaire are higher than 70% (0.727); thus, it can be claimed that this tool has high validity.

## Exploratory Factor Analysis

All items were derived from a conceptual framework that is itself a repetition of the extensive literature review. Therefore, the construct validity of the data collection tool was confirmed. The convergent and divergent or diagnostic and convergent validity of the structures was tested using principal component analysis (PCA) with the help of varimax rotation in exploratory factor analysis. For this purpose, exploratory factor analysis was performed separately to examine each of the structures. The result of exploratory factor analysis identified only one factor with specific values higher than 1 for each of the structures. The Kaiser-Meyer-Olkin measure of sampling adequacy of each structure was greater than 0.6 (0.708), indicating the adequacy of sampling.

Furthermore, the significant value of Bartlett's test for all structures was <0.05 (Sig = 0.000), indicating that the matrix was not a unit and factor analysis could be used to identify the structure. The results of this analysis also introduced six structures with specific values higher than 1, which together explained about 68% of the total variance.

## Validity Analysis

In the present study, the content validity was used to determine the validity of the measurement tool because this method ensures that the tool has a sufficient number of appropriate questions to measure the concept (Kalantari, 2012, p. 35). Also, construct validity was used to test the validity of the questionnaire questions. For this purpose, the final questionnaire was obtained to collect data after consulting with experts in the field of biotechnology.

## Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was applied using LISREL version 8.54 (Scientific Software International, Inc., USA) to assess the validity of the items and to ensure the one-dimensionality of the scales of each structure and the validity of the evaluated model. Table 2 shows the standard coefficients and significant values of the studied model or biotechnology tree, respectively.

**Table 2: The goodness of fit index (GFI) for model or tree of biotechnology**

| Row | Model Fitting Criteria | index | Dimension | Desirable limit | Result |
|---|---|---|---|---|---|
| 1 | Chi-square relative | $\chi^2/df$ | 1/71 | <3 | very well |
| 2 | Root Mean Square Error of Approximation | RMSEA | 0/042 | <0/1 | A good fit |
| 3 | Root Mean Square Residual | RMR | 0/051 | About zero | Acceptable |
| 4 | Normed fit index | NFI | 0/96 | >0/90 | Acceptable |
| 5 | Non-normed fit index | NNFI | 0/98 | About one | Very well |
| 6 | Comparative fit index | CFI | 0/98 | >0/90 | Very well |
| 7 | Relative fit index | RFI | 0/96 | >0/90 | Very well |
| 8 | Incremental Fit Index | IFI | 0/98 | >0/90 | Very well |
| 9 | Goodness-of-fit index | GFI | 0/94 | >0/90 | Very well |
| 10 | Adjusted goodness-of-fit index | AGFI | 0/92 | >0/90 | Well |

## Root Mean Square Error of Approximation

The root mean square error of approximation (RMSEA) is actually a test of the deviation of any degree of freedom. RMSEA <0.05 indicates a good fit of the model. Values higher than 0.08 indicate a reasonable error for approximation in the population. Models with an RMSEA of 0.1 or more have a poor fit. RMSEA in this model is equal to 0.042, indicating that the model has a relatively good fit.

$\frac{x^2}{df}$ test

The $X^2$ test simply shows whether the model describes the structure of relationships between the observed variables. The value of this statistic should be <3. Regarding model variables, the value of this statistic was found to be 1.71.

## Root Mean Square Error (RMSE)

RMSE is the standard deviation of the residuals and can be changed only in relation to variances and covariances. In a model that has a goodness of fit index (GFI), these residues are very small; thus, a smaller index (closer to zero) indicates a better fit of the model. The value of this index in the model was equal to 0.051.

## Adjusted Goodness of Fit Index (AGFI) and Goodness of Fit Index (GFI)

LISREL (linear structural relations) is capable of estimating structural equation models (SEMs). LISREL calculates the ratio of the sum of squares explained by the model to the total sum of squares of the estimated matrix in the community. This index is similar to the correlation coefficient in terms of usefulness. Both of these criteria vary from 0 to 1, although they may theoretically be negative. The proximity of adjusted GFI (AGFI) and GFI to number 1 is related to the good fit of the model. The GFI and AGFI values in the model were 0.94 and 0.92, respectively.

Normed Fit Index, Non-Normed Fit Index, and Comparative Fit Index

In the Normed Fit Index (NFI; also called the Bentler–Bonett Normed Fit Index), Bentler and Bountt (1980) recommended values equal to or greater than 0.9 as an incremental measure of goodness of fit for a statistical model, while some researchers use a cut-off point of 0.80. Another indicator is the Tucker–Lewis Index, also known as the Non-Normed Fit Index (NNFI). This index is similar to NFI and is an incremental fit index applied in linear mean and covariance structure modeling, especially in exploratory factor analysis. Values less than 0.9 require revision of the model. A Comparative Fit Index (CFI) greater than 0.90 is acceptable and indicates a good fit for the model. This index also tests the amount of improvement by comparing an independent model, in which there is no relationship between the variables and the proposed model.

CFI is a normed fit index ranging from 0 and 1 with higher values, showing a better fit. The values of these three indices (NFI, NNFI, CFI) in the model are 0.96, 0.98, and 0.98, respectively. All items related to each of the structures had positive and significant factor weights (minimum t-value of 4.73 was obtained), indicating that the convergent validity criterion is satisfactory. The one-dimensionality and convergent validity of the structures were also investigated using the composite reliability scale and the Average Variance Extracted (AVE) (Tong and Howley, 2009). All composite reliability values were higher than 0.6, and all AVE structures were higher than 0.50, indicating the suitability of convergent validity. The results of the confirmatory factor analysis indicated the full validity of the questionnaire used.

## B: Weighting priorities and extracting the final list of priorities of relevant universities and centers

We first tried to get the initial opinions of different working groups of the Biotechnology Development Council in sections, including medicine, agriculture, environment, and industry.

