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Analyzing Factors Effective in Marketing Knowledge-Based Products of Basic Chemicals in Iran

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Highlights

- Current policies and incentives have only augmented scientific research papers and have not led this subdivision to move for the development of the markets of these products, which have inevitably allocated a small share of income to themselves.
- Knowledge management does not much influence the marketing of knowledge-based products in Iran's basic chemicals industry.

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Abstract

The present study aims to identify and prioritize the factors affecting the marketing of knowledge-based products of basic chemicals. This research is applied in terms of objectives and a data-based cross-sectional survey concerning its method. Initially, the factors affecting the marketing of products in this sector were identified based on library and field studies and by purposive sampling of 15 senior managers of knowledge-based chemical companies (research experts) utilizing a semi-structured interview in the form of a questionnaire. Cochran's formula was then employed, and 400 experts and staff working in this department were selected as the study's statistical population through simple random sampling. Subsequently, confirmatory factor analysis was used to analyze the data and check the final model's fitting. In the end, each factor's relative importance was determined by the fuzzy Dematel analytic network process (DNAP) method. The results led to the identification of 16 sub-criteria under 7 main criteria, including technical and managerial, information and knowledge, economic, infrastructural, legal, and support issues, besides supply capabilities. The results revealed that the information and knowledge criterion and the innovation sub-criterion had the highest score, while the supply capability criterion and the knowledge management sub-criterion were ranked last.

Keywords: Basic chemicals, Fuzzy DNAP, Knowledge-based products, Marketing

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1. Introduction

In the economy of the present era, which is based on knowledge and knowledge capital, the most successful companies are those which can produce knowledge constantly and distribute it all over the world and soon turn it into technology and product. Knowledge enterprises have a special position

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worldwide due to their high potential for making innovative and knowledge-based products and services in all countries. Therefore, the development of innovative products, the quality improvement of knowledge-based products, the promotion of Iranian products brand in the global community, and obtaining maximum economic productivity by offering products in international domains make paying attention to global markets inevitable.

Passing through the digital economy and network economy and the beginning of the fourth wave of the industrial revolution, which includes economy information and knowledge enterprises, show the role and importance of knowledge enterprises in the economic development and progression of the country's objectives. Sales of the chemical business can be divided into a few broad categories, including basic chemicals (about 35%–37% of the dollar output), life sciences (30%), specialty chemicals (20%–25%), and consumer products (about 10%). Basic chemicals, or "commodity chemicals" are a broad chemical category, including polymers; bulk petrochemicals, intermediates, other derivatives, and basic industrials; inorganic chemicals; and fertilizers. Thus, the term knowledge agency and institute describe agencies whose knowledge assets are their main source of competitive advantages, obtained as a result of commercializing new ideas and innovations, and are the outcome of the interaction between their physical assets and knowledge capital. Knowledge enterprises create knowledge, form entrepreneurial and innovative businesses toward a special objective, and work in a specialized major. These enterprises are the result of knowledge-based entrepreneurs trying to enhance productivity and produce products recognizing local, national, and even global markets even with accepting risks and increasing their competition by relying on market knowledge.

According to the United States Patent and Trademark Office (USPTO), the number of patent certificates reached 333530 cases in 2019, which increased by 15% and 64.2% compared to 2018 and 2010, respectively. The above information reveals the importance of knowledge and research and the production of knowledge-based products in the global economy. Governments have to insist on this duty not to fall behind in this breathtaking competition, not only guiding the country toward the fourth generation of the industrial revolution by encouraging outstanding and experienced entrepreneurs but also orienting the space of entrepreneurship to the interest of producing knowledge-based products and services.

Considering clause A of General Policies of 1404 Energy and clause 5 of General Policies of National Production, which support work and Iranian capital, and clauses 13 and 15 of General Policies of Resistance Economy—which is the promotion of technology, the completion of the value chain in this industry, and the increase of petrochemical products exports—and considering the optimal capacity created in the petrochemistry upstream industries in the country, the development of chemical knowledge-based industries may contribute to the achievement of the goals of general economic policies. However, many knowledge enterprises may not be able to achieve effective marketing models and methods on their own considering the young and newly-established nature of most knowledge enterprises of basic chemicals and other issues, including not recognizing suitable markets and how to enter them, unawareness of competitors' abilities and knowledge-based products, and mental obstacles and fear from entering global markets and the existence of so many problems in the internal market (Rezvani and Toghraei, 2011). Given the abovementioned explanations, the importance of knowledge-based companies' marketing as a challenge for these companies, the focus of the main research only on the issue of commercialization of the products of knowledge companies in this field, and particularly addressing marketing and eliminating the challenges in this area, the current study aims to identify and prioritize the factors affecting the marketing of knowledge-based products. Proposing this issue may largely eliminate the challenge. Consequently, this study seeks to answer the main question below:

What are the effective factors in the marketing of knowledge-based products in basic chemicals?

The study initially reviews the literature on marketing knowledge-based products and then presents the results obtained from interviews and surveys, as well as the fuzzy Dematel analytic network process (DNAP) method in these companies. Ultimately, the key findings are discussed and supported.

2. Methodology

Ghasemi, Faghihi, and Alizadeh (2018) conducted a study titled "The Necessities of Achieving Large-Scale Knowledge Economy: the Analysis of Legal Framework in Iran and Representing Political Recommendations". They reported that despite different rules and regulations in development plans and other permanent rules of the country, there is still a distance to a comprehensive and integrated legal framework to move toward the knowledge economy. The institutional regime and economic structure of the country have to be reinforced while there are still some legal gaps in supporting entrepreneurship and innovation. The development of human capital and information and communication technology enjoys more acceptable conditions in the current legal framework compared with the two previous pillars.

Yahyaei and Hassanzadeh (2016) represented a commercialization model in the knowledge enterprises in ICT. The results of this study showed that all the six factors of PESTLE were effective on technology commercialization, the most and least important of which were the economic and legal factors, respectively. Amini and colleagues (2016) investigated the effective factors on the development of knowledge enterprises using AHP. The indices of technology, economy, and rules were the three main factors from the managers' point of view in knowledge enterprises. Environmental, social, and political criteria were selected as the least important ones.

Daneshfard (2016) conducted a study entitled "Analyzing Effective Factors on Strategy and Establishment of Knowledge Enterprises and Representing a Suitable Model". The research findings showed that six main factors were significantly related to performing knowledge enterprises strategy. The empowerment factor and the map of the path in performance achieved the first and the last ranking, respectively.

