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Prioritizing the Effective Factors on Knowledge Commercialization Using Fuzzy Analytic Hierarchy Process: A Case Study

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Abstract

Purpose: The purpose of the present study is to prioritize the effective factors on knowledge commercialization using fuzzy AHP at Isfahan University.

Methodology: This research is an applied type of research that is conducted with mixed data collection method. The research community included 790 managers, executives, researchers and faculty members of the Isfahan University, and using stratified sampling 260 individuals were selected. The data collection tool is a questionnaire.

Findings: Using fuzzy method, it was determined that among the triple factors, the contextual factors, and among the investigated sub-criteria, the commercialization culture sub-criteria, the knowledge base and research quality, and innovative infrastructure have the highest importance. In prioritizing the investigated indexes, the index of developing and promoting the commercialization culture and entrepreneurship, processing the results for different purposes, and focusing and considering the needs of market and customer are prioritized.

Discussion and Conclusion: Due to the direct relation of the contextual factors with economics and politics, they have the most impact on knowledge commercialization at Isfahan University. Likewise, the content factors due to their relation with knowledge quality and human skills are considered in the second priority. Among the indexes, the index of developing and promotion of the commercialization culture, processing of results for different purposes, and also focusing and considering the needs of the market and the customer had the highest importance. Therefore, culturalization, the use of research results in different dimensions, and moving toward meeting the needs of diverse customers can help the process of knowledge commercialization Isfahan University.

Keywords: Knowledge management, Knowledge Commercialization, Fuzzy AHP, Isfahan University, Iran.

Introduction

Economic evolutions and the reduction of public research funding have led to academic reforms in many countries to increase the commercialization of research results. In recent decades, universities played a more important role in the invention and innovation process. And along it, new perspectives on the role of the university in knowledge production system, the old mission of universities meaning education and research, have changed gradually, and have undertaken a "third mission" titling commercial activities, including inventions, licensing and company establishment(Baldini, 2006a). At present, the universities are expected not only to support and maintain the economic growth, but also to play a role in creation of economic growth through production of new knowledge, human capital, licensing innovation, and creating new companies.

Formation of expectations about the direct participation of universities in economic growth, allowing universities to grant patents, and establishing technology transfer offices are examples of reforming the process of knowledge commercialization.(Etzkowitz, Webster, Gebhardt, و Terra, 2000) have explained academic revolution as the acceptance of the commercialization function of knowledge as one of the main tasks of universities. In fact, the academic revolution led the universities to knowledge commercialization, opportunism, and the nature of entrepreneurship, and caused the emergence and growth of fourth-generation universities according to the knowledge-based economy.

Since higher education is one of the main infrastructures of the development of each country, paying attention to higher education is always one of the important concerns of decision-makers and planners in each society. Because paying attention to the commercialization of research results is one of the manifestations of accepting the importance and position of science and technology and its effect on the economic, social and cultural development of societies.

Nowadays, the intervention of universities into knowledge commercialization has become a necessity from being an advantage. This will be achieved when there is an effective relation and communication between the university and industry. Considering the infrastructures and common opinions in every society (universities and research centers), recognition of effective factors on the knowledge commercialization as well as prioritizing these factors requires conducting research with the priority of localization of commercialization patterns. Therefore, the present study tends to introduce the prioritization of the effective factors on the knowledge commercialization using the fuzzy hierarchy process by examining the opinions of experts in the knowledge commercialization field at Isfahan University.

Literature Review

Commercializing the academic knowledge includes the economic usage of intellectual properties (Rasmussen, Moen, و Gulbrandsen, 2006). For the first time, the academic knowledge commercialization entered the Economic Development Program of United States in the 1980s and then it was expanded into European countries in the 1990s.