In this section, we first tried to form an advisory working group at the Biotechnology Development Council level. Then, the different priorities of the staff working groups were assessed in a face-to-face meeting. By summarizing the expert opinions, an attempt was made to reach an initial draft of the priority list at the level of the Biotechnology Development Council, which is presented in Table 3. It was next tried to extract the three priorities of universities in accordance with the initial priorities of the various working groups of the Biotechnology Development Council.

**Table 3: Priorities introduced by the advisory working group and universities**

| | | Priorities introduced by the Advisory Working Group and Universities | |
|---|---|---|---|
| Biotechnology tree | Agriculture | Transgenic plants | Resistance to non-biological stresses |
| | | | Resistance to biological stresses |
| | | Transgenic animals | |
| | | Molecular agriculture | Antibodies and other proteins |
| | | | Oral vaccines |
| | | | Metabolite Engineering |
| | | Seeds and seedlings using micropropagation and | |
| | | Biofertilizers and bio-inhibitors | |
| | | Secondary metabolites | |
| | | Biotechnology-based livestock, poultry and aquatic feed supplements | |
| | | Vaccines for livestock, poultry and aquatic animals | |
| | | Diagnostic kits for important plant and animal diseases | |
| | Industry | Equipment in the infrastructure industry | |
| | | Equipment in the upstream industries | |
| | | Equipment in the production and intermediate industries | |
| | | Equipment in downstream and purification industries | |
| | | Equipment in quality control | |
| | medicine | Production of peptides with the role of antibiotics | |
| | | Purification of pharmaceutical products | |
| | | Fermentation industries | Production of biofuels |
| | | | Production of starters and probiotics |
| | | | Production of industrial enzymes |

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| | | | Production of amino acids |
| | | | Production of organic acids |
| | | | Production of yeasts and bread yeast |
| | | | Production of antibiotics |
| | | | Production of vitamins and related compounds |
| | | | Production of biopolymers such as xanthan gum |
| | | | Production of bioemulsifiers and microalgae |
| | | Production of anti-cancer drugs | |
| | | Production of diagnostic biosensors | |
| | | Production of high-yield cell lines | |
| | | Production of recombinant monoclonal antibodies | |
| | the environment | inputs and biological controls | |
| | | Biofuel | |
| | | Bioremediation of oil and petrochemical industries | |
| | | Air and dust | |
| | | Legal and biosafety | |
| | | Petroleum biotechnology | |
| | | Water and soil bioremediation | |
| | | Preservation of oak forests and natural resources | |

Finally, we combined the three views of the Biotechnology Development Council working group, the advisory working group, and the universities in a series of specialized meetings based on the opinions of experts in this field. As it turned out, all criteria and sub-criteria have acceptable average to experts. After the final approval of the criteria, we reached the final review of the priorities presented by the experts. Therefore, a list was provided after merging different opinions (Table 4).