Davidson et al. (2013) studied Swedish knowledge enterprises and investigated effective factors on them. The results showed that effective factors for the growth and development of these enterprises were the age of the company, the size of business, the section of business, the place of business, the legal form of the company, and the resistance of the manager and owner to growth.

Seu et al. (2016) paid attention to competitive policies for technological innovations in the age of the knowledge-based economy in their study. The results of their study showed the positive effect of competitive policies on technological innovations.

In a study entitled "Modeling for the Release of Innovation Complexes through Social Networks", Asnowa (2018) showed that informal entrepreneurs began a business and achieved innovation through todays' knowledge instruments, using elite forces, transforming themselves into a brand, overtaking other competitors, and allocating a considerable share of the market to themselves. Selecting new methods in research and study is their main reason for achievement, which may be sometimes in contrast with previous studies.

The results of a study by Ghahremanpour et al. (2020) on 146 production and export drug companies highlighted the positive and significant effects of organizational flexibility capacity and organizational learning with the change of product innovation mediation on the marketing performance of these enterprises. Accordingly, the companies can make continuous innovations in products to respond to the ever-changing requests of customers and then enhance the performance and competitive position of the

organization. However, the findings of the study by Shirmohammadi et al. (2020) showed that innovation in the product affected innovation in marketing and innovative performance positively and significantly. Also, innovation in marketing had a positive and significant effect on innovative performance, and production performance affected market performance; product export also influenced product internationalization. Therefore, innovation capacity was one of the necessary factors for managers to reinforce the company to guide superior products and business services and model.

The significant results of the study by Zarghami et al. (2021) to design an eco-friendly marketing pattern in Iran's oil industry were finding the interveners, including productivity, governmental support, social institutions, and sustainable development, along with the strategies, including reviewing the energy section structure, improving the managers' perspectives, and developing the green investments. Mahdavi Sabet et al. (2021) suggested that the antecedents of Iranian oil products' export performance should include market orientation, company resources, marketing mix, and macroenvironment. The items of Iranian oil products' export performance include financial performance, customer satisfaction, and customer retention. In another study, Mazruei et al. (2020) concluded that entrepreneurial marketing mix positively and significantly influenced the achievement of knowledge enterprises. Moreover, marketing plays a moderating role between two variables of the entrepreneurial marketing mix and entrepreneurial achievement in these businesses. These results show that knowledge enterprises with a marketing approach seek to consider marketing factors in their marketing mix, meet customers' new demands, and satisfy their current and competitive needs.

A study by Tabatabaei Nasab et al. (2021) suggested a significant association between market orientation and marketing capability, in addition to a significant relationship between organizational innovation capability and organizational competitiveness in knowledge-based companies. Nevertheless, the results of Namakian and Kahrizi (2021) showed the impact of service marketing, internet marketing, and marketing of new products on the performance of knowledge-based companies. However, Ismailpour et al. (2021) believed that Iranian knowledge-based companies should adopt an active and competitive approach to achieve a successful and sustainable presence in global markets, in addition to following a combination of resource-based, entrepreneurial, and network-based theories according to the Iranian business conditions.

Kakaei et al. (2021) concluded that entrepreneurial marketing positively and significantly affected the companies' human capital. Another result of this study revealed the mediating role of human capital in the relationship between entrepreneurial marketing and innovative performance. Nevertheless, the study by Ghaderi and Rahimnia (2022) suggested that product and process innovation strategies should have a positive and significant relationship with the business performance of knowledge-based companies. The research results of Javan Emami and Akbari (2022) showed a positive and significant relationship between leadership and marketing infrastructure in knowledge-based leadership companies with marketing strategy. On the other hand, there was neither a positive or significant relationship between leadership and market analysis and understanding nor between market analysis and understanding and marketing mix. Bayat et al. (2022) realized that in knowledge-based companies, the organizational trust components, including vertical, horizontal, and institutional trust significantly affected the knowledge commercialization.

This study is applied in terms of objectives but grounded and cross-sectional survey in the method. First, the effective factors in the marketing of knowledge-based products were identified based on extensive library studies, including valid national and international articles and journals. Data were also collected through field studies using semi-structured interviews with 15 senior managers of type I and type II chemical production knowledge-based enterprises active in the field of advanced chemicals (researcher experts) in the form of a questionnaire. The reliability and validity of the questionnaire were

approved using Cronbach's alpha and content and confirmatory validity, respectively. Then, confirmatory factor analysis was used to analyze data for the final model.

The statistical population of the study included all experts and employers active in knowledge-based enterprises producing chemical industry products. The Cochran formula and simple random sampling were used to select a sample group, leading to the selection of 400 individuals (130 women and 270 men), 270 of whom had the lowest level of BA education and 3 years of useful background in this field. After collecting information from interviews and sources, the grounded and coding methods (selective) were used to classify data. Further, research literature, sources, interviews with local people, and the opinions and guidelines of a group of experts were considered. The final revisions were made before coding to determine the internal validity (the capability of validity) of the findings and select and approve the data using theoretical basics. At last, the investigation by research members was employed to confirm the accuracy of the data on the research validity. We used theoretical saturation, coding specific procedures and symbols, sign analysis, and data-rich description to determine external validity (transferability) of the findings. Finally, 7 technical, managerial, information and knowledge, economic, infrastructural, legal, supportive, and supply capability criteria were classified into 16 sub-criteria. Moreover, the fuzzy DNAP method was employed to prioritize factors. Then, the effectiveness of the criteria and sub-criteria was determined by those 15 research experts considering the items extracted from the previous stage, followed by the transformation of data into fuzzy numbers and their integration. Accordingly, among the main criteria of information and knowledge, economic, and infrastructural issues were the causes of higher effectiveness, and other criteria were considered the effect.

According to the abovementioned studies and the research experts' viewpoints, the effective factors and subcriteria for the marketing of knowledge-based products in the chemical industry could be exhibited according to the selected model in Figure 1.

3. Research findings

3.1. Data normality test

Before using parametric tests, it is necessary to make sure of the normality of the population. Therefore, the Kolmogorov–Smirnov test was used as presented in Table 1.

Table 1

The results of the Kolmogorov–Smirnov test

Number	K–S	DF	p-value
400	0.918	399	0.316

According to the results of the Kolmogorov–Smirnov test, K–S was not significant, demonstrating the normality of the distribution. Therefore, it is possible to use parametric tests to analyze data in this study; Table 2 lists the results.