The American model of knowledge commercialization is based on an entrepreneurial university model that contributes in technology transfer through a patent and establishing a new company (Etzkowitz, 2003). Bayh-Dole Act has been a turning point in creation of knowledge commercialization in the United States. After the approval of the Bayh-Dole Act, the US universities increased their efforts in technology transfer, issuing licenses, and investment in new companies. After twenty years, the number of universities that contributed to licensing for technology was eight times more, and the volume of registered inventions of universities increased four times(Mowery و Shane, 2002)

However, Bayh-Dole Act was not the only factor of increasing the commercialization of academic research(Kortum و Lerner, 1999; Mowery, Nelson, Sampat, و Ziedonis, 2001). The Increase in amount and complexity of scientific researches, the increase of the demand of society for scientific research; increased competition among scientists, and use of business activities including registering patents and new companies as criteria for ranking universities were effective in creating this conversion in academic culture(Kumar, 2010). As a result of Bayh-Dole Act and the above factors, helping to the economic growth has become the "third mission" of US universities, and includes commercial activities such as registering patents, licensing, and establishment of companies, along with education and research(Baldini, 2006b).

The knowledge commercialization in European countries is known as the "third mission" of universities(Van Geenhuizen, 2010) . This relatively new role began to emerge in Europe since the early 1980s. The first knowledge commercialization began in the United Kingdom in the early Lockett, 2002), and then was expanded to a region in Netherlands, andو1980s(Wright, Vohora, Europe countries, and recently is expanded to Southern European countries, then to other Northern including France and Italy. In the 1990s, the actions related to technology commercialization expanded in many European countries.

Effective Factors on Knowledge Commercialization

According to the investigated community, many factors can influence the knowledge commercialization. Some of the identified factors in previous researches include policy formulation (Heidari & Pourezzat, 2011), supplying operating institutes(Fakour, Hosseini, 2008; Hmieleski, Powell, 2018), providing financial resources (Fakour, Hosseini, 2008),(Heidari & Pourezzat, 2011),(Hmieleski, Powell, 2018) expansion of contribution between university, industry, and government(Mozaffari & Shamsi, 2011),(Hashemnia, Emadzadeh, Samadi, Saketi, 2009), (Heidari, Pourezzat, 2011), the number and rank of faculty members, supporting the dissertations of higher education students, Networking(Abbasi Esfanjani, Foruzandeh Dehkordi, 2015; Gholipour, Pourezzat, 2011; Kalantari, Poori, Yadollahi Farsi, 2015; Yadollahi Farsi, Zarea, Hejazi, 2012), human resource management (Abbasi Esfanjani و Foruzandeh Dehkordi, 2015; Zare و Mirjalili, 2014), the formation of commercial companies(Abbasi Esfanjani, Foruzandeh Dehkordi, 2015; Jalili, Mousakhani, Behboudi, 2011; Mozaffari و Shamsi, 2011; Wu, ٢٠١٠) creativity and innovation (Jahed و Arasteh, 2013), Creation and expansion of commercialization culture(Fakour, Hosseini, 2008; Hafezi, Ekrami, Ghorchiyan, Sarmadi, 2016; Hmieleski, Powell, 2018; Kalantari, MigoonPoori, Farsi, 2015).

The Analytic Hierarchy Process

The analytic hierarchy process is the decision-making process of choosing a strategy among the existing strategies or prioritizing the proposed strategies. One of the novel methods of decision-making is Multiple Criteria Decision Making (MCDM). One of the first methods of decision-making with multiple criteria is Analytical Hierarchy Process (AHP), which is used more than other methods in management science. The Analytical Hierarchy Process can be used in case of decision-making practice encountering multiple competing choices and decision criteria. The proposed criteria can be quantitative or qualitative. The base of this decision-making method is the pairwise comparison. The decision-maker begins by providing a hierarchical tree. The hierarch decision tree represents the evaluated compared factors and competing choices in the decision. Then a series of pairwise comparisons are performed. These comparisons indicate the weight of each of the factors in line with the evaluated competing choices in the decision. Ultimately, the logic of the analysis hierarchy process combines the matrixes derived from the pairwise comparison in a way to obtain the optimal decision.

In the ultimate stage, using the analysis hierarchy process, the main, sub-criteria, and final criteria that affect the knowledge commercialization will be prioritized.

Objectives and Research Questions

This article as part of an expanded research that identifies the effective factors on the knowledge commercialization at Isfahan University, has focused on prioritizing the identified and effective criteria on knowledge commercialization at Isfahan University.