**Table 4: Final priorities introduced by the experts**

| code | Criteria | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Merge comments | Normalized | code | Sub-criteria | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Merge comments | Normalized |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | **Research output** | 9 | 7 | 5 | 7 | 9 | 5 | 9 | 9 | 7.500 | 83% | F1 | **Research product (cultivar, commercial hybrid, scientific article, patent, final product, patent and product)** | 9 | 7 | 7 | 7 | 9 | 5 | 9 | 9 | 7.750 | 86% |
| C2 | **Need to technology or product / Immediate or future** | 7 | 9 | 7 | 9 | 9 | 7 | 9 | 9 | 8.250 | 92% | F2 | **The bottleneck of technology** | 7 | 7 | 9 | 9 | 7 | | 9 | 9 | 8.143 | 90% |
| | | | | | | | | | | | | F3 | **Country needs** | 9 | 7 | 7 | 9 | 9 | 7 | 9 | 9 | 8.250 | 92% |
| | | | | | | | | | | | | F4 | **Emerging and innovative technology** | 7 | 5 | 5 | 7 | 5 | 5 | 7 | 5 | 5.750 | 64% |
| C3 | **Impact on welfare and general issues of life** | 7 | 7 | 5 | 7 | 9 | 5 | 9 | 9 | 7.250 | 81% | F5 | **Impact on health / treatment** | 9 | 9 | 7 | 9 | 9 | 7 | 7 | 7 | 8.000 | 89% |
| | | | | | | | | | | | | F6 | **Provide food security** | 9 | 7 | 5 | 9 | 7 | 7 | 7 | 9 | 7.500 | 83% |
| | | | | | | | | | | | | F7 | **Impact on energy** | 7 | 7 | 5 | 5 | 5 | 7 | 7 | 5 | 6.000 | 67% |
| | | | | | | | | | | | | F8 | **Impact on water and natural resources** | 9 | 9 | 5 | 7 | 7 | 7 | 9 | 9 | 7.750 | 86% |
| | | | | | | | | | | | | F9 | **Effect on reducing water consumption** | 9 | 7 | 9 | 7 | 9 | 7 | 9 | 9 | 8.250 | 92% |
| | | | | | | | | | | | | F10 | **Effect on reducing input consumption** | 7 | 7 | | 7 | 5 | 7 | 7 | 5 | 6.429 | 71% |
| | | | | | | | | | | | | F11 | **Impact on employment and entrepreneurship** | 5 | 7 | 9 | 7 | 7 | 7 | 7 | 9 | 7.250 | 81% |
| C4 | **Economic achievement** | 7 | | 7 | 9 | 7 | 5 | 7 | 9 | 7.286 | 81% | F12 | **Economic added value** | 7 | 7 | 7 | 9 | 7 | | 7 | 9 | 7.571 | 84% |
| | | | | | | | | | | | | F13 | **Export value** | 5 | 9 | 7 | 7 | 9 | | 7 | 7 | 7.286 | 81% |
| | | | | | | | | | | | | F14 | **Effect on import ban** | 9 | 7 | 7 | 7 | 7 | | 7 | 9 | 7.571 | 84% |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | F15 | Effect on farmers or beneficiaries | 9 | 5 | 5 | 7 | 5 | 7 | 5 | 9 | 6.500 | 72% |
| | | | | | | | | | | | | F16 | Effect on reducing production costs or producing a cheaper product | 9 | 5 | 5 | 9 | 7 | 7 | 7 | 9 | 7.250 | 81% |
| | | | | | | | | | | | | F17 | Impact on the prevention of raw material sales | 7 | 9 | 9 | 9 | 7 | | 7 | 5 | 7.571 | 84% |
| C5 | The importance of planning | 5 | 9 | 9 | 7 | 5 | 7 | 9 | 3 | 6.750 | 75% | F18 | Value / necessity for region / province | 5 | 9 | 9 | 9 | 7 | 9 | 7 | 7 | 7.750 | 86% |
| C6 | Impact on environmental issues | 9 | 9 | 0 | 9 | 7 | | 9 | 3 | 6.571 | 73% | F19 | Biological recovery | 7 | 7 | 7 | 7 | 5 | 5 | 5 | 7 | 6.250 | 69% |
| | | | | | | | | | | | | F20 | Bio-recycling | 7 | 7 | 5 | 7 | 7 | | 7 | 7 | 6.714 | 75% |
| | | | | | | | | | | | | F21 | Revival of soil resources | 9 | 7 | 5 | 7 | 7 | 5 | 7 | 7 | 6.750 | 75% |
| | | | | | | | | | | | | F22 | Increase water resource efficiency | 9 | 7 | 9 | 7 | 7 | 7 | 7 | 9 | 7.750 | 86% |
| | | | | | | | | | | | | F23 | Environmental Protection | 9 | 9 | 1 | 9 | 9 | 7 | 7 | 5 | 7.000 | 78% |
| | | | | | | | | | | | | F24 | Reduction of pollutants | 9 | 9 | 9 | 9 | 7 | 7 | 9 | 9 | 8.500 | 94% |
| | | | | | | | | | | | | F25 | Reduce pesticide consumption | 9 | 9 | 7 | 9 | 7 | 7 | 7 | 9 | 8.000 | 89% |
| C7 | Impact on culture (positive or negative) | 7 | 5 | 0 | 7 | 7 | 5 | 7 | 0 | 4.750 | 53% | F26 | Impact on community culture | 7 | 5 | 3 | 7 | 7 | 7 | 7 | 0 | 5.375 | 60% |
| C8 | Impact on resources and national reserves | 7 | 7 | 3 | 7 | 7 | 7 | 7 | 5 | 6.250 | 69% | F27 | Preservation of genetic resources | 9 | 7 | 3 | 9 | 7 | 7 | 7 | 5 | 6.750 | 75% |
| | | | | | | | | | | | | F28 | Production of a new product | 7 | 5 | 7 | 5 | 7 | 5 | 5 | 3 | 5.500 | 61% |
| C9 | Technological attractiveness | 7 | 7 | 5 | 7 | 5 | 3 | 9 | 5 | 6.000 | 67% | F30 | Technology rival | 5 | 7 | 7 | 7 | 3 | | 5 | 9 | 6.143 | 68% |
| | | | | | | | | | | | | F31 | The future of technology | 7 | 7 | 7 | 7 | 5 | | 7 | 9 | 7.000 | 78% |
| | | | | | | | | | | | | F32 | Synergy with other technologies | 5 | 7 | 9 | 7 | 5 | | 7 | 3 | 6.143 | 68% |
| | | | | | | | | | | | | F33 | The complexity of technology | 5 | 5 | 5 | 7 | 5 | | 7 | 5 | 5.571 | 62% |
| | | | | | | | | | | | | F34 | The cost of acquisition | 5 | 7 | 0 | 9 | 7 | | 7 | 9 | 6.286 | 70% |
| | | | | | | | | | | | | F35 | Market | 7 | 7 | 5 | 9 | 9 | | 7 | 9 | 7.571 | 84% |
| C10 | Existence of infrastructure | 7 | 7 | 7 | 9 | 5 | 9 | 7 | 5 | 7.000 | 78% | F36 | Hardware required | 7 | 7 | 3 | 7 | 5 | 9 | 5 | 5 | 6.000 | 67% |
| C11 | Existence of knowledge | 7 | 7 | 5 | 7 | 7 | | 7 | 7 | 6.714 | 75% | F37 | Knowledge dependence | 7 | 7 | 5 | 7 | 7 | | 7 | 9 | 7.000 | 78% |
| C12 | Cooperation and implementation capacity | 7 | 7 | 5 | 9 | 5 | | 5 | 7 | 6.429 | 71% | F38 | Related fields of study | 7 | 7 | 5 | 7 | 3 | 9 | 7 | 1 | 5.750 | 64% |
| | | | | | | | | | | | | F39 | Annual student recruitment capacity | 5 | 5 | 3 | 5 | 3 | | 7 | 1 | 4.143 | 46% |
| | | | | | | | | | | | | F40 | Number of dissertations / dissertations extracted from it | 5 | 5 | 3 | 5 | 1 | | 5 | 1 | 3.571 | 40% |
| | | | | | | | | | | | | F41 | Share cooperation capacity (national and international) | 7 | 7 | 5 | 7 | 5 | 7 | 7 | 7 | 6.500 | 72% |
| C13 | Presence of special abilities | 7 | 7 | 5 | 7 | 7 | | 9 | 9 | 7.286 | 81% | F42 | University feature to select priority | 7 | 7 | 5 | 7 | 5 | 5 | 5 | 9 | 6.250 | 69% |
| | | | | | | | | | | | | F43 | Duration or speed of achievement | 7 | 5 | 7 | 7 | 7 | | 7 | 9 | 7.000 | 78% |
| | | | | | | | | | | | | F44 | Logistic feature (geographical) | 5 | 9 | 5 | 9 | 7 | | 7 | 1 | 6.143 | 68% |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | F45 | **Previous experiences and preparation** | 7 | 5 | 7 | 7 | 5 | 7 | 5 | 9 | 6.500 | 72% |
| | | | | | | | | | | | | F46 | **Existing specialized manpower** | 9 | 7 | 9 | 7 | 9 | 9 | 7 | 9 | 8.250 | 92% |
| | | | | | | | | | | | | F47 | **Existing infrastructure** | 7 | 5 | 5 | 7 | 9 | 9 | 7 | 9 | 7.250 | 81% |
| C14 | Relation with industry | 9 | 7 | 5 | 9 | | | 5 | 3 | 6.333 | 70% | F48 | **Industrialization capacity (laboratory, semi-industrial and industrial)** | 9 | 7 | 9 | 9 | 7 | 5 | 9 | 9 | 8.000 | 89% |
| C15 | **Increase water-use efficiency in crops and horticulture** | 9 | 5 | 5 | 7 | 9 | 7 | 7 | 9 | 7.250 | 81% | F49 | | 0 | | | | | | | | 0.000 | 0% |
| C16 | **Attract international cooperation** | 9 | 7 | 5 | 7 | 7 | 7 | 7 | 7 | 7.000 | 78% | F50 | | 0 | | | | | | | | 0.000 | 0% |
| C17 | **Attract international funding** | 7 | 9 | 5 | 5 | 5 | 7 | 7 | 9 | 6.750 | 75% | F51 | | 0 | | | | | | | | 0.000 | 0% |
| C18 | **International importance** | 7 | 7 | 9 | 5 | 5 | | 5 | 9 | 6.714 | 75% | F52 | | 0 | | | | | | | | 0.000 | 0% |
| C19 | **Create superiority** | 7 | 7 | 7 | 5 | 7 | | 7 | 9 | 7.000 | 78% | F53 | | 0 | | | | | | | | 0.000 | 0% |
| C20 | **Tourism** | 7 | 5 | 9 | 5 | 3 | 3 | 7 | 3 | 5.250 | 58% | F54 | | 0 | | | | | | | | 0.000 | 0% |
| C21 | **Passive Defense** | 7 | 7 | 5 | 5 | 7 | 5 | 5 | 0 | 5.125 | 57% | F55 | | 0 | | | | | | | | 0.000 | 0% |