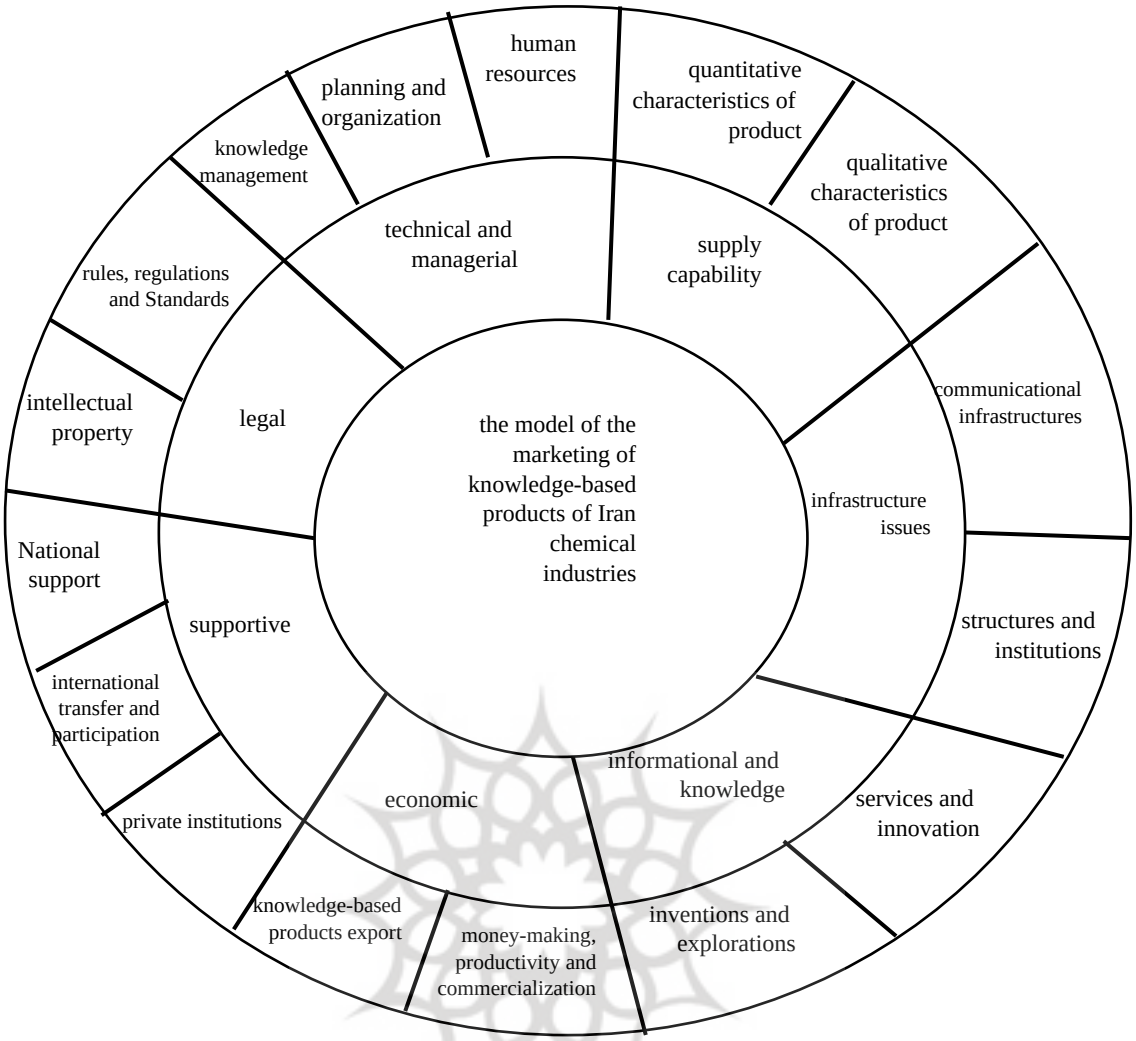

Figure 1

The model of the marketing of the knowledge-based products of basic chemicals

Table 2

The descriptive indices of research factors

Kurtosis	Skewness	Mean	Factors
1.809	–1.274	5.49	Human resources
2.039	–1.020	5.45	Knowledge management
1.180	–0.512	5.35	Planning and organization
1.370	–1.287	5.34	Inventions and explorations
1.575	–1.474	5.32	Innovation and creativity
1.179	–1.904	5.18	Knowledge-based products export
2.820	–0.427	5.12	Money-making, productivity, and commercialization
2.435	–1.142	5.93	Communicational and environmental infrastructures
2.51	–1.651	4.78	Structures and institutions
2.183	–1.244	5.49	Rules, regulations, and standards
1.390	–1.174	5.35	Intellectual property
2.54	–1.174	5.34	International transfer and participation

Kurtosis	Skewness	Mean	Factors
2.29	–1.150	5.32	Private institutions
1.089	–1.512	5.25	National support
1.770	–1.35	5.12	Qualitative characteristics of product
2.019	–1.150	5.1	Quantitative characteristics of product
1.575	–1.474	5.32	Technical and managerial
2.575	–0.474	5.65	Informational and knowledge
1.179	–0.904	5.69	Economic
3.020	–0.457	4.04	Infrastructural issues
3.135	–0.142	5.40	Legal
3.071	–1.651	5.25	Supportive
3.135	–0.904	5.49	Supply capability

Confirmatory factor analysis was employed to generalize the results to the desired society. According to confirmatory factor analysis, the researcher looks for a model supposed to describe, explain, and approve experimental data based on relatively few parameters. This model is based on pre-experimental information about the structure of data. The main difference between exploratory and confirmatory factor analyses is that the former is the most economical method to explain the shared infrastructural variance of a correlation matrix. However, the confirmatory method (hypothesis testing) determines whether data are consistent with a determined factory structure (in hypothesis) or not. This study also used confirmatory factor analysis to show whether the identified criteria enjoyed a consistent factor structure or not.

The results in Table 3 confirmed all indices of the goodness of fit concerning the marketing criteria of knowledge-based products of basic chemicals.

Table 3

The goodness-of-fit indices of the marketing criteria of the knowledge-based products of basic chemicals

Supply capability	Supportive	Legal	Infrastructural issues	Economic	Informational and knowledge	Technical and managerial	Dimensions
2.23	2.17	1.24	1.63	1.88	2.65	1.65	$(\chi^2)^*$
0.91	0.90	0.94	0.94	0.90	0.92	0.93	Goodness of fit (GFI)
0.90	0.92	0.94	0.92	0.92	0.91	0.91	AGFI†
0.042	0.061	0.031	0.049	0.03	0.06	0.069	RMSEA‡
0.91	0.94	0.98	0.91	0.93	0.92	0.95	CFI§
0.92	0.93	0.95	0.91	0.91	0.92	0.95	NFI**
0.91	0.93	0.97	0.93	0.92	0.94	0.95	NNFI††
0.94	0.93	0.98	0.94	0.94	0.95	0.97	IFI‡‡

To answer the question of prioritizing the effective factors in the marketing of knowledge-based products, the DNAP method was used as follows.