The main question of the present study is that how is the prioritization of the effective factors on knowledge commercialization at Isfahan University? In this regard, the effective factors on knowledge commercialization at Isfahan University are already identified and in this study the criteria, sub-criteria and identified indexes are prioritized. It is obvious that prioritizing the mentioned factors will affect the decision making by authorities and researchers to promote the commercialization of research results of the university.

Methodology

Regarding that the results of this research will be applied in developing the applied knowledge in the field of commercialization of the academic research results and the presentation of a native model, in this regard, it is applicable. Likewise, regarding the approach aspect, this research applies mixed research method. The research community consists of 790 individuals including policy makers (managers), executives (staff of the entrepreneurship and industrial relationships department), researchers and faculty members of Isfahan University. Regarding the heterogeneity of the community in this section, 260 individuals were selected using stratified sampling. A questionnaire is the data collection tool is in this research. In order to calculate the reliability of the questionnaire the Cronbach alpha coefficient was used. Accordingly, the Cronbach alpha

coefficient for all aspects was calculated greater than 0.7 and for the total questionnaire was 0.895. Therefore, the reliability of the questionnaire was evaluated to be desirable.

Table1. Computing of Cronbach alpha coefficient.

	Commercialization steps	Contextual indexes	Structural indexes	Content indexes	Total questionnaire
Number of questions	9	10	9	10	38
Cronbach alpha coefficient	0.783	0.770	0.738	0.873	0.895

The Research Process

After identifying the effective indexes on knowledge commercialization through studying the previous resources, these indexes were introduced to Delphi panel members in three stages. The result of performing Delphi for three times was identification of 29 effective indexes (10 contextual indexes, 9 structural indexes, and 10 content indexes) (Table 2). Then, the identified indicators were classified in the form of sub-criteria related to the main criteria (contextual criteria include four sub-criteria of "innovative infrastructure", "political and legal environment", "technical, economic and market environment", and "Commercialization culture". The structural criteria include three sub-criteria of "financial and informational resources", "strategic links" and "hard abilities, processes, and capabilities". Content criteria include three sub-criteria of "knowledge base and research quality", "soft capabilities, human skills and marketing", and "internal management of the organization". After placing the identified indexes in the related sub-criteria, the criteria, sub-criteria, and identified indexes, were prioritized. AHP was used to prioritize the criteria.

Table2. Prioritizing the criteria of the sub-criteria and final indicators

Criteria	Sub-criteria	Symbol	Ultimate Criteria	Symbol
Structural	Financial and informational resources	S1	Providence of the required financial resources	SS01
			Access to the informational resources	SS02
	Strategic links, networking	S2	Creating strategic relations between university and industry	SS03
			Communication between the researchers, inventors and executives of the business plans	SS04
	Hard abilities, processes, and capabilities	S3	Strategic programming of the researches	SS05
			The alignment of policies and rules with commercialization purpose	SS06
			Establishment of a commercialization center/ institution	SS07
			Documenting and introducing successful experiences of commercialization	SS08
			Having lab, workshop and equipment	SS09
Content	Knowledge base and research quality	S4	Paying attention and focusing on the needs of the market and customer	SS10
			Management of research and commercialization projects	SS11
			Processing the results for different purposes	SS12
	Soft capabilities; human skills and marketing	S5	Enriching the universities with research base and position	SS13
			Ability to execute and operationalization of the research results	SS14

			Users' knowledge and belief of the research results	SS15
			incentive supporting system of commercialization	SS16
	Internal management of the organization	S6	Strengthening and promoting commercialization culture in universities	SS17
			Training courses of teachers and higher education students	SS18
			Training and attracting people with commercialization skills	SS19
	Innovative infrastructures in national information system	S7	Creation and expansion of communication circles between institutions and related organizations	SS20
			Infrastructures of communication	SS21
			Comprehensive information network of research results	SS22
	Political and legal environment	S8	Supportive policies	SS23
			Rules and regulations supporting the Commercialization	SS24
Contextual	Technical, economic and market environment	S