The weights of the criteria were then extracted by the decision-making trial and evaluation laboratory (DEMATEL) technique and fuzzy network analysis (Table 5). Accordingly, the priorities were then weighed and ranked (Table 6).

**Table 5: The weights of the criteria based on the DEMATEL technique and fuzzy network analysis**

| Code | Criteria | Weight | Code | Sub-criteria | Weight |
|---|---|---|---|---|---|
| C1 | Research output | 4.60% | F1 | Research product (cultivar, commercial hybrid, scientific article, patent, final product, patent and product) | 4.60% |
| C2 | Need to technology or product/ Immediate or future | 5.01% | F2 | The bottleneck technology | 2.01% |
| | | | F3 | Country needs | 1.65% |
| | | | F4 | Emerging and innovative technology | 1.35% |
| C3 | Impact on welfare and general issues of life | 4.07% | F5 | Impact on health / treatment | 0.91% |
| | | | F6 | Provide food security | 0.73% |
| | | | F7 | Impact on energy | 0.57% |
| | | | F8 | Impact on water and natural resources | 0.54% |
| | | | F9 | Effect on reducing water consumption | 0.51% |
| | | | F10 | Effect on reducing input consumption | 0.57% |
| | | | F11 | Impact on employment and entrepreneurship | 0.24% |
| C4 | Economic achievement | 4.04% | F12 | Economic added value | 0.89% |
| | | | F13 | Export value | 0.84% |
| | | | F14 | Effect on import ban | 0.71% |

| | | | | | |
|---|---|---|---|---|---|
| | | | F15 | Effect on farmers or beneficiaries | 0.63% |
| | | | F16 | Effect on reducing production costs or producing a cheaper product | 0.53% |
| | | | F17 | Impact on the prevention of raw material sales | 0.44% |
| C5 | The importance of planning | 3.59% | F18 | Value / necessity for region / province | 3.59% |
| C6 | Impact on environmental issues | 3.67% | F19 | Biological recovery | 0.85% |
| | | | F20 | Bio-recycling | 0.68% |
| | | | F21 | Revival of soil resources | 0.52% |
| | | | F22 | Increase water resource efficiency | 0.58% |
| | | | F23 | Environmental Protection | 0.42% |
| | | | F24 | Reduction of pollutants | 0.35% |
| | | | F25 | Reduce pesticide consumption | 0.27% |
| C7 | Impact on culture | 3.98% | F26 | Impact on community culture | 3.98% |
| C8 | Impact on resources and national reserves | 4.54% | F27 | Preservation of genetic resources | 2.35% |
| | | | F28 | Production of a new product | 2.19% |
| C9 | Technological attractiveness | 5.21% | F30 | Technology rival | 0.78% |
| | | | F31 | The future of technology | 0.91% |
| | | | F32 | Synergy with other technologies | 0.82% |
| | | | F33 | The complexity of technology | 0.73% |
| | | | F34 | The cost of acquisition | 0.98% |
| | | | F35 | Market | 0.99% |
| C10 | Existence of infrastructure | 5.23% | F36 | Hardware required | 5.23% |
| C11 | Existence of knowledge | 4.73% | F37 | Knowledge dependence | 4.73% |
| C12 | Cooperation and implementation capacity | 4.62% | F38 | Related fields of study | 1.11% |
| | | | F39 | Annual student recruitment capacity | 0.88% |
| | | | F40 | Number of dissertations / dissertations extracted from it | 0.95% |
| | | | F41 | Share cooperation capacity (national and international) | 1.68% |
| C13 | Presence of special abilities | 5.54% | F42 | University feature to select priority | 1.11% |
| | | | F43 | Duration or speed of achievement | 0.98% |
| | | | F44 | Logistic feature (geographical) | 0.93% |
| | | | F45 | Previous experiences and preparation | 0.88% |
| | | | F46 | Existing specialized manpower | 0.83% |
| | | | F47 | Existing infrastructure | 0.81% |

| | | | | | |
|---|---|---|---|---|---|
| C14 | Relation with industry | 4.05% | F48 | Industrialization capacity (laboratory, semi-industrial and industrial) | 4.05% |
| C15 | Increase water-use efficiency in crops and horticulture | 4.05% | F49 | Increase water-use efficiency in crops and horticulture | 4.05% |
| C16 | Attract international cooperation | 4.31% | F50 | Attract international cooperation | 4.31% |
| C17 | Attract international funding | 5.01% | F51 | Attract international funding | 5.01% |
| C18 | International importance | 6.24% | F52 | International importance | 6.24% |
| C19 | Create Superiority | 6.60% | F53 | Create Superiority | 6.60% |
| C20 | tourism | 5.41% | F54 | tourism | 5.41% |
| C21 | Passive Defense | 5.51% | F55 | Passive Defense | 5.51% |
| | | 100.00% | | | 100.00% |

