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Developing a Multi-methodology for Identification and Prioritization of Supply Chain Marketing Strategies for Biotechnology Knowledge-based Companies

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ABSTRACT

While knowledge-based companies can leverage their specialized human and technological resources to increase market share and compete with established firms, they face the challenging and complex task of evaluating and selecting supply chain marketing strategies. This challenge arises due to differences in company type, objectives, size, location, and the varying experiences of decision-makers. The research aims to identify and prioritize supply chain marketing strategies for biotechnology knowledge-based companies by developing and applying a multi-methodological approach. This approach combines the advantages of Soft Operational Research (Soft OR), SWOT analysis, and multi-criteria decision-making (MCDM) to address the complex nature of real-world problems more effectively. The study consists of two main phases. In Phase I, a mixed-method approach using Soft OR (JOURNEY Making method) and SWOT analysis is employed to assess the current situation and formulate potential strategies. A combined AHP-PROMETHEE approach is proposed in Phase II to prioritize the identified strategies. The model enhances decision-making efficiency by helping decision-makers select the best strategy, benefiting from the strengths of Soft OR and MCDM in tackling real-world complexities. Results show that biotechnology knowledge-based companies should prioritize sustainable international presence through proactive, competitive, innovative, and collaborative behaviors, leveraging distinctive resources and strategic alliances to improve technological innovation and knowledge sharing while employing appropriate models to select effective supply chain marketing strategies based on their conditions. Additionally, a sensitivity analysis is conducted to evaluate the impact of criteria weights on the decision-making process, providing valuable insights and confident recommendations for future research.

Keywords

Knowledge-based company, Supply chain marketing strategy, Sustainable competitive advantage, Biotechnology, PROMETHEE, JOURNEY making.

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1. Introduction

Knowledge-based companies are undoubtedly the driving force behind the economic systems of both developed and developing countries. The long-term impact of the knowledge-based economy on Iran's economic growth has been well-documented in studies (Behboudi and Amiri, 2010). The primary objective of establishing knowledge-based companies is to effectively commercialize knowledge and transform technological ideas into highly profitable economic products or services (Illiashenko et al., 2023).

Statistics from studies on knowledge-based companies in various countries indicate a high failure rate due to a lack of appropriate development strategies (Cantamessa et al., 2018). However, it is important to note that startups can succeed and thrive with the right strategies and expertise. While less than 10% of startups survive for more than three years, with the figure being approximately 5% in Iran (Khayatian et al., 2019), those that do survive often achieve great success. However, through diligent research, the crucial issue of sustainability can be addressed and ensure the survival of knowledge-based startup companies.

Knowledge-based companies must align their product, market, and supply chain strategies to ensure long-term and sustainable survival in today's complex world. The supply chain comprises organizations involved in the flow of products, services, and information from a source to a customer. To ensure survival and growth, companies must shift their focus from short-term sales and profits to sustainable competitive advantage. By selecting appropriate strategies for supply chain marketing, they can minimize associated risks.

60% of Iran's knowledge-based exports are related to the biotechnology field, and the global market size for this industry is estimated to exceed $800 billion by 2025. Of more than 9,000 Iranian knowledge-based companies, 429 operate in the "Biotechnology, Agriculture, and Food Industries" sector. The two main characteristics of this industry that have led to a relatively low number of companies compared to the total are 1) high complexity and 2) the need for significant capital. These issues seem solvable by looking at the supply chain and taking advantage of its opportunities.

The question arises: How can biotechnology knowledge-based companies select the appropriate supply chain marketing strategy to achieve sustainable competitive advantage? To answer this question, the authors must identify feasible strategies by examining biotechnology knowledge-based companies' environmental and internal conditions. However, to properly develop strategies, it needs to have a thorough knowledge of the key players and influencers in the market. Therefore, the case's complexity arises from two main sources: the inherent

complexity of understanding the problem itself, known as structural complexity, and the involvement of multiple participants with diverse objectives, referred to as behavioral complexity. Consequently, researchers often choose to use multiple methods within a single intervention to avoid a narrow perspective and better address the complexities of real-world scenarios (Nassereddine et al., 2021; Sibevei et al., 2022). Thus, an integrated approach is proposed using JOintly Understanding, Reflecting, and NEgotiating strategY (JOURNEY) and SWOT analysis to understand the current situation and formulate possible strategies.

Then, based on how each of these strategies helps the company achieve the ultimate goal of gaining sustainable competitive advantage, we must prioritize them. Since sustainable competitive advantage can have different dimensions, answering this issue requires a multi-criteria decision-making method. Therefore, a merged multi-criteria decision-making (MCDM) approach that combines the analytic hierarchy process (AHP) and preference ranking organization method for enrichment evaluation (PROMETHEE) method is used to rank the alternative solutions.

The first innovation of this research lies in addressing the issue of supply chain marketing strategies specifically for biotechnology knowledge-based companies in Iran. Additionally, the study introduces a novel multi-methodological approach to effectively tackle the problem situation and decision-making. By integrating the strengths of various methods, this new approach improves the efficiency of the decision-making process, assisting decision-makers in selecting the most effective strategy.

The different sections of the paper include the following: In the second section, the research background and theoretical foundations are reviewed. The third section describes the research method, briefly reviewing the JOURNEY making and AHP and PROMETHEE methods. The fourth section presents the research results. The fifth section discusses the results and research limitations. The sixth section provides the conclusion and future recommendations.

2. Background and theoretical foundations of the research

2.1. Biotechnology-based knowledge companies

In recent decades, significant attention has been directed towards biotechnological advancements and the development of knowledge-based companies within this domain. These companies typically secure substantial capital, collaborate with universities and research institutions, and attract elite talent in life sciences to innovate solutions addressing medical, agricultural, environmental, and industrial challenges (Breschi et al., 2014). In other words,

biotechnology-based knowledge companies operate within the life sciences sector and collaborate with other enterprises to apply their technologies in other sectors, such as agriculture, food products, energy, and environmental preservation (Nielsen et al., 2022).

Due to inherent risks and specific characteristics, one of the challenges for the success of these companies is sustaining their growth and stability; statistics indicate that most of them either vanish over time or remain small-scale, with only a few transitioning into larger enterprises. Consequently, knowledge-based companies must establish sustainable competitive advantages to continue their growth and development and avoid eliminating from the competitive arena.

2.2. Sustainable competitive advantage

Sustainable competitive advantage refers to a company or organization's ability to continuously maintain its competitive edge in the market. This concept implies that a company should excel in competing against its rivals and maintain its competitive advantage over time and in the face of changing market conditions (Nasifoglu et al., 2020). The literature identifies four primary sources for sustainable competitive advantage: 1) effective supply chain management, 2) innovation and product differentiation, 3) organizational responsiveness, and 4) cost leadership (Vinayan et al., 2012). The study by Khayatian et al. (2016), titled "The Model of Sustainability of Knowledge-Based Companies in Iran," investigates the factors affecting companies' sustainability and the resulting outcomes. It categorizes the influencing factors into internal (founder individual factors, organizational factors) and external (business characteristics, innovation system components). The sustainability outcomes of knowledge-based companies are classified into four categories:

- financial results (continuation of sales growth, profitability sustainability),
- market results (market share growth, brand credibility),
- innovation results (product development,
- technology advancement), and entrepreneurship results (job creation, structure formation).