* Chi-squared on degree of freedom
† Adjusted goodness of fit index
‡ Root mean square error of approximation
§ Comparative fit index
** Normed fit index
†† Non-normed fit index
‡‡ Improving fit index

3.1.1. Fuzzy DNAP method

The DNAP technique is from the result of new approaches of mixing two DEMATEL methods. This approach has formed ANP super matrices using DEMATEL complete-communication matrix and calculates the weight of research indices. The steps of this method are as follows (Hu et al., 2015: 9):

Step 1. Calculating direct communication matrix (*D*)

The respondents were supposed to show the effectiveness of criterion i on criterion *j* using Table 4. The arithmetic means were taken from all experts based on Equation (1).

$$\tilde{z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^3 \oplus \ldots \oplus x^p}{p} \quad (1)$$

where *p* is the number of experts; $\tilde{x}^1$, $\tilde{x}^2$, and $\tilde{x}^p$ are pairwise comparison matrices of expert1, expert 2, and expert *p*, respectively; $\tilde{z}$ represents the fuzzy triangular number: $\tilde{z}_{ij} = (l'_{ij}, m'_{ij}, u'_{ij})$.

Table 4

Linguistic scales for the influential degree of the criteria

Fuzzy equivalent	Variable
(0.0, 0.0, 0.25)	Ineffective
(0.0, 0.25, 0.5)	Low effect
(0.25, 0.5, 0.75)	Medium effect
(0.5, 0.75, 1)	High effect
(0.75, 1, 1)	Very high effect

Step 2. Normalizing direct communication matrix

Equations (2) and (3), called matrix H, were used to normalize matrix achieved from the previous stage.

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}\right) = (l''_{ij}, m''_{ij}, u''_{ij}) \quad (2)$$

where *r* is obtained from the following:

$$r = max_{1 \le i \le n}\left(\sum_{j=1}^{n} u'_{ij}, \sum_{i=1}^{n} u'_{ij}\right) \quad (3)$$

Step 3. Calculating complete-communication matrix of criteria (Tc)

After calculating the normal matrix, the fuzzy complete-communication matrix is calculated using Equations (4)–(7).

$$T = \lim_{k \to +\infty} (\tilde{H}^1 \oplus \tilde{H}^2 \oplus \ldots \oplus \tilde{H}^k) \quad (4)$$

where every entry is a fuzzy number as $\tilde{t}_{ij} = \left(l^t_{ij}, m^t_{ij}, u^t_{ij}\right)$, calculated as follows:

$$\left[l_{ij}^{t}\right] = H_l \times (I - H_l)^{-1} \quad (5)$$

$$\left[m_{ij}^{t}\right] = H_m \times (I - H_m)^{-1} \quad (6)$$

$$\left[\mathrm{u}_{\mathrm{ij}}^{\mathrm{t}}\right] = \mathrm{H_u} \times (\mathrm{I} - \mathrm{H_u})^{-1} \quad (7)$$

where I represents the identity matrix, and H_l, H_m, and H_u are $n \times n$ matrix, whose entries are the low, middle, and high values of matrix H fuzzy triangular numbers, respectively.

Step 4. Calculating dimensions complete-communication matrix

First, T_D matrix has to be extracted from criteria complete-communication matrix T_c. Therefore, every entry of matrix T_D is calculated as follows.

If every entry of matrix T_D is considered t_{ij}, every t''_{ij} is obtained from the mean of every T_C^{ij}.

Step 5. Calculating the intensity and direction of impact

Indices ri and cj are calculated according to Equations (8) and (9). The ri index is the sum of i^{th} row, and cj index denotes the sum of j^{th} column of matrix T_c, considering the related dimension. $\tilde{R}$ and $\tilde{D}$ indices are calculated in the same way. The ri index is the sum of i^{th} row, and the cj index is the sum of j^{th} column of matrix T_D. To draw and analyze the diagram, two indices of impression and impressionability and the direction of impact are required, which are calculated by ri and cj. For every $i = j$, we have:

$$\tilde{D} = \left(\tilde{D}_i\right)_{n\times 1} = \left[\sum_{\mathrm{j}=1}^{\mathrm{n}} \tilde{\mathrm{T}}_{\mathrm{ij}}\right]_{n\times 1} \quad (8)$$

$$\tilde{R} = \left(\tilde{R}_i\right)_{1\times n} = \left[\sum_{\mathrm{i}=1}^{\mathrm{n}} \tilde{\mathrm{T}}_{\mathrm{ij}}\right]_{1\times n} \quad (9)$$

Accordingly, $\tilde{\mathrm{D}}$ and $\tilde{\mathrm{R}}$ have the dimensions $n \times 1$ and $1 \times n$, respectively.

Then, the importance of indices ($\tilde{\mathrm{D}}_{\mathrm{i}} + \tilde{\mathrm{R}}_{\mathrm{i}}$) and relationship between criteria ($\tilde{\mathrm{D}}_{\mathrm{i}} - \tilde{\mathrm{R}}_{\mathrm{i}}$) was specified. If $\tilde{\mathrm{D}}_{\mathrm{i}} - \tilde{\mathrm{R}}_{\mathrm{i}} > 0$, the related criterion is influential, and the related criterion is impressionable.

$\boldsymbol{ri + dj}$: the intensity of impression and impressionability; in other words, the higher the $ri + dj$ of a factor, the more interaction that factor has with the other factors of the system.

$\boldsymbol{ri - dj}$: the direction of impression and impressionability; hence, if $ri - dj > 0$, the related criterion is a cause, and if $ri - dj < 0$, the relate criterion is an effect.