**Table 6: A view of the final weight of priorities; environment section has not shown.**

| Biotechnology priorities shrub | | | | Weight |
|---|---|---|---|---|
| Industry | Equipment Working Group | Equipment in the infrastructure industry | Water purifiers | 0.4866% |
| | | | Air conditioning systems and clean rooms | 0.5677% |
| | | | Clean steam generation machines | 0.4866% |
| | | | Tanks for preparing the culture medium, etc., | 0.4866% |
| | | | Steel plumbing | 0.4866% |
| | | | Sterilization systems | 0.4866% |
| | | | Transmission pumps | 0.4866% |
| | | | Construction of biorefinery systems | 0.5677% |
| | | Equipment in the upstream industries | Types of incubators | 0.2433% |
| | | | Ultracentrifuge | 0.4866% |
| | | | Autoclave | 0.3244% |
| | | | Chemical hoods | 0.2433% |
| | | | Accurate scales | 0.3244% |
| | | | Sampler | 0.4055% |
| | | | Types of flasks | 0.4866% |
| | | | Stirrer | 0.2433% |
| | | | Falcon and microtube | 0.4866% |
| | | | Invert microscope | 0.3244% |
| | | | PH meter | 0.5677% |
| | | | Ben Marie (water bath), magnetic stirrer, rotator, magnet | 0.1622% |

| | | | | | |
|---|---|---|---|---|---|
| | | | Measurement systems, production of advanced reactors for the production of biofuels, biofuel consumption systems | | 0.2839% |
| | | Equipment in the production and intermediate industries | Types of fixed and movable steel capacitors | | 0.2433% |
| | | | Types of bioreactors with mechanical, electrical and automation accessories | | 0.2433% |
| | | | Biofuel production hybrid systems | Solar collectors | 0.2028% |
| | | | | Fuel cell | 0.1622% |
| | | | | Fossil power plant | 0.0811% |
| | | … Equipment in the downstream and … | Types of filters | | 0.1622% |
| | | | Electrophoresis | | 0.2433% |
| | | | Filling systems | | 0.1622% |
| | | | Dryer | | 0.2433% |
| | | | Chromatographic columns | | 0.1622% |
| | | | Granulation production machine | | 0.1622% |
| | | | Cooling dryer | | 0.1622% |
| | | | Biofilm phenomenon and biological clogging | | 0.1622% |
| | | Quality control equipment | Spectrophotometer | | 0.4055% |
| Industry | Biomining (microbial mining) | Biological recovery of metals from low-grade mineral resources | | | 0.4055% |
| | Fermentation industries | Production of fossil fuels | | | 0.0811% |
| | | Production of starters and probiotics | | | 0.5677% |
| | | Production of industrial enzymes | | | 0.5677% |
| | | Production of amino acids | | | 0.5677% |
| | | Production of organic acids | | | 0.4055% |
| | | Production of yeasts and bread dough | | | 0.4055% |
| | | Production of antibiotics | | | 0.7299% |

| | | | | |
|---|---|---|---|---|
| | | Production of vitamins and related compounds | | 0.5677% |
| | | Production of biopolymers | Xanthan gum | 0.4055% |
| | | Production of bioemulosiners and microphilics | | 0.5677% |
| Agriculture | Research, development and production of transgenic products | Transgenic plants (corn, cotton, rapeseed, soybeans, rice, potatoes) | Resistance to abiotic stresses | 0.4055% |
| | | | Resistance to biological stresses | 0.4055% |
| | | Transgenic animals | Genetic engineering of livestock breeds with superior traits | 0.5677% |
| | | | Evaluation and selection of animal genomes | 0.5677% |
| | | Molecular agriculture | Production of antibodies and other recombinant proteins | 0.5677% |
| | | | Oral vaccines | 0.4055% |
| | | | Genetic engineering of plant cultivars with superior traits | 0.4866% |
| | | | Metabolite Engineering | 0.5677% |
| | | | Production of double haploid lines in products | 0.4055% |
| | | | Use of molecular markers in genetic material screening | 0.4866% |
| | | | Production of seeds from the virus (such as the potato virus) | 0.4866% |
| | | | Oilseeds fortified with other bioactive compounds; Optimization of oilseeds with the ability to produce unsaturated fatty acids. | 0.4866% |
| | | Production of microbial strains | As a biofertilizer | 0.4866% |
| | | | Biotoxins | 0.4055% |
| | | | Production of valuable by-products from waste and scrap | 0.4055% |
| | Seeds, seedlings, and use of micropropagation and molecular breeds | Organic farming | | 0.4055% |
| | | Identification and exploitation of alternative plants and harsh environmental conditions | | 0.4866% |
| | | Plant tissue culture | Cultivation of woody plant tissue and production of disease-free seedlings | 0.5677% |