This systematic literature review explores the relationship between dynamic capabilities and competitive advantage in small and medium-sized enterprises. The review introduces three categories of factors: 1) dynamic capabilities, innovation, and brand capabilities; 2) strong interpersonal and inter-organizational relationships with customers, distribution channels, suppliers, and governmental entities; and 3) human capital (Fabrizio et al., 2022). This study examines the relationship between dynamic capabilities, human capital, and supply chain perspectives. It has been noted in several articles that human resources play a crucial role in

knowledge-based companies as a source of sustainable competitive advantage. For example, Hatch and Dyer (2004) and Zahra and Nielsen (2002) researched this topic.

In 2019, Shirazi et al. conducted a study on the impact of internal organizational factors on competitive advantage in knowledge-based companies. The factors that were studied included organizational resources such as human, material, and immaterial resources, as well as innovation capabilities such as product and process innovation capability. The study analyzed the impact of these factors on both cost advantage and differentiation advantage. The article explores the impact of technology commercialization performance on the relationship, such as the number of new products, time taken to develop new products, future market, effective use of patents, and technical knowledge. It is suggested that companies based on knowledge may not achieve sustainable success if they cannot commercialize their technologies effectively and lack a long-term strategic market perspective despite having organizational resources, including human resources.

2.3. Supply chain management in biotechnology-based knowledge companies

With increased competition among companies in recent decades and the globalization of markets, it is widely acknowledged that marketing challenges have also intensified. Organizations have realized that improving internal efficiency alone is insufficient for delivering products and services in a timely and cost-effective manner.. Instead, their entire supply chain must become competitive. Hence, it can be observed that supply chain management has become a crucial necessity for maintaining competitiveness in the global market, as noted by Li et al. (2006).

Proper supply chain management leads to opportunities for cost reduction and achieving cost competitive advantage over competitors (Tukamuhabwa et al., 2021). However, cost advantage is not the sole benefit of supply chain management; effective supply chain management can create extraordinary customer value, satisfaction, and loyalty, ultimately improving profitability margins, enhancing profitability, and fostering organizational growth (Flint, 2004). Gathering information from customers and competitors improves the strategy formulation process and is essential for a company's long-term success.

To achieve sustainable competitive advantage, companies must promote a culture of innovation within their organization and plan to share and manage knowledge internally and throughout their value chain (Arsawan et al., 2020; Vickery et al., 2003). Based on network theory and resource-based view, Kang and Na (2020) contend that a network of strategic

resources, managed through intricate relationships and communications, which is challenging to replicate, creates a sustainable competitive advantage. Access to strategic resources such as licensing rights to technology or invention in a network centered around a company can lead to the development of the company's value chain and ultimately achieve sustainable competitive advantage (Gassmann and Keupp, 2007).

2.4. Marketing strategy in the supply chain of knowledge-based companies

As mentioned at the beginning of the literature review section, biotechnology-based knowledge companies, due to the nature of their technologies and products, have the potential to be part of supply chains in various industries. It necessitates finding a suitable position for themselves in diverse supply chains. Instead of solely focusing on the end customer and understanding their needs, they must establish relationships with all supply chain members and find a suitable position relative to their competitors within their own chain.

The nature of supply chain strategies is inter-organizational, while marketing strategies are customer-centric. Companies must effectively integrate marketing strategies with their supply chain to achieve success and sustainable competitive advantage. This integration can improve internal strategy formulation processes and enhance strategic alignment with customers and suppliers (Jüttner et al., 2010).

Collaboration within the supply chain is one approach to integrating marketing and supply chain strategies. Four types of collaboration can be defined: intra-organizational, with suppliers, customers, and competitors. These collaborations can lead to developing strategies that meet both parties' needs and preferences. For example, the involvement of customers in the product design process can lead to product improvement, increased customer satisfaction, and ultimately increased sales for the company. As a result, such collaboration can significantly contribute to business sustainability (Chen et al., 2017).

2.5. Marketing strategy alignment

Marketing strategy alignment refers to the development and execution of marketing strategies at the supply chain level by partners involved to create the maximum value for the ultimate supply chain customers (Min and Mentzer, 2000). This alignment leads to improved supply chain performance, which, through enhanced marketing performance, will also result in improved company financial performance (Green et al., 2012).

Knowledge-based companies, mostly small and medium-sized enterprises, must establish strategic collaborations to successfully leverage their intellectual and technological assets, adding value to their supply chain (Stonkute, 2015). Additionally, knowledge brokers can facilitate communication between seekers, providers, innovators, and framers by creating a common language and strengthening bilateral interactions, thus aiding in the technical knowledge marketing of knowledge-based companies (Abbate et al., 2011).

2.6. Research gap

The literature on knowledge-based companies has been examined in detail, with each relevant aspect being addressed separately. Factors influencing sustainable competitive advantage have been studied, as well as the importance of aligning supply chain and marketing strategies. However, it is important to acknowledge that there is potential for further improvement in developing a model for decision-making and prioritization of marketing strategies used by knowledge-based companies within their supply chains. This article aims to fill this gap for biotechnology-based knowledge companies, providing suggestions for necessary changes to improve performance.

Scientific literature highlights multi-methodology as one of the most important developments in OR/MS research (Paucar-Caceres, 2010; Ellakkisa et al., 2024). In conclusion, this paper focused on developing and applying multimethodological intervention benefiting from the advantages of Soft OR and MCDM to deal more effectively with the complex nature of real-world problems. JOURNEY Making has been utilized as a problem-structuring method to comprehend the situation. At the same time, SWOT analysis is employed to develop strategies, and MCDM models are then applied to prioritize these strategies. The proposed model can also be evaluated and applied to other domains in future research.

3. Research methodology

The literature review section highlights the importance of developing marketing strategies in the supply chain and aligning them. In order to address the research question raised in the introduction, a comprehensive approach is required to understand biotechnology-based knowledge companies in Iran, which will enable tailoring marketing strategies to their specific characteristics. A mixed-method (qualitative-quantitative) approach was employed for the research to achieve this understanding.

The study's population comprises emerging and innovative knowledge-based companies in Iran's biotechnology, agriculture, and food industries. The sample was selected by examining the list of biotechnology-based knowledge companies in Tehran on the Vice Presidency for Science and Technology website, from which ten companies were chosen out of the 100 listed. A group of ten experts actively involved in technology commercialization in knowledge-based companies, CEOs of knowledge-based companies, and planners were selected to achieve the research objective. The criteria are obtained through a review of the literature and the use of the Delphi method. The research process is outlined in Figure 1.