Considering the above calculated values, indices $ri + dj$ and $ri - dj$ as well as $\tilde{\mathrm{D}}_{\mathrm{i}} + \tilde{\mathrm{R}}_{\mathrm{i}}$ and $\tilde{\mathrm{D}}_{\mathrm{i}} - \tilde{\mathrm{R}}_{\mathrm{i}}$ are calculated for dimensions and are then defuzzificated using Equation (10):

$$\text{defuuzy} = \frac{\left((u - l) + (m - l)\right)}{3} + l \quad (10)$$

Step 6. Drawing network relation map (NRM)

It is necessary to calculate the reference value to determine the NRM. Partial relations may be ignored using this method, and the noteworthy network relations are drawn. Only relations whose values are bigger than the reference value in matrices T_C and T_D will be shown in the NRM. It is enough to calculate every T_C^{ij} (in matrix T_C) and the mean of matrix T_D (to draw the map of dimensions relations) using experts' opinions and the value mean to calculate the relation reference value. After determining the reference value, all values smaller than the reference have to be zero; that is, the causal relation is not considered. Therefore, complete-communication of criteria and dimensions are defuzzificated using Equation (10).

Step 7. Normalizing complete-communication matrix of dimensions ($T_D^{\propto}$)

Considering Equation (11), matrix T_D is normalized. Therefore, the sum of each row of matrix T_D is calculated considering the related dimension, and then the element of each row is divided by the sum of the elements of that row; finally, the rows and columns are transposed.

$$\boldsymbol{T_D} = \begin{bmatrix} t_{11}^{\boldsymbol{D_{11}}} & \dots & t_{1j}^{\boldsymbol{D_{1i}}} & \dots & t_{1m}^{\boldsymbol{D_{1m}}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{\boldsymbol{D_{i1}}} & \dots & t_{ij}^{\boldsymbol{D_{ii}}} & \dots & t_{im}^{\boldsymbol{D_{im}}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{m1}^{\boldsymbol{D_{mi}}} & \dots & t_{mj}^{\boldsymbol{D_{mi}}} & \dots & t_{mm}^{\boldsymbol{D_{mm}}} \end{bmatrix} \begin{matrix} \\ \\ \rightarrow d_1 = \sum_{j=1}^{m} t_{1j}^{\boldsymbol{D_{1i}}} \\ \rightarrow d_i = \sum_{j=1}^{m} t_{ij}^{\boldsymbol{D_{ii}}} \;, d_i = \sum_{j=1}^{m} t_{ij}^{\boldsymbol{D_{ii}}} , i = 1, \dots, m \\ \rightarrow d_m = \sum_{j=1}^{m} t_{mj}^{\boldsymbol{D_{mi}}} \end{matrix} \tag{11}$$

$$\boldsymbol{T_D^{\propto}} = \begin{bmatrix} t_{11}^{\boldsymbol{D_{11}}}/d_1 & \dots & t_{1j}^{\boldsymbol{D_{1j}}}/d_1 & \dots & t_{1m}^{\boldsymbol{D_{1m}}}/d_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{\boldsymbol{D_{i1}}}/d_i & \dots & t_{ij}^{\boldsymbol{D_{ij}}}/d_i & \dots & t_{im}^{\boldsymbol{D_{im}}}/d_i \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{m1}^{\boldsymbol{D_{m1}}}/d_m & \dots & t_{mj}^{\boldsymbol{D_{mj}}}/d_m & \dots & t_{mm}^{\boldsymbol{D_{mm}}}/d_m \end{bmatrix} = \begin{bmatrix} t_D^{\propto 11} & \dots & t_D^{\propto 1j} & \dots & t_D^{\propto 1n} \\ \vdots & & \vdots & & \vdots \\ t_D^{\propto i1} & \dots & t_D^{\propto ij} & \dots & t_D^{\propto in} \\ \vdots & & \vdots & & \vdots \\ t_D^{\propto n1} & \dots & t_D^{\propto nj} & \dots & t_D^{\propto nn} \end{bmatrix}$$

Step 8. Normalizing complete-communication matrix of criteria ($T_C^{\propto}$) and forming disharmonious super-matrix

Considering Equations (12)–(14), matrix T_C is normalized. Therefore, the sum of each row of T_C^{ij} is calculated considering the related dimension; then in every T_C^{ij}, the element of each row is divided by the sum of the elements of that row. For example, if every $T_C^{\propto}$ consists of a set of $T_C^{\propto ij}$, $T_C^{\propto 11}$ is obtained from normalization T_C^{11}. Disharmonious super-matrix is calculated using matrix $T_C^{\propto}$ transpose.

$$\boldsymbol{T_C^{\alpha}} = \begin{array}{c} \\ \boldsymbol{D_1} \\ \vdots \\ \boldsymbol{D_i} \\ \vdots \\ \boldsymbol{D_n} \end{array} \begin{array}{c} \begin{matrix} \boldsymbol{D_1} & & \boldsymbol{D_j} & & \boldsymbol{D_n} \\ c_{11} \dots c_{1m_1} & \dots & c_{j1} \dots c_{jm_j} & \dots & c_{n1} \dots c_{nm_n} \end{matrix} \\ \begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \dots & \boldsymbol{T}_c^{\alpha 1j} & \dots & \boldsymbol{T}_c^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha i1} & \dots & \boldsymbol{T}_c^{\alpha ij} & \dots & \boldsymbol{T}_c^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha n1} & \dots & \boldsymbol{T}_c^{\alpha nj} & \dots & \boldsymbol{T}_c^{\alpha nn} \end{bmatrix} \end{array} \tag{12}$$

$$d_{ci}^{11} = \sum_{j=1}^{m_1} t_{cij}^{11} \ , i = 1, 2, \dots, m_1 \tag{13}$$

$$\boldsymbol{T_C^{\propto 11}} = \begin{bmatrix} t_{c11}^{11}/d_{c1}^{11} & \cdots & t_{c1j}^{11}/d_{c1}^{11} & \cdots & t_{c1m1}^{11}/d_{c1}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_{ci}^{11} & \cdots & t_{cij}^{11}/d_{ci}^{11} & \cdots & t_{cim1}^{11}/d_{ci}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm11}^{11}/d_{cm1}^{11} & \cdots & t_{cm1j}^{11}/d_{cm1}^{11} & \cdots & t_{cm1m1}^{11}/d_{cm1}^{11} \end{bmatrix} \tag{14}$$

$$= \begin{bmatrix} t_{c11}^{\propto 11} & \cdots & t_{c1j}^{\propto 11} & \cdots & t_{c1m1}^{\propto 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\propto 11} & \cdots & t_{cij}^{\propto 11} & \cdots & t_{cim1}^{\propto 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm1\,1}^{\propto 11} & \cdots & t_{cm1j}^{\propto 11} & \cdots & t_{cm1m1}^{\propto 11} \end{bmatrix}$$

Step 9. Forming harmonious super-matrix

Then, the matrix $T_D^{\propto}$ is multiplied by *W*. Thus, every $t_D^{\propto ij}$ is multiplied by W_{ij}.