| | | | | |
|---|---|---|---|---|
| | | | Production of potato microtubules through tissue culture | 0.4866% |
| | | | Molecular modification of economically important plants | 0.5677% |
| | | Biodiversity conservation | | 0.5677% |
| | | Rescue endangered species | Sorbus forest tree | 0.5677% |
| | | Reduction of agricultural waste | | 0.6488% |
| | Biofertilizers and bio-inhibitors | Microbial biofertilizer | Thiobacillus biofertilizer | 0.5677% |
| | | | Rhizobiums coexist with the plant | 0.4866% |
| | | Pesticides | Nematol pesticide | 0.4055% |
| | | | Biomax pesticide | 0.6488% |
| | | | Bio pesticide | 0.5677% |
| Agriculture | Secondary metabolites | Metabolic engineering | Engineering of plant material metabolites for drug production | 0.6488% |
| | | | Animal metabolite engineering for drug production | 0.5677% |
| | | | Isolation of beneficial genes from organisms and other living organisms | 0.4866% |
| | | | Comprehensive development of biological processes for mass production of recombinant proteins | 0.5677% |
| | | Secondary metabolites of medicinal and aromatic plants | | 0.4866% |
| | Livestock, poultry and aquatic feed supplements | Enzyme | Phytaze | 0.5677% |
| | | Starter | Dairy starter | 0.5677% |
| | | Production of quantitative and qualitative growth enhancers for plants and livestock | | 0.5677% |
| | Vaccines for livestock, poultry and aquatic animals | | Gumboro | 0.5677% |
| | | Bacterial | Streptococcus / Lactococcin | 0.5677% |
| | | Parasitic and fungal | Hydatid cyst | 0.5677% |
| | | Plant and animal serums | | 0.5677% |
| | Kits for diagnosing | Genetic diagnosis | | 0.5677% |

| | | | | |
|---|---|---|---|---|
| | important plant and animal diseases | Biological diagnosis | | 0.7299% |
| | | Biochemical diagnosis | | 0.4055% |
| Medical | Production of peptides with the role of antibiotics | | | 0.4055% |
| | Production of anti-cancer drugs | Utilization of native microorganisms in Kavir plain | | 0.5677% |
| | | Production of secondary metabolites | | 0.5677% |
| | Purification of pharmaceutical products | | | 0.5677% |
| | Production of recombinant monoclonal antibodies | Diagnostic and research of poly and monoclonal antibodies | | 0.7299% |
| | | Antibody engineering | Chimeric | 0.5677% |
| | | | Humanized | 0.5677% |
| | Production of diagnostic biosensors | | | 0.5677% |
| | Production of high-yield cell lines | | | 0.7299% |
| | Diagnosis and treatment of human diseases | Use of medicinal plants to treat common and costly diseases Early diagnosis | | 0.7299% |
| | | Early diagnosis and treatment of cancer with nanoparticles | | 0.7299% |
| | | Treatment of infertility and recurrent abortion | | 0.7299% |
| | | Diagnosis of birth defects and diseases | | 0.5677% |
| | | Discover new cancer markers and treatment goals. | | 0.4055% |
| | | Cell therapy | | 0.5677% |
| | | Gene Therapy | | 0.5677% |
| | | Restorative medicine | | 0.5677% |
| | | Production of diagnostic kits | | 0.5677% |
| | | Development of genomics methods | | 0.4055% |
| | | Engineering of pharmaceutical recombinant proteins | | 0.4055% |
| | | Stem cells and tissue engineering | Retina construction | 0.4055% |
| | | | Artificial skin | 0.5677% |
| | | | Building human organs in farm animals | 0.4055% |

| | | | | |
|---|---|---|---|---|
| | | | Repair of central and peripheral nervous system | 0.5677% |
| | | Production of new drugs | Expression of TPA in tobacco | 0.7299% |
| | | Drug release systems | | 0.7299% |
| medicine | System Biotechnology | Production of bio-products on engineered platforms | | 0.5677% |
| | Polymer field | Design, manufacture and evaluation of bioimplants | | 0.5677% |
| | | Preparation and development of PLA based biodegradable systems | | 0.7299% |
| | | Preparation and development of applications for nanocomposite systems | | 0.5677% |
| | | Preparation and development of polymer membranes | | 0.5677% |
| | Design and production of human vaccines | Microbial vaccines | Leishmaniasis | 0.7299% |
| | | | Helicobacter pylori oral vaccine | 0.7299% |
| | | Anti-cancer vaccines | | 0.5677% |
| | | In vivo experiments | | 0.4055% |
| | Transgenic animals | Production of transgenic animals using stem cell potential | | 0.7299% |
| | | Cloning | | 0.6488% |
| | | Reproduction of animals with high genetic potential | | 0.5677% |

Finally, the final priorities were extracted and then allocated to the universities (Table 7). The amount and manner of support of centers and universities were determined. The conditions for monitoring universities and scientific centers were also announced.

**Table 7: A view of priorities reported to universities; the priorities of all universities are not shown**

| Priority titles of universities and research centers | | |
|---|---|---|
| University title | Priorities | Weight |
| Shiraz University Biotechnology | Plant secondary metabolites - Anti-cancer properties - Emulsifire production | 100% |
| Biotechnology Research Institute of Urmia University | Transgenic plants, molecular farming, secondary metabolites | 39% |
| | Production of medical monoclonal antibodies | 32% |
| | Production of diagnostic biosensors | 29% |
| Iran Polymer and Petrochemical Research Institute | Development of technical knowledge and production of photocatalytic nanocomposite coatings to reduce air pollution | 43% |
| | evelopment of technical knowledge and production of appropriate wound dressings for common types of wounds in Iran | 32% |
| | Development of technical knowledge for making artificial vessels on a semi-industrial scale | 25% |
| Faculty of New Medical Technologies - Shahid Beheshti | Technology of semi-industrial production of recombinant drugs (streptokinase, etc.) | 41% |
| | Monoclonal antibody production technology (human Scfv against PSMA) | 35% |
| | Cancer diagnosis with biomarker technology | 24% |
| Bu Ali Sina University | Bioremediation includes: | 45% |
| | Identification of pollutants using biotechnology methods | 12% |
| | Removing pollutants | 12% |
| | Diagnosis and control of plant and animal diseases | 11% |
| | Medicinal organisms and medicinal plants | 10% |
| | Production of alternative pesticides and fertilizers and quantitative and qualitative growth enhancers for plants and livestock: | 35% |
| | Diagnosis and control of animal and plant diseases | 13% |