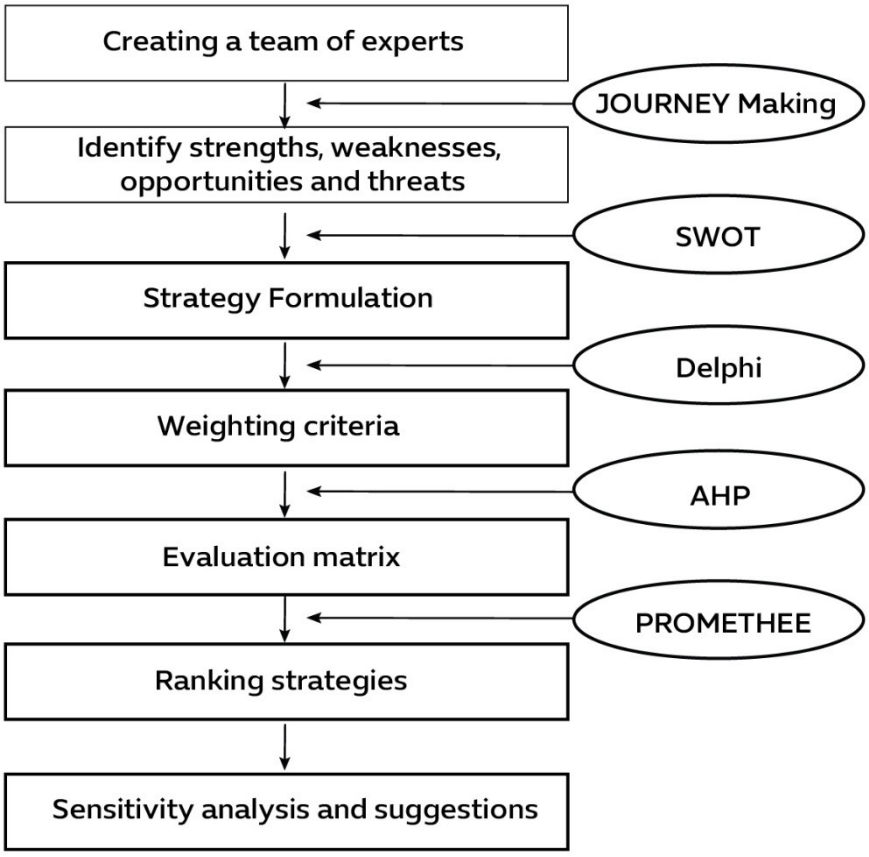

Figure 1. Research process

3.1. JOURNEY making (JM)

JM was originally developed as a methodology to assist organizations in exploring strategic options and solving problems (Eden and Ackerman, 2013). The JM intervention provides a process to help practitioners and scholars understand complex real-world issues. It is based on the premise that every organization has some strategic direction. JM effectively addresses external and internal complexity related to the organizational environment and is associated with methodically developing strategies amidst diverse viewpoints and interests. Essentially,

JM involves two main components: (a) identifying emerging strategies and (b) reflecting and negotiating to achieve consensus (refer to Table 1 for more details).

Table 1. JOURNEY making steps

Part	Stage	Step
Surfacing emergent strategies	Familiarization with the situation	Understanding the situation
		Labeling the participant' s roles
	Mapping the situation	Building individual cognitive maps
		Combining maps to form strategy maps
		Analyzing emergent strategies/strategizing
Reflecting and negotiating to gain agreement	Options and scenarios	Generating a set of options
		Generating a set of scenarios
		Comparing the options and scenarios
	Results and reporting	Analyzing the comparison results
		Making recommendations

In the proposed multi-methodology model, the authors focus on the "surfacing emergent strategies" part, especially familiarizing the situation. In the initial stage, the practitioner gains a broad understanding of key issues related to an event and the emergent strategies. Within the JM framework, information is gathered from experts through individual interviews. This information is then applied to the power/interest grid. Compiling a power/interest grid is a remarkable way for JM to analyze stakeholders' positions and interrelationships. On the grid, according to the stakeholders' relative power and their interest in the situation, they are classified into four types as follows (Figure 2):

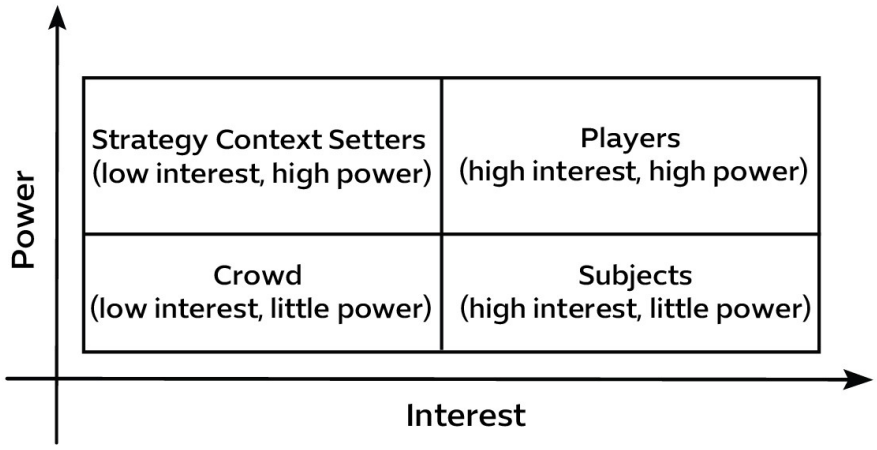

Figure 2. Power/interest grid

3.2. Analytic hierarchy process (AHP)

In the present article, the Analytic Hierarchy Process (AHP), one of the most commonly used methods in multi-criteria decision-making (Saaty, 2004), has been employed to weight the criteria for strategy prioritization. In the AHP method, experts' opinions on the criteria are quantitatively derived through pairwise comparisons.

The AHP method has three main stages:

(1) Creating a hierarchical structural model
(2) Pairwise comparison of criteria
(3) Prioritization of criteria

For pairwise comparisons, the Likert scale is used in various ranges of five, seven, nine, and eleven points. The authors consider a set of criteria $C = (C_j | j = 1, 2, \dots, n)$. The results of pairwise comparisons are summarized in the evaluation matrix (A).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

$$a_{11} = a_{22} = \cdots = a_{nn} = 1 \qquad a_{ij} = \frac{1}{a_{ji}} \qquad i = 1,2, \dots, n \qquad j = 1,2, \dots, n$$

Then, the normalized evaluation matrix (B) is derived from equation (2), such that for each value in matrix B, the corresponding value in matrix A is divided by the sum of the values in the relevant column:

$$B = [b_{ij}]_{n \times n} \qquad b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad i = 1,2, \dots, n \qquad j = 1,2, \dots, n \quad (2)$$

Now, the authors calculate the eigenvector (W), which is composed of the eigenvalues (w_i). The eigenvalues for each row are derived from equation (3) (Kilic et al., 2015):

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n} \quad W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (3)$$

After obtaining the eigenvector (W), the relative priority vector (λ_max) is obtained from equation (4):

$$AW = \lambda_{max} W \; W' = AW = \begin{bmatrix} w'_1 \\ w'_2 \\ \vdots \\ w'_n \end{bmatrix} \quad and \quad \lambda_{max} = \frac{1}{n}\left(\frac{w'_1}{w_1} + \frac{w'_2}{w_2} + \cdots + \frac{w'_n}{w_n}\right) \quad (4)$$

Then, the Consistency Index (CI) and the Consistency Ratio (CR) are calculated using relationships (4). If the Consistency Ratio is less than or equal to 10 percent, there is appropriate consistency among the weights of the criteria. Otherwise, the values of the pairwise comparisons should be reviewed.

$$CI = \frac{\lambda_{max}-n}{n-1} \; CR = \frac{CI}{RI} \tag{5}$$

The Random Consistency Index (RI) for different n values can be calculated from the table 2.