Step 10. limiting harmonious super-matrix

According to Equation (15), harmonious super-matrix is raised to a power (consecutive odd numbers) until all numbers in each row converge.

$$\lim_{Z\to\infty} (W^{\propto l})^Z \ , \lim_{Z\to\infty} (W^{\propto m})^Z \ , \lim_{Z\to\infty} (W^{\propto u})^Z \tag{15}$$

3.1.2. Introducing research factors

Table 5 lists the factors of the marketing of knowledge-based products in Iran's basic chemicals, including 16 sub-criteria and 7 main criteria.

Table 5

The marketing factors of the knowledge-based products of Iran's basic chemicals

Criteria	Code	Sub-criteria	Code
Technical and managerial	A	Human resources	A1
		Knowledge management	A2
		Planning and organization	A3
Informational and knowledge	B	Inventions and explorations	B1
		Innovation and creativity	B2
Economic	C	Knowledge-based products export	C1
		Money-making, productivity, and commercialization	C2
Infrastructural issues	D	Communicational and environmental infrastructures	D1
		Structures and institutions	D2
Legal	E	Rules, regulations, and standards	E1
		Intellectual property	E2

Criteria	Code	Sub-criteria	Code
Supportive	F	International transfer and participation	F1
		Private institutions	F2
		National support	F3
Supply capability	G	Product qualitative characteristics	G1
		Product quantitative characteristics	G2

3.1.3. DNAP results

First, the effect of sub-criteria on each other was considered based on Table 1 and 15 experts' opinions. Then, it was turned into a fuzzy number and integrated using Equation (1), mentioned as a direct communications matrix in Table 6. After forming the normal matrix, a direct communication matrix was created based on Equations (5)–(7), as mentioned in Table 7. According to these matrices, the type of criteria was specified considering the cause-and-effect relationships, including the values of D + R, in which D and R were the row sum and the column sum of the direct communications matrix, respectively. Tables 8 and 9 present the results of the criteria and sub-criteria. Hence, among the main criteria, information and knowledge, economic, and infrastructure issues are the cause of a higher impression, and the rest of the criteria are the effect.

Table 6

The direct communications matrix

	A1	A2	A3	B1	…	F2	F3	G1	G2
A1	(0, 0, 0.25)	(0.517, 0.767, 0.933)	(0.45, 0.7, 0.85)	(0.4, 0.633, 0.833)	…	(0.233, 0.4, 0.6)	(0.15, 0.367, 0.617)	(0.283, 0.533, 0.717)	(0.217, 0.467, 0.683)
A2	(0.15, 0.383, 0.617)	(0, 0, 0.25)	(0.45, 0.7, 0.883)	(0.533, 0.783, 0.9)	…	(0.217, 0.4, 0.65)	(0.283, 0.5, 0.733)	(0.2, 0.417, 0.65)	(0.3, 0.517, 0.733)
A3	(0.583, 0.833, 0.967)	(0.383, 0.633, 0.833)	(0, 0, 0.25)	(0.45, 0.667, 0.833)	…	(0.267, 0.517, 0.75)	(0.25, 0.45, 0.667)	(0.55, 0.8, 0.95)	(0.517, 0.767, 0.967)
B1	(0.6, 0.85, 0.967)	(0.617, 0.867, 0.983)	(0.383, 0.633, 0.85)	(0, 0, 0.25)	…	(0.567, 0.817, 0.967)	(0.517, 0.817, 0.967)	(0.217, 0.433, 0.65)	(0.15, 0.383, 0.6)
…	…	…	…	…	…	…	…	…	…
F2	(0.133, 0.35, 0.6)	(0.183, 0.383, 0.633)	(0.15, 0.383, 0.633)	(0.217, 0.45, 0.683)	…	(0, 0, 0.25)	(0.533, 0.783, 0.933)	(0.2, 0.383, 0.6)	(0.1, 0.25, 0.5)
F3	(0.317, 0.517, 0.733)	(0.267, 0.517, 0.75)	(0.2, 0.35, 0.55)	(0.167, 0.383, 0.633)	…	(0.117, 0.3, 0.55)	(0, 0, 0.25)	(0.267, 0.483, 0.717)	(0.35, 0.583, 0.767)
G1	(0.433, 0.683, 0.9)	(0.317, 0.567, 0.767)	(0.45, 0.7, 0.917)	(0.55, 0.8, 0.9)	…	(0.483, 0.733, 0.917)	(0.267, 0.517, 0.75)	(0, 0, 0.25)	(0.35, 0.6, 0.833)
G2	(0.5, 0.75, 0.933)	(0.533, 0.783, 0.95)	(0.567, 0.817, 0.95)	(0.583, 0.833, 0.95)	…	(0.483, 0.733, 0.883)	(0.317, 0.567.0.783)	(0.217, 0.467, 0.7)	(0, 0, 0.25)

Table 7

The dimensions complete-communications matrix

	A1	A2	A3	B1	…	F2	F3	G1	G2
A1	(0.017, 0.078, 0.472)	(0.053, 0.132, 0.524)	(0.048, 0.132, 0.524)	(0.048, 0.127, 0.526)	…	(0.034, 0.11, 0.509)	(0.028, 0.106, 0.507)	(0.036, 0.113, 0.498)	(0.028, 0.098, 0.458)
A2	(0.03, 0.112, 0.521)	(0.018, 0.084, 0.498)	(0.051, 0.134, 0.541)	(0.058, 0.144, 0.553)	…	(0.036, 0.117, 0.536)	(0.04, 0.122, 0.538)	(0.032, 0.111, 0.515)	(0.035, 0.107, 0.481)
A3	(0.062, 0.149, 0.572)	(0.048, 0.136, 0.567)	(0.021, 0.091, 0.524)	(0.055, 0.143, 0.577)	…	(0.042, 0.132, 0.571)	(0.039, 0.125, 0.561)	(0.058, 0.143, 0.562)	(0.052, 0.129, 0.522)
B1	(0.63, 0.151, 0.578)	(0.063, 0.152, 0.583)	(0.048, 0.137, 0.572)	(0.022, 0.097, 0.541)	…	(0.062, 0.153, 0.59)	(0.058, 0.148, 0.587)	(0.035, 0.12, 0.547)	(0.026, 0.104, 0.502)
…	…	…	…	…	…	…	…	…	…
F2	(0.023, 0.095, 0.477)	(0.026, 0.097, 0.483)	(0.024, 0.097, 0.481)	(0.03, 0.105, 0.495)	…	(0.014, 0.072, 0.463)	(0.052, 0.127, 0.509)	(0.028, 0.096, 0.47)	(0.018, 0.077, 0.428)
F3	(0.035, 0.102, 0.47)	(0.031, 0.101, 0.474)	(0.027, 0.091, 0.459)	(0.026, 0.097, 0.475)	…	(0.022, 0.09, 0.468)	(0.013, 0.066, 0.444)	(0.031, 0.097, 0.462)	(0.035, 0.096, 0.431)
G1	(0.051, 0.138, 0.567)	(0.043, 0.13, 0.562)	(0.052, 0.139, 0.57)	(0.061, 0.15, 0.581)	…	(0.056, 0.146, 0.581)	(0.04, 0.129, 0.567)	(0.018, 0.086, 0.512)	(0.04, 0.117, 0.512)