| | | |
|---|---|---|
| | Design and manufacture of biological materials and vaccines | 12% |
| | Production of transgenic organisms | 10% |
| | Design and production of livestock and human vaccines | 20% |
| | Production of monoclonal antibodies | 12% |
| | In vivo tests | 8% |
| University of Zanjan | Preparation of nutritional and medicinal supplements from algae (Chlorella vulgaris) | 60% |
| | Extraction of energy from household waste using anaerobic digestion systems and conversion of biogas produced to liquefied gas | 40% |
| Kerman Shahid Bahonar University | Production of plants tolerant to dehydration and salinity using modern biotechnology and molecular breeding methods | 47% |
| | Identifying and determining the diversity of agricultural plant pathogens | 38% |
| Shahroud University of Medical Sciences | Production of recombinant proteins with a therapeutic and diagnostic approach in medicine | 47% |
| | Early detection and biotherapy of common cancers including:<br>1. Using molecular diagnostic methods using DNA, RNA and free protein in environmental fluids such as blood (Liquid biopsy) for non-invasive diagnosis of cancer or control of the treatment process.<br>2. Research on biosensors to detect biomarker molecules in common cancers<br>3. Use of immunotherapy, gene therapy and cell therapy, and targeted therapies in common cancers<br>4. Use of bioactive phytochemicals to reduce drug resistance and targeted therapies for cancers and metabolic diseases to reduce drug side effects | 33% |
| | Reproductive biotechnology research field including clinical trials, mass production and commercialization of some required products and production of special products, especially in the field of diagnosis and treatment | 20% |
| North Khorasan University of Medical Sciences | Production of recombinant monoclonal antibodies | 40% |
| | Purification of pharmaceutical products | 30% |
| | Production of special / high product cell lines | 30% |
| Sabzevar University of Medical Sciences | Nature-friendly waste bin production plan | 35% |
| | Production of new combination drugs: Diclofenac-Diazepam combined suppository and difficult catheterization gel | 33% |
| | Medical, Safety and Hygiene Equipment: Empty containers without the use of washing and disinfecting solutions, with minor upgrades, by changing the shape of the gallon lid, these containers become Safety Box. | 32% |
| Arak University of Medical Sciences | Production of peptides with various roles: Production of recombinant proteins with different applications, including in the fields of basic sciences such as cell proliferation and differentiation, and clinical applications such as oncology, tissue repair (cardiology, diabetes, etc.) | 100% |
| Guilan University of Medical Sciences | Production of anti-cancer drugs | 45% |
| | Production of peptides with the role of antibiotics | 31% |
| | Molecular diagnostic kits for important human diseases, diagnosis and gene therapy of thalassemia | 24% |
| Hormozgan Molecular Medical Research Center | Marine herbal capsules for infertility, oral jellies for the treatment of male infertility, mogza drug | 36% |
| | The effect of drugs derived from soy and cabbage in the treatment of cancer | 34% |
| | Pregnancy poisoning prognosis kit, captophyt capsule | 30% |
| Shahid Madani University of Azerbaijan | Production of transgenic crops and orchards with high quality traits | 39% |
| | Production of recombinant pharmaceutical proteins | 31% |
| | Enzyme production | 30% |
| Semnan University of | Production of fungal phytase | 38% |

| | | |
|---|---|---|
| Medical Sciences | Production of antibacterial peptide | 25% |
| | Production of Xolair in the CHO cell line | 12% |
| | Production of industrial enzymes | 9% |
| | In vitro production of recombinant human chorionic gonadotropin (hCG) and luteinizing hormone (LH) (Recombinant hCG & LH) | 7% |
| | Fabrication of hydrogel-nanocomposite scaffolds by ECM modeling to differentiate bone marrow mesenchymal cells into chondrocytes (in the field of tissue engineering and cell therapy) | 5% |
| | Evaluation of the effect of liposomal nanosystems on alpha-synuclein protein fibrillation and cytotoxicity on neurons | 4% |
| Advanced postgraduate and industrial education in Kerman | 1- Optimization of oilseeds with the ability to produce unsaturated fatty acids with several double bonds and other nutritionally valuable compounds<br>2- Molecular race<br>3. Molecular agriculture<br>4. Plants | 35% |
| | 1. Production of anti-cancer judges<br>2. Purification of pharmaceutical products<br>3- Production of special cell lines for the product<br>4- Production of peptides with the role of antibiotics | 33% |
| | Production of industrial enzymes - production of starters and Pro Unique | 32% |
| Noshirvani University of Babol | Production of product-based biofuels | 40% |
| | Production of biofuels | 37% |
| | Production of fuel and energy to meet the small needs of the region | 23% |

## DISCUSSION

Today, many quantitative and qualitative factors (such as quality, price, flexibility, and delivery performance) must be considered for making a decision. For this purpose, speech variables can be used to determine rates and weights, and they can be expressed as triangular or trapezoidal fuzzy numbers. Therefore, the purpose of this paper was to develop the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method in decision-making with fuzzy data, where the decision-making team acquires the ability to select the appropriate option in an environment of vague criteria.

Based on the concept of the TOPSIS technique in MCDM, the coefficient index is defined by calculating the distance from the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) through the simultaneous fuzzy number ranking approach for each option to rank all options. Finally, a numerical example is given to further illustrate the proposed method. A study indicated that the use of fuzzy set theory in the project location allowed the decision-maker to use qualitative and uncertain information. Accordingly, the site selection of projects has been considered by MCDM using fuzzy logic in the new research. In the mentioned paper, with a new approach, the site selection of artificial feeding sites has been done using fuzzy logic by combining AHP and FTOPSIS methods. The decision-maker opinion is applied to classes of criteria in the form of triangular fuzzy numbers in weighting using fuzzy logic. In today's competitive environment, the managers of car companies try to turn the market into a competitive organization by creating the ability to deliver quality products on time according to the needs of customers. In this regard, product maintenance and repair play a key role in reducing costs, minimizing equipment downtime, improving quality, increasing productivity, ensuring equipment reliability, and achieving quantitative and qualitative organizational goals. Choosing the right maintenance strategy in the automotive industry is a kind of MCDM problem to achieve these goals.