Table 2. Random consistency index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In this paper, due to the application of the Group Analytic Hierarchy Process (AHP) for criteria weighting, experts are requested to perform prioritization individually. Eventually, to amalgamate their opinions and arrive at a final eigenvalue, the geometric mean is taken between their values for each criterion (Saaty, 2004).

3.3. PROMETHEE method

The PROMETHEE method is a multi-criteria decision-making approach that supports various studies' decision-making processes. This method, belonging to the family of outranking comparison methods, compares options based on degrees of preference and indifference toward each other. In this research, PROMETHEE is employed to prioritize strategies. Among the benefits of using this method for strategy prioritization are the ability to weigh different criteria, select various preference functions for different criteria depending on their type and options, and the sensitivity analysis of the prioritization outcome based on changes in criteria weights and preference functions.

The steps of the PROMETHEE method are as follows (Behzadian et al., 2010):

1- Determining the pairwise differences between options based on each criterion:

$$d_j(a,b) = g_j(a) - g_j(b) \tag{6}$$

In equation (1), $d_j(a,b)$ represents the difference between options a and b in criterion j.

2- Calculating the preference function for each criterion:

$$P_j(a,b) = F_j\left[d_j(a,b)\right] \qquad j = 1, \dots, n \tag{7}$$

In equation (2), the function $P_j(a,b)$, or the preference function, indicates the preference of option a over b based on the magnitude of their difference in criterion j.

3- Calculating the overall preference index:

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$$\forall\, a, b \in A \quad \pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j \qquad j = 1, \ldots, n \tag{8}$$

Where set A consists of the options available for decision-making.

The preference index of a over b, $\pi(a,b)$, is derived from the weighted sum of preferences of a over b in each criterion, where w_j is the weight of each criterion.

Calculating the outranking flows, partial ranking in PROMETHEE I:

$$\phi^{+}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a,x) \tag{9}$$

$$\phi^{-}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x,a) \tag{10}$$

$\phi^{+}(a)$ is the positive outranking flow and $\phi^{+}(a)$ is the negative outranking flow for each option a.

- Calculating the net outranking flow, complete ranking in PROMETHEE II:

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \tag{11}$$

In equation (11), $\phi(a)$ is the net outranking flow for each option.

A critical aspect of the PROMETHEE method is selecting an appropriate preference function for each criterion (Nassereddine and Eskandari, 2017). Changing the type of preference function alters the outcome of the decision-making problem. Therefore, careful consideration must be given to the type of criterion and the objective of the decision-making issue when selecting it.

Six types of preference functions for criteria in the PROMETHEE method are as follows, which are observable in Figure 3 (Brans and Vincke, 1985):

(1) Usual Criterion: In this case, if the scores of two options are equal in one criterion, there will be no difference, and if one is slightly higher, it will be chosen.
(2) U-shaped Criterion: As long as the difference in scores between two options is less than q, there will be no difference.
(3) V-shaped Criterion: As long as the score difference between two options is less than p, the preference is weak, and the value of the preference function equals the ratio of the score difference to the threshold value (p). With an increase in d and passing the threshold p, the preference is strict, and the value of the function will be one.
(4) Level Criterion: Similar to the U-shaped criterion, but preferences increase stepwise. The preference function has three states: indifference, weak preference, and strict preference.
(5) Linear Criterion: It has two values q and p, which are the thresholds for indifference and preference, respectively. Similar to the V-shaped criterion, for differences in

scores greater than q, the value of the preference function equals the ratio of (d-q) to (p-q).

(6) Gaussian criterion: The preference function value for positive score differences follows a Gaussian function.