A1	A2	A3	B1	…	F2	F3	G1	G2
G2 (0.056, 0.142.0.562)	(0.058, 0.144, 0.567)	(0.06, 0.144, 0.567)	(0.063, 0.152, 0.576)	…	(0.056, 0.144, 0.571)	(0.043, 0.131, 0.561)	(0.034, 0.119, 0.537)	(0.015, 0.074, 0.464)

Table 8

The dimensions complete-communications matrix

Criterion	Code	$(Di)^{defuzzy}$	$(Ri)^{defuzzy}$	Di + Ri	Di – Ri	Criterion type
Technical and managerial	A	1.635	1.652	3.287	–0.017	Effect
Informational and knowledge	B	1.799	1.709	3.508	0.090	Cause
Economic	C	1.824	1.668	3.492	0.156	Cause
Infrastructural issues	D	1.656	1.539	3.195	0.117	Cause
Legal	E	1.422	1.667	3.089	–0.245	Effect
Supportive	F	1.474	1.831	3.304	–0.357	Effect
Supply capability	G	1.705	1.803	3.507	–0.098	Effect

Table 9

The sub-criteria impression and impressionability

Criterion	Code	$(Di)^{defuzzy}$	$(Ri)^{defuzzy}$	Di + Ri	Di – Ri	Criterion type
Human resources	A1	0.656	0.671	1.327	–0.015	Effect
Knowledge management	A2	0.662	0.686	1.348	–0.024	Effect
Planning and organization	A3	0.724	0.685	1.408	0.039	Cause
Inventions and explorations	B1	0.489	0.488	0.977	0.000	Cause
Innovation and creativity	B2	0.509	0.510	1.019	0.000	Cause
Knowledge-based products export	C1	0.502	0.509	1.011	–0.006	Effect
Money-making, productivity, and commercialization	C2	0.507	0.501	1.008	0.006	Cause
Communicational and environmental infrastructures	D1	0.430	0.420	0.851	0.010	Cause
Structures and institutions	D2	0.415	0.425	0.841	–0.010	Effect
Rules, regulations, and standards	E1	0.369	0.388	0.758	–0.019	Effect
Intellectual property	E2	0.397	0.378	0.776	0.019	Cause
International transfer and participation	F1	0.680	0.608	1.288	0.072	Cause
Private institutions	F2	0.620	0.621	1.241	0.000	Cause
National support	F3	0.570	0.461	1.211	–0.072	Effect
Product qualitative characteristics	G1	0.429	0.436	0.864	–0.007	Effect
Product quantitative characteristics	G2	0.414	0.407	0.822	0.007	Cause

Figure 2 draws the network relation map of the criteria relationships according to the values of D + R and D – R. Among these main criteria, the information and knowledge criterion has the most relationship with the other criteria. In other words, all the criteria influence the information and knowledge criterion and vice versa. On the other hand, this criterion can be considered the cause; it is also possible to consider informational and knowledge the key criterion because it has considerable impression and impressionability in the model and has many relationships with the other criteria. Table 10 presents the ultimate weights of the factors and their rankings, according to which the information

and knowledge criterion with a weight of 0.15477 is ranked first. The criteria of economic and supportive with a corresponding weight of 0.1502 and 0.14762 are ranked second and third, respectively. Among the sub-criteria, innovation and creativity with a weight of 0.07982 is ranked first. Money-making, productivity, and commercialization with a weight of 0.07521 and knowledge-based products export with a weight of 0.07499 attain the second and third rankings, respectively.