A study applied a hybrid DEMATEL and ANP approach for suitable maintenance approach selection, where the Delphi technique was also used to determine effective factors on the suitable maintenance approach, and DEMATEL was used to determine the direction of the relationships between the criteria in two Iran KHODRO Diesel and SAIPA Diesel companies [26].

Another study aimed to select a marketing strategy using a combination of ANP and TOPSIS decision-making methods by a five-step algorithm in premium and regular hotels in Khuzestan, Tehran, and Isfahan provinces, Iran. They have identified the weights associated with several indicators using the network analysis process technique and then prioritized the marketing strategy using the TOPSIS approach [27].

The fuzzy DEMATEL method has previously been applied to develop supplier selection criteria to improve the performance and provide a novel approach of decision-making information in supply chain management of electronic industry suppliers. The aforementioned study constructed the strategy map among these influential criteria using DEMATEL [28]. Experts believe that supplier selection is one of the most important functions of the purchasing sector for saving material costs and increasing competitive advantage [29].

DEMATEL has been applied to find factors influencing the selection of supply chain management suppliers. The DEMATEL method evaluates supplier performance to find key metrics for performance improvement and provides a new approach to decision-making information in supplier selection. The DEMATEL method has the benefit of being able to demonstrate the association of factors influencing other factors in supplier selection (direct and indirect influence among criteria), resulting in computation of the causal association and strength among supplier selection factors [28].

The study by Chen and Chen (2010) described an innovation support system (ISS) for Taiwanese higher education institutes to assess their innovation performance. This paper addressed an MCDM approach that was capable of showing the dependent relationships between each of the measurement criteria. Thus, DEMATEL, FANP, and TOPSIS were applied to develop an ISS that considers the interdependence and relative weight of each measurement criterion, where the DEMATEL method aimed at constructing a relation structure by measurement criteria for innovation evaluation. FANP was able to address the interdependence and relative weights of each criterion. TOPSIS was also used to rank optimal alternatives for innovation configurations [30].

The use of hybrid MCDM approaches for engineering and other fields is being more widely applied because of their ability to help decision-makers to handle miscellaneous information [31].

As known, there is more than one decision criterion for most problems. A fuzzy hybrid MCDM approach composed of combining three different techniques (i.e., FANP, FTOPSIS, and ELimination Et Choix Traduisant la REalite approaches) has been adopted for more accurate personnel selection, providing the use of both qualitative and quantitative factors. Proposing an MCDM approach for real personnel selection is described as the unique characteristic of the mentioned study [32].

It has been stated that determining the right suppliers (suitable and green suppliers) in the supply chain has become a key strategic consideration in recent years. The nature of supplier selection is a complex multi-criteria problem involving quantitative and qualitative factors that may be conflicting or uncertain. A study provided a novel hybrid MCDM approach to propose an evaluation framework for green suppliers and the requirement of improving green supply chain management initiatives in a specific company by an MCDM model consisting of DEMATEL, ANP, and TOPSI [33].

As the problem complexity of MCDM was raised in the distribution of COVID-19 vaccines, solid and robust MCDM methods (including fuzzy-weighted zero-inconsistency [FWZIC] and fuzzy decision by opinion score method [FDOSM]) have been applied based on the T-SFSs environment to solve different MCDM challenges through two phases including decision matrix adoption in the COVID-19 vaccine distribution and development, where an inductive methodology based on the detailed weighting (weighting the distribution criteria) and prioritization (prioritizing the vaccine recipients) were proposed [34].

An interval arithmetic-based fuzzy MCDM approach has been developed for technology transfer strategy selection in biotechnology, where the ratings of various strategies, various criteria, and the weights of various criteria can be evaluated in fuzzy numbers and/or linguistic terms, by which membership functions were provided for the final fuzzy evaluation values of the technology transfer strategies [35].

In the biological field, the division plan, macro-organization, and determination of labor priorities of the relevant units have not been done so far. Of course, it may have been done at the level of university units, but so far, it has not been done at the level of the Biotechnology Development Council in Iran.

## CONCLUSION

This research was conducted to help the integrated management of biosciences and technology development, as well as systematic and intelligent support of research centers and universities, where the results can be helpful to increase production capacities and activities in this field, as well as to achieve objectives stated in specialized biotechnology documents.

As a matter of fact, the aim of this project was to guide and support the production of new and effective products in agriculture, medicine, nutrition, environment, alternative fuel sources, etc., which will lead to economic prosperity and the production of wealth, resulting in a resilient economy. The project can not only contribute to the health care services and products, safe environment, entrepreneurship and employment, setting point, and regional and national priorities, but also can contribute to the national consensus on biotechnology research priorities by their identification in the current situation of the country.

Finally, priority areas in terms of universities and centers were extracted, including four key areas, 274 key sub-areas, 21 criteria, and 48 sub-criteria. The ranking of projects and priorities has been done using MCDM techniques, scientometric map-based verification, preparation of a tree of priorities and needs of universities and research centers. The output of this study will facilitate the planning and monitoring of universities and bioresearch centers, so that the following achievements will be achieved: (1) possibility of defining joint projects between universities with complementary missions, (2) differentiation of universities and research centers and their specialization, (3) determination of key technologies, (4) fields and sub-fields of the priority of bioscience and biotechnology, (5) determination of necessary infrastructures and resources for development or acquisition of key sub-fields, (6) strengthening the country's scientific and technological capacity in each axis, (7) coordinating and increasing productive capacities, and (8) organizing and monitoring the country's allocated budgets in the field of biotechnology.

### Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare that they have no competing interests

### Authors' contributions

Authors designed the study, drafted the manuscript, and contributed to the discussion, collected and analyzed the data, reviewed the manuscript. All authors approved the submitted version.

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