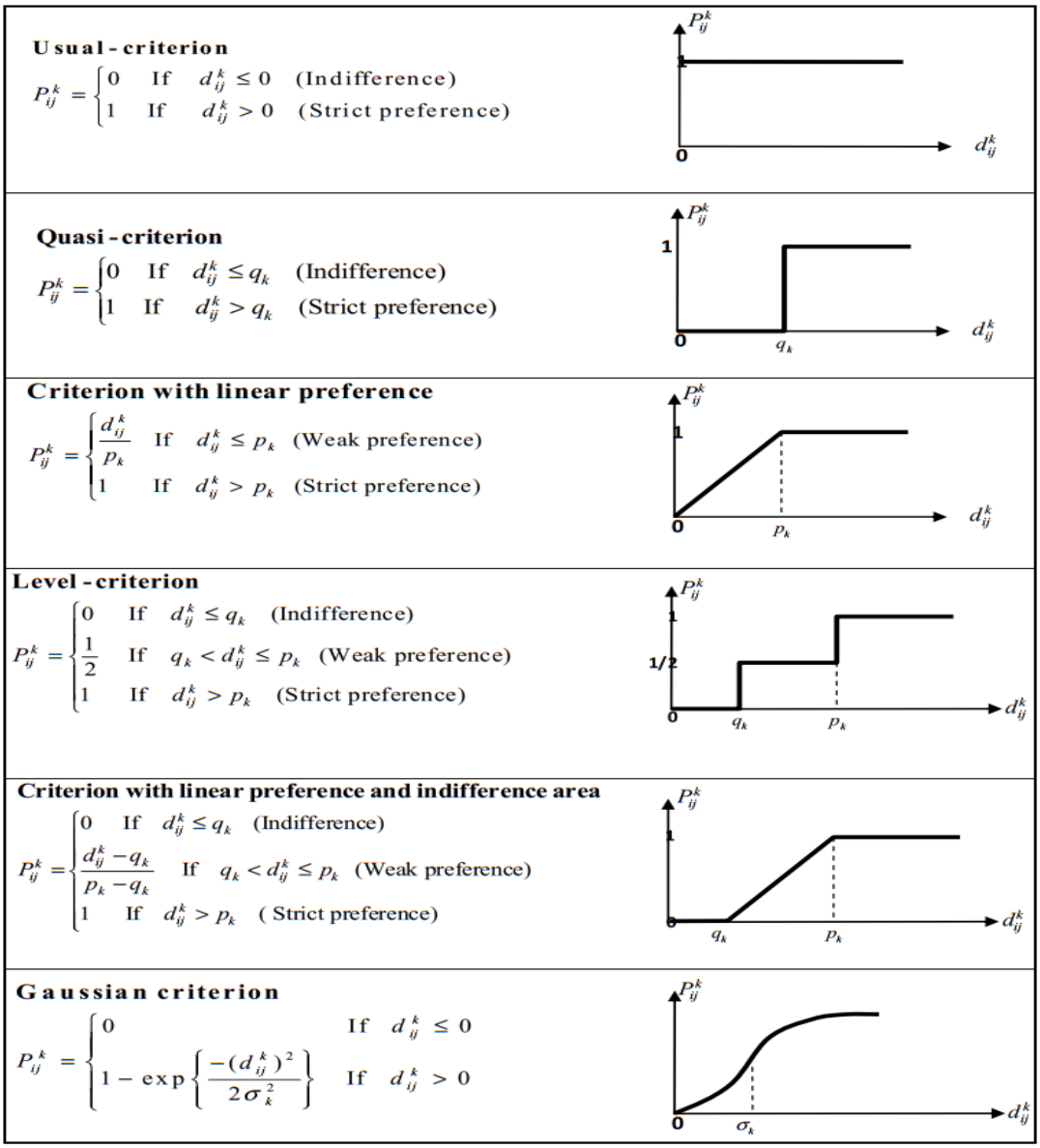

Figure 3. Preferred functions of the PROMETHEE method

A general schematic of the supply chain process in these companies was drawn based on interviews with experts from companies active in the biotechnology, agriculture, and food industries. In these companies, skilled and experienced human resources, advanced laboratory equipment, and high-quality raw materials are key success factors. Typically, nascent knowledge-based companies in this sector lack production equipment, distribution networks, and sales channels, thereby losing the opportunity for sustainable and long-term commercialization of products. Figure 4 shows the supply chain in the biotechnology industry.

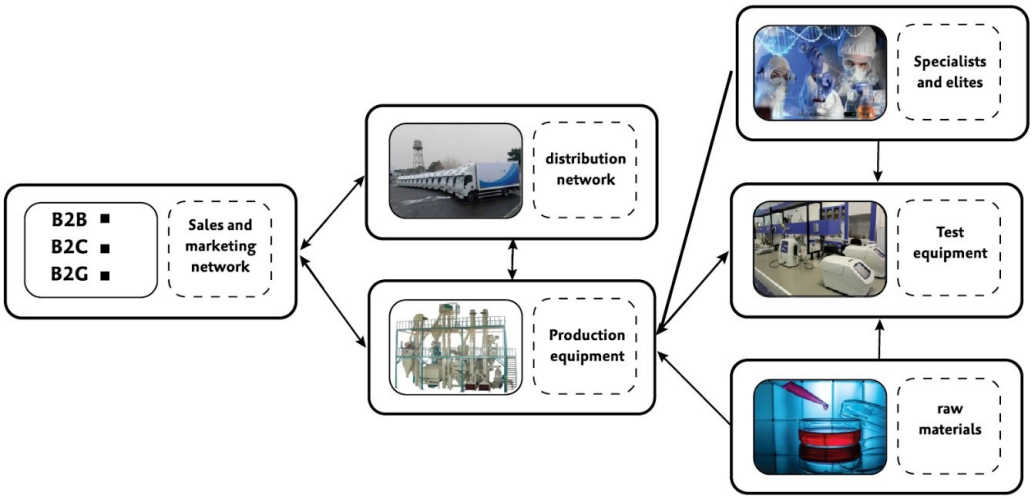

Figure 4. Supply chain in the biotechnology industry

This section contains JM's results and responses to the research questions based on information obtained from expert interviews.

JM can be an effective research tool for overcoming the complexity of problems and aiding decision-making in practice. It is useful for understanding situations, developing options, and predicting scenarios. Therefore, the first stage of JM has been applied to familiarize with the situation. This stage (familiarization with the situation) involves understanding the situation and labeling the participants' roles. The results of the participants' roles are listed in Table 3.

Table 3. Power and Interest of participant

Nb	Actor's name	Labelling the participant' s role 1 TO 5	
		Power	Interest
1	Suppliers	٤.1	3
2	Knowledge Based Companies	3.1	4.5
3	Customers	3.2	2.8
4	Brokers	3.3	2.3
5	Knowledge-based deputy	3.4	٤.4
6	Universities	2.6	3.8
7	Foreign start-up companies	4.7	2.9
8	Export management companies	3.3	4.3
9	Science and technology parks	4.6	4.5

Following the JM phase, experts now possess a more comprehensive understanding of the issue, particularly regarding the key players, enabling them to respond to questions more effectively and achieve more dependable results. Following the JM phase, experts now possess a more comprehensive understanding of the issue, particularly regarding the key players, enabling them to respond to questions more effectively and achieve more dependable results. The questions are:

Question 1: What are the environmental threats and opportunities for marketing by biotechnology knowledge-based companies in the supply chain?

The experts were asked to outline the supply chain process around their company and identify strengths and weaknesses for marketing in the chain. The interviews were conducted and coded, as shown in Table 4. After summarizing the items, the experts were requested to assign a numerical value ranging from 1 to 4 to each of them based on their significance as either a strength or weakness (1: indicating a severe weakness, 2: indicating a relative weakness, 3: indicating a relative strength, and 4: indicating a strong strength). The relative importance coefficient was also determined for each item, starting from number one. The final score for each item was calculated by multiplying the rank value by the relative importance coefficient.

Table 4. Internal factors assessment matrix

	No	Internal factors	Weigh	Rating	Weighted Score
Strengths	S_1	Benefiting from an expert workforce and access to elite networks in biotechnology, agriculture, and food industry parks.	0.04	4	0.16
	S_2	The cost of domestic knowledge-based products is lower than that of their foreign counterparts.	0.06	4	0.24
	S_3	The possibility of exporting many products related to the food industry as raw materials (B2B) and finished products (B2C).	0.08	4	0.32
	S_4	The dynamism and agility of the organizational structure and bureaucracy are greater than those of established companies.	0.04	3	0.12
	S_5	Expanding the atmosphere of entrepreneurship and business development among university graduates.	0.03	3	0.09
	S_6	Possession of medium and advanced technologies in the field of biotechnology by knowledge-based companies.	0.07	3	0.21
	S_7	Possession of patents by some of the founders.	0.05	3	0.15
	S_8	The ability to use technologies related to biotechnology, agriculture, and food industries in each other's industries and the possibility of their joint development.	0.09	4	0.36
Weaknesses	W_1	Weakness in offering new products and lack of market confidence in new knowledge-based products compared to established companies.	0.05	1	0.05
	W_2	The unwillingness of new knowledge-based companies to expand and their tendency to settle for a small number of products with average profit.	0.04	2	0.08
	W_3	Weakness in knowledge management in the supply chain of knowledge-based companies.	0.03	1	0.03
	W_4	Lack of attention to the importance of managing the supply chain of products and technologies in most knowledge-based companies.	0.08	1	0.08
	W_5	The low motivation of specialists in knowledge-based companies is due to relatively low salaries and benefits.	0.06	2	0.12
	W_6	Weakness in management and system knowledge, especially regarding scale-up.	0.05	2	0.1
	W_7	Weakness in inter-company cooperation and the establishment of joint research and development centers.	0.04	2	0.08
	W_8	Higher domestic product prices compared to market expectations.	0.07	2	0.14
	W_9	There is a lack of loyalty among specialized forces and difficulty in long-term planning for the company.	0.04	2	0.08
	W_{10}	Lack of communication and weakness in attracting technology investors to commercialize patents.	0.08	2	0.16
		Sum	∑=1		2.57

The internal factors assessment matrix indicates that biotechnology knowledge-based companies have more strengths than weaknesses, with a score of 2.57 in the last row. However, the difference in numerical values is insignificant, suggesting that strengths and weaknesses are relatively balanced.

Question 2: What potential environmental factors may biotechnology knowledge-based companies encounter in the marketing supply chain?

Similar to strengths and weaknesses, opportunities and threats were identified by experts. The list of opportunities was then elaborated by studying other upstream documents in the biotechnology development field. The experts were presented with the list again to determine the relative importance coefficient and rank of each opportunity and threat through hierarchical analysis (Table 5).

Table 5. External factors assessment matrix

	No	External factors	Weigh	Rating	Weighted Score
Opportunities	O_1	The opportunity to benefit from the empowerment and commercialization services of knowledge-based companies provided by the Vice President for the Development of Knowledge-Based Companies.	0.02	3	0.06
	O_2	Supporting programs of the technology corridor to the market through the Deputy for the Development of Domestic and Foreign Markets of Knowledge-Based Companies.	0.03	3	0.09
	O_3	The increase in the exchange rate pushes the market towards domestic knowledge-based products, leading to a preference for these products over imported ones.	0.09	4	0.36
	O_4	The opportunity to benefit from Iran's National Fan Market Network, a new technology exchange infrastructure that serves as a platform to present technological capabilities and needs.	0.05	3	0.15
	O_5	The import of certain biotech raw materials, such as cultivation medium, has been stopped due to sanctions.	0.06	3	0.18
	O_6	The import of certain biotech raw materials, such as cultivation medium, has been stopped due to sanctions.	0.03	3	0.09
	O_7	The high priority of biological technologies, agriculture, and food industries is to meet the country's essential needs in health, environment, and food security.	0.04	3	0.12
	O_8	Iran's membership in the International Centre for Genetic Engineering and Biotechnology (ICGEB) and the implementation of joint biotechnology research with some advanced countries in agriculture.	0.05	4	0.2
	O_9	Executive regulations to facilitate investment and export development for knowledge-based companies and institutions.	0.02	3	0.06
	O_{10}	Knowledge-Based Production Leap Law.	0.04	3	0.12
	O_{11}	Larg Iranian manufacturing companies with a history of exports, market presence, and production equipment exist.	0.05	3	0.15
Threats	T_1	The import of contraband goods is similar to some domestic knowledge-based products.	0.09	1	0.09
	T_2	The existence of intermediaries who sell knowledge-based products reduces the profit margin for producers.	0.06	2	0.12
	T_3	Weaknesses in administrative structures and procedures related to the establishment and development of knowledge-based companies.	0.03	2	0.06

No	External factors	Weigh	Rating	Weighted Score
T_4	The high inflation rate in Iran has led to economic instability, resulting in a reluctance among people to start knowledge-based companies, especially manufacturing ones.	0.05	1	0.05
T_5	The high emigration rate among the country's elites decreased interest in value-creating activities.	0.04	1	0.04
T_6	Weaknesses in the infrastructure related to the smart supply chain and its strategic management.	0.06	2	0.12
T_7	The incompleteness of intellectual property and copyright laws in Iran.	0.03	2	0.06
T_8	The immaturity of the intellectual property market in Iran.	0.03	2	0.06
T_9	Many raw materials are imported, such as those needed to make acidifiers, which are animal feed preservatives.	0.06	1	0.06
T_{10}	The low quality of imported raw materials despite their high cost.	0.04	2	0.08
	Sum	∑=1		2.38

As observed in the last row of the external factors assessment matrix, the score is 2.38, below 2.5. It suggests that environmental threats are more significant than opportunities and should be considered when developing a strategy.

Question 3: Regarding the SWOT analysis, what marketing strategies could be implemented by biotechnology knowledge-based companies in the supply chain?

After identifying the strengths, weaknesses, opportunities, and threats, the next step is to formulate strategies. Strategies are derived from the intersection of environmental conditions and organizational status and fall into four general categories: aggressive (SO), conservative (WO), competitive (ST), and defensive (WT). The SWOT matrix in Table 6 suggests six marketing strategies for nascent and innovative knowledge-based companies in the supply chain. The six strategies were selected based on the final scores of each opportunity, threat, strength, and weakness.

Table 6. SWOT matrix

	Strengths	**Weaknesses**
Opportunities	SO strategy 1) Using production equipment available in growth centers and science and technology parks and selling through large companies'brand and distribution network. O_6 ،O_{11} ،S_6 ،S_7 5) Conducting joint research and development with companies active in other industries (technology spillover). O_4 ،O_7،S_1 ،S_8	WO strategy 4) Signing a cooperation agreement with export management companies with a distribution and sales network can help develop the knowledge-based brand. T_2 ، T_6 ،T_{11} ،S_3 ،S_2 ،S_4
Threats	ST strategy 2) Production and joint investment with knowledge-based companies active in their supply chain: O_4 ،O_9 ،O_{10} ،W_1 ،W_6 ،W_7 3) Conclusion of technology transfer + product export contracts with neighboring start-up companies: O_2 ،O_8 ،O_6 ،W_4 ،W_3 ،W_8	SW strategy 6) Definition of academic research and development projects and then their commercialization. T_5 ،T_7 ،T_8 ،W_{10} ،W_9 ، W_7

Question 4: What are the prioritization criteria for determining the best marketing strategy in the supply chain for biotechnology knowledge-based companies (components of sustainable competitive advantage)?

The criteria were collected by reviewing relevant literature on supply chains in small and medium-sized knowledge-based companies. The collected criteria relate to supply chain performance, marketing performance, and sustainable competitive advantage (Table 7).

Table 7. Criteria for strategies

Nb	Criteria	Code	Definition	Ref.
1	Strategic relationship with suppliers	C_1	A long-term relationship between the organization and its suppliers is aimed at leveraging the strategic and operational capabilities of the participating organizations to achieve continuous benefits.	(Li et al., 2006)
2	communication with clients	C_2	A set of actions taken to manage customer complaints, establish long-term relationships with customers, and improve customer satisfaction.	(Li et al., 2006)
3	Information sharing level	C_3	The extent to which critical and proprietary information is communicated to a supply chain partner.	(Li et al., 2006)
4	Level of information quality	C_4	Accuracy, timeliness, and adequacy of information exchanged.	(Li et al., 2006)
5	Access to strategic resources	C_5	Resources that are valuable, rare, inimitable, and non-substitutable are called strategic resources, such as advanced technologies.	(Nasifoglu et al., 2020)
6	Innovation	C_6	Innovation has various dimensions, including product, process, and organization. Innovation contributes to competitive advantage by replacing old products with new ones and maintaining market share.	(Tidd et al., 2006)
7	operational excellence	C_7	It refers to an organization providing higher value to its customers while operating faster, better, and more cost-effectively.	(Bag et al., 2020)
8	Access to knowledge and technology brokers	C_8	Knowledge brokers facilitate communication between knowledge seekers, providers, innovators, and framers.	(Magliocca et al., 2023)
۹	Access to new markets	C_9	Markets in other cities and countries, as well as related industries.	(Javalgi et al., 2011)
10	Access to basic infrastructure	C_{10}	Technological infrastructure that facilitates various supply chain activities, such as equipment for transporting and storing food under special conditions.	(Chakraborty et al., 2023)
11	Facilitating social entrepreneurship	C_{11}	The possibility of engaging in activities that seek to create social value, not just generate income and economic value.	(Nayak et al., 2022)

The literature was initially reviewed to identify the essential criteria for selecting supply chains in small and medium-sized knowledge-based companies. Through this review, eleven criteria were identified. Additionally, two rounds of the Delphi method were conducted to reach a consensus among experts, with no significant differences observed in their opinions after the second round. Based on the experts' opinions, six of the most important criteria were selected: strategic relationship with suppliers (C1), customer relationship (C2), access to strategic resources (C5), innovation (C6), access to technology brokers (C8), and access to new markets (C9).

Question 5: What are the relative weights of the criteria?

The table shows the weights of the criteria and other values related to the AHP method by presenting the six criteria listed in the previous section (question 5) to the experts and asking them to make pairwise comparisons between these criteria (Table 8).

Table 8. Pairwise comparison results of criteria

Criteria	Symbol	Criteria in software	Weight	Indexes
Strategic relationship with suppliers	C_1	Suppliers	0.16	
communication with customers	C_2	Customers	0.09	λ_{max}= 6.31
Access to strategic resources	C_5	Resources	0.28	CI= 0.063
Innovation	C_6	Innovation	0.03	RI= 1.24
Access to knowledge and technology brokers	C_8	Brokers	0.05	CR= 0.05
Access to new markets	C_9	New Markets	0.39	

As mentioned above, a consistency ratio of less than or equal to 10% is acceptable, which is 5% here. According to the experts, accessing new markets is the most important criterion, with a weight of 39%, followed by accessing strategic resources with 28%, strategic relationships with suppliers with 16%, customer relationships with 9%, access to technology brokers with 5% and finally innovation with 3%. It seems that when formulating marketing strategies in the supply chain, companies are looking for opportunities to enter new markets, and accordingly, this criterion has the highest score. The other two important criteria, strategic resources and strategic relationships with vendors rank second and third, respectively, reflecting the importance of raw materials, equipment, and other resources, including knowledge and technology, in the biotechnology value chain. As most biotechnology companies are at the beginning of the value chain, the relationship with the final customers of the chain is less important for them. Technology intermediaries and innovation also received the lowest scores. This may be due to the poor functioning of intermediaries in the past, their insufficient knowledge of the market, or the fact that innovation can be seen as an inherent characteristic of all knowledge-based firms.

Question 6: Based on the weightings obtained for the criteria, which strategies have the greatest impact on achieving sustainable competitive advantage?

The Visual PROMETHEE software can be used to prioritize strategies based on the weighted criteria in question 5 and the methods developed in response to question 3. Figure 5 shows the decision model used to answer this question.

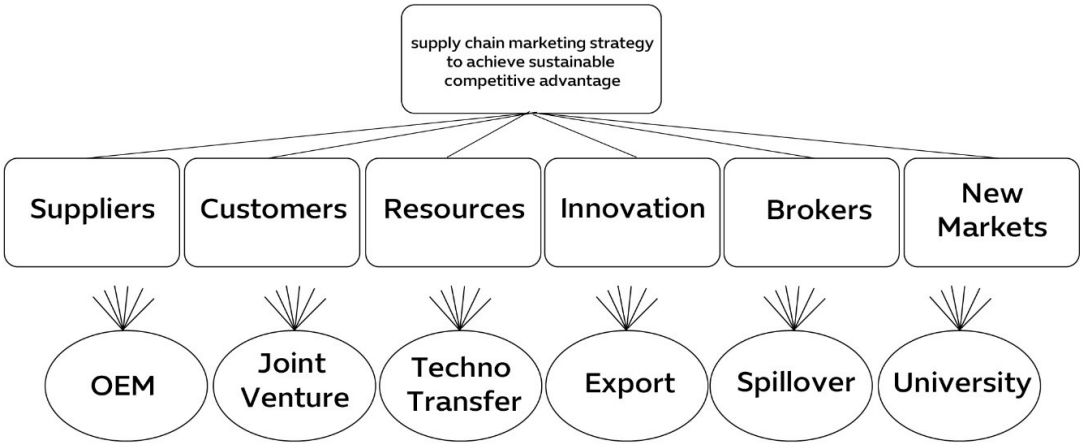

Figure 5. Decision model for prioritizing strategies

The six strategies resulting from the SWOT method are:

OEM production of products by knowledge-intensive companies under brands of domestic and foreign pharmaceutical and food companies (OEM).

(1) Joint production and investment with knowledge-intensive companies in their supply chain (joint venture)
(2) Export contracts + technology transfer to foreign start-up companies (Technology Transfer)
(3) Collaboration with export management companies in the pharmaceutical and food industry, such as "Avita Bios Pharma" (Export)
(4) Collaborative R & D to develop products in the supply chain of different industries based on technologies available in the knowledge-based company (technology spill-over).
(5) Definition of university R&D projects and their subsequent commercialization (University)

New titles used in the Visual PROMETHEE software for each option (strategy) are given in brackets. Using the Delphi method to create a matrix for evaluating the options, the experts were asked to rate each strategy on a scale from 1 to 9 according to how much it strengthens a criterion. The scoring method is shown in Table 9.

Table 9. Nine-point intensity of importance scale and its description.

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2, 4, 6, 8

Then, by averaging the expert scores to each strategy for each criterion, the strategy evaluation matrix (options) is obtained in Table 10.

Table 10. Strategy evaluation matrix

Criteria and alternatives	New Markets	Brokers	Innovation	Resources	Customers	Suppliers
Weight	0.39	0.05	0.03	0.28	0.09	0.16
OEM	7.2	5.4	6.4	4.8	6.8	5.4
Joint Venture	4.6	3.8	6.2	3.2	5.2	6.2
Techno Transfer	6.8	6.6	5.8	3.2	5.8	4.8
Export	8.8	6.6	3.8	5.2	7.6	4.6
Spillover	6.8	6.8	7.2	6.6	5.6	6.2
University	3.6	4.4	7.4	5.8	2.6	5.8

Due to the nature of the decision criteria, which are all qualitative and quantified using the Likert spectrum, the linear ranking function of the Visual PROMETHEE software was used for them. Table 11 shows the results of the prioritization strategies.

Table 11. Strategy prioritization

Strategies	Positive flow ($\emptyset^+$)	Negative flow ($\emptyset^-$)	Net flow ($\emptyset$)	Rank
OEM	0.2001	0.0616	0.1385	3
Joint Venture	0.0916	0.3796	—0.2880	6
Techno Transfer	0.1273	0.2757	—0.1484	4
Export	0.3247	0.1423	0.1823	2
Spillover	0.3589	0.0257	0.3331	1
University	0.1598	0.3774	—0.2176	5

Strategies can be used together and create synergies. Combining strategies can lead to greater or lesser synergies or even contradictions that threaten overall strategic performance. For this reason, the experts were asked to compare pairs of strategies in terms of synergies using the nine-point Likert scale, and the average results for synergies between strategies are presented in Table 12. A comparison of the prioritization table results from the two methods, PROMETHEE and Synergy. For a more reliable result, it is better to take weighted averages between the results (Nassereddine et al., 2019). It means that each decision system should be taken into account according to its importance, with a weight of 1 in total, and finally, the ranking of the strategies will be obtained.

Table 12. Pairwise comparison of synergy between strategies

Strategies	OEM	Joint Venture	Techno Transfer	Export	Spillover	University	Total synergy score
OEM	-	6.2	6	6.8	4.2	2.6	5.16
Joint Venture	-	-	6	3.6	6.2	4.4	5.28
Techno Transfer	-	-	-	8.2	5	4.6	5.96
Export	-	-	-	-	4.6	2.4	5.12
Spillover	-	-	-	-	-	4.2	4.84
University	-	-	-	-	-	-	3.64

The results of MCDM and synergy evaluation are presented in Table 13. Table 13 gives us a systemic view of evaluation by presenting the rank of each strategy (MCDM results) and the share of each from the collective strategies (synergy results). The final rank can be calculated as shown in the equation below.

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Table 13. MCDM and synergy results

Criteria	MCDM	Rank	Synergy	Rank
OEM	0.1385	3	5.16	3
Joint Venture	—0.2880	6	5.28	2
Techno Transfer	—0.1484	4	5.96	1
Export	0.1823	2	5.12	4
Spillover	0.3331	1	4.84	5
University	—0.2176	5	3.64	6

$$Final\ Rank = W_1 * PROMETHEE\ Ranking + W_2 * Synergy\ Ranking$$

$$W_1 + W_2 = 1 \quad (12)$$

W1 is the relative importance of using only one strategy, while W2 is the relative importance of synergy result. the allocation of weights is based on expert opinion.

4. Discussion and research limitations

Biotechnology is widely used and growing in the pharmaceutical, agricultural, and food industries. Developed countries are increasingly using biotechnology to improve the quantity and quality of agricultural and food products to maintain their food security, especially in the face of droughts and population growth (Björnberg et al., 2015). Additionally, biotechnology has numerous applications in the medical and disease treatment fields. Iran is a leading country in Western Asia for human drug production infrastructure. It is currently one of the top 10 countries in the world and the first in the region for biotechnology drug production. The country produces 28 types of biotechnology drugs.

As mentioned in the results section, according to the PROMETHEE model, the first strategy is the spillover strategy or technology spillover. In order to use their technologies in different industries and to better define their development path, biotechnology, agri-food, and knowledge-based companies need to carry out joint research and development projects. For example, a company producing human probiotics can expand its supply chain if it can develop animal probiotics for livestock and poultry to be used in the agri-food industry. An ornamental plant tissue culture company will have new value chain development opportunities through the cultivation of medicinal plants. The use of the technology exchange infrastructure (technology marketplace) available to companies through the Office of the Deputy President for Science and Technology can also be effective.

Cooperation with export management companies is the next strategy in the chosen model (export). Companies that provide sales channels specifically for biotechnology companies (e.g., AvitaBiosPharma) can take advantage of key success factors, contribute to the rapid growth of

knowledge-driven companies, and secure their success in competition with large and established companies. In some cases, depending on their resources, knowledge-based companies may prefer to pursue an OEM strategy rather than a branding strategy and direct customer relationships. For example, a probiotics company may initially choose to sell its product wholesale to a domestic or export-oriented foreign food manufacturer and expand sales to other direct marketing strategies in the future.

The Deputy of Development of Knowledge-Based Enterprises provides infrastructure for biotechnology companies to conclude technology transfer and export agreements with emerging foreign companies in countries like China, Russia, Lebanon, Turkey, and Iraq. Technology transfer involves a company transferring a specific biotechnology technology to another company in exchange for an export license to that country. Future research may focus on the method of technology transfer.

As places for conducting applied research, universities can assist nascent knowledge-based companies that lack resources for hiring specialized personnel at the beginning of their journey. Defining university research and development projects and supporting them can lead to forming relationships between knowledge-based companies and one of their key success factors, namely university experts, expanding the company's human network in the future.

The study's model ranked the Joint Venture strategy as the least effective. It may be because emerging knowledge-based firms often lack production equipment and rely solely on laboratory equipment in growth centers and science and technology parks. Therefore, this strategy could facilitate the future exchange of technology and production infrastructure between knowledge-based firms. However, it first needs to be integrated with other strategies.

It is important to note that the strategies that can be adopted and their prioritization may differ depending on the industry in which the knowledge-based company operates, its lifespan and size, and the weight of criteria. For this study, we selected companies in the biotechnology, agriculture, and food industries from the list of knowledge-based companies available on the website of the Deputy of Knowledge-based Companies Development of the Presidency. We aimed to include only nascent and innovative companies to ensure reliable research results. However, there were still differences in terms of the lifespan and size of the companies.

5. Conclusion and future recommendations

Evaluating and selecting the appropriate supply chain marketing strategy is an important yet challenging task for knowledge-based companies due to differences in company type,

objectives, size, location, the varying and inconsistent experiences of decision-makers, and the interaction among several actors. This paper focused on developing and applying multimethodological intervention benefiting from the advantages of Soft OR and MCDM to deal more effectively with the complex nature of real-world problems. JOURNEY Making has been utilized as a problem-structuring method to comprehend the situation. At the same time, SWOT analysis is employed to develop strategies, and MCDM models are then applied to prioritize these strategies. As a summary of the research findings, the attention of managers of biotechnology knowledge-based companies shown that the goal of companies should be a sustainable international presence through opportunity seeking and finding a superior competitive position based on distinctive resources and creating value-creating networks, and companies are expected to exhibit proactive, competitive, innovative, collaborative, and customer-centric behaviors. Also, technology-oriented companies should be proactive in strategic alliances that will have effects such as improving technological innovations and knowledge sharing in inter-organizational collaborations. Furthermore, companies should define and use appropriate criteria and models for selecting suitable marketing strategies in the supply chain based on their specific conditions.

It is suggested that the prioritization model of strategies for knowledge-based companies in other sectors be redesigned and compared between companies in different sectors. For example, it can be examined how a model derived for information technology knowledge-based companies differs from a model derived for biotechnology knowledge-based companies in terms of similarities and differences. The model can be enriched by increasing the number of criteria and formulating strategies. Additionally, increasing the number of samples can improve the accuracy of the decision model and prioritization. Future research could explore formulating implementation plans for each strategy.

Disclosure statement

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