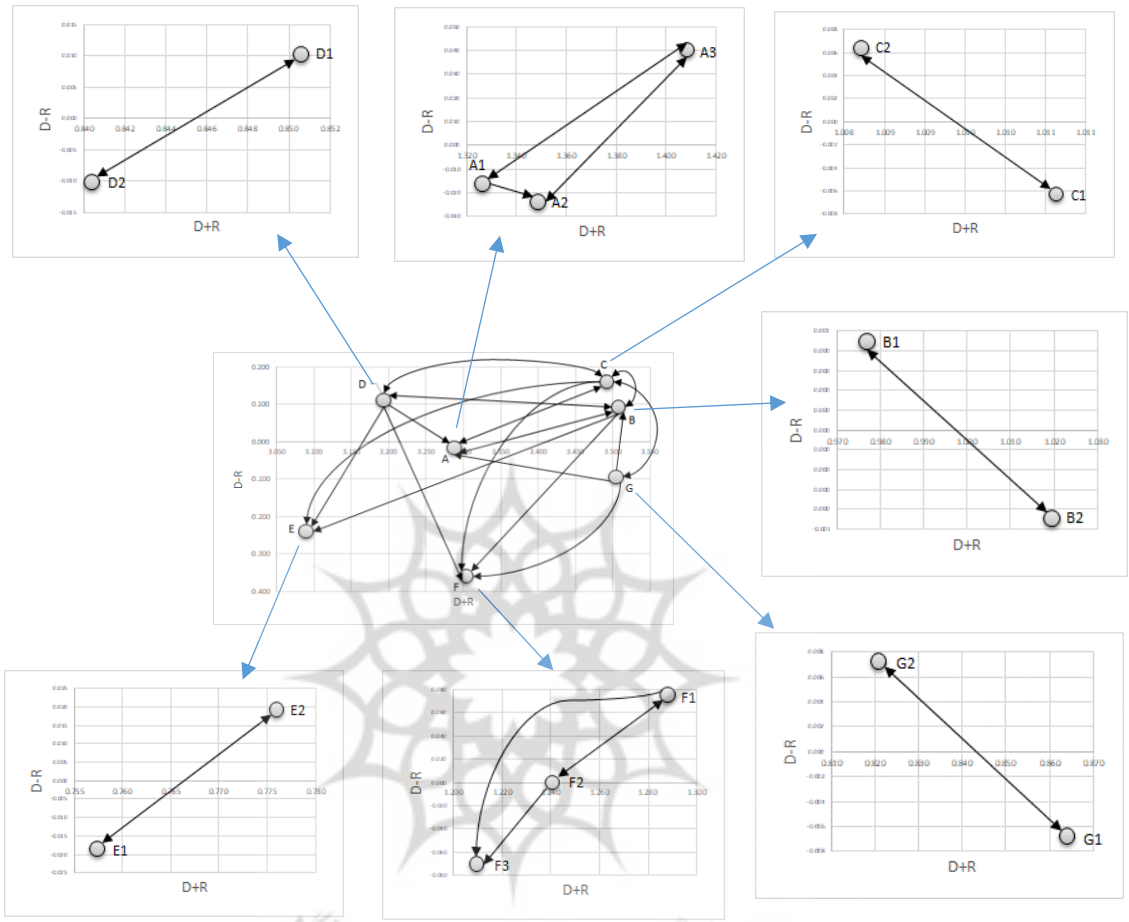

Figure 2

The NRM of the criteria

Table 10

The ultimate weight of the criteria

Criterion	Code	Weight	Ranking
Technical and managerial	A	0.14293	
Human resources	A1	0.04758	15
Knowledge management	A2	0.04720	16
Planning and organization	A3	0.04815	14
Informational and knowledge	B	0.15477	
Inventions and explorations	B1	0.07495	4
Innovation and creativity	B2	0.07982	1

Criterion	Code	Weight	Ranking
Economic	C	0.1502	
Knowledge-based products export	C1	0.07495	3
Money-making, productivity, and commercialization	C2	0.07521	2
Infrastructural issues	D	0.13515	
Communicational and environmental infrastructures	D1	0.06631	9
Structures and institutions	D2	0.06884	7
Legal	E	0.14103	
Rules, regulations, and standards	E1	0.06798	8
Intellectual property	E2	0.07305	5
Supportive	F	0.14762	
International transfer and participation	F1	0.04887	12
Private institutions	F2	0.05001	11
National support	F3	0.04874	13
Supply capability	G	0.1283	
Product qualitative characteristics	G1	0.06922	6
Product quantitative characteristics	G2	0.05908	10

4. Discussion and conclusions

Iran's current political and economic conditions have provided opportunities and threats for the chemical industry of this country. However, regarding basic chemicals and other issues, the young and newly-established nature of most knowledge-based enterprises, including not recognizing suitable markets and how to enter them, prevents most knowledge-based enterprises from marketing and selling their products successfully on their own. The first step to develop the markets of the products of knowledge-based enterprises in basic chemicals is understanding the effective factors in their marketing. However, the investigations show that the country has not paid enough attention to this important issue. Accordingly, this research sought to represent some approaches and fill this gap by identifying and prioritizing the main effective factors in the marketing of knowledge-based products in basic chemicals. According to the previous studies, the fuzzy DNAP method was employed to prioritize effective factors in the marketing of knowledge-based products in this industry. Some innovations of the study include designing strategic approaches and plans, as well as the arrangement of the patterns related to this subject.

To answer the main research question of this study concerning the effective marketing factors of knowledge-based products in basic chemicals, experts' opinions and a statistical population were asked. While investigating the related literature on the subject and summing up the related studies, we identified 16 sub-criteria under 7 criteria selected as influential factors in this field. Considering the final results of the study, technical and managerial; information and knowledge; economic and infrastructural issues; and legal, supportive, and supply capability criteria contributed significantly to the marketing of knowledge-based products in this industry. These results are consistent with the results of the studies conducted by Ghasemi, Faghihi, and Alizadeh (2018), Yahyaei and Hassanzadeh (2016), and Amini et al. (2016).

The fuzzy DNAP method was employed in the second part to prioritize factors effective in the marketing of knowledge-based products in basic chemicals and remove uncertainties in decision-making considering the high number of research factors and their interdependence. The research findings in the second part show that information and knowledge, economic, and supportive criteria, and the sub-criteria of innovation and creativity, money-making, productivity and commercialization, and knowledge-based products export achieve the highest score.

To achieve the goals and purposes determined and defined for the organization, managers have to primarily try to identify the human resources, needs, ideals, abilities, and capabilities of their employees well and constructively interact with them to show respect for their presence and activity in the organization. On the other hand, they have to provide a background to develop knowledge management in the organization and implement knowledge management by determining suitable mechanisms to internalize the culture of knowledge management in all parts beneficiary of development.

Managers have to try to provide necessary conditions for growth and development by allocating budgets suitable for goals, determining operational plans to avoid the space of laziness and lack of motivation, and preparing effective motivational plans for beneficiaries.

On the other hand, organizations have to provide a background for individuals to show their innovation and creativity by making trust to represent ideas and products with innovation and creativity, develop creative marketing strategies for new products, and enhance and expand risk-taking abilities in them, which may need suitable backgrounds to monitor, purify, and bring up ideas and turn ideas into products.

Moreover, it is worth mentioning that organizations have to create and develop commercialization centers as an interface ring in the research cycle to increase money-making and productivity in this field. They should also pay special attention to commercializing and increasing the products to mass production to export them to other countries and regions. Therefore, different factors contribute significantly to this field as follows: Serious governmental support and operational and active measures to commercialize knowledge-based products in the country; conceptual, structural, procedural, and operational definitions of productivity in knowledge-based enterprises; making markets representative of knowledge-based products; determining marketing methods for the products of knowledge-based enterprises; constructive interaction with successful countries to use their experiences in commercializing, identifying, and establishing virtual markets and marketing techniques; and finally identifying real markets to offer knowledge-based products. This may finally lead to the identification of elites and provide suitable backgrounds to connect these individuals with organizations investing in this field, resulting in the growth and development of knowledge-based enterprises and providing a suitable background for the revenue-generating of these organizations.

The different results of this study are consistent with the results of previous works. However, in some rare cases, these results differ from those of studies considering the condition of companies producing chemicals and different research methods. At last, it is suggested that training workshops and courses should be held to familiarize managers and experts related to three fields of government, industry, and institute to promote the culture and knowledge related to the marketing of knowledge-based products. Further, it is recommended that centers should be designed and established to measure and evaluate human resources based on the criteria and sub-criteria of marketing of knowledge-based products in the Vice-Presidency for Science and Technology to grant the required facilities and services.

Nomenclature

DNAP	Dematel analytic network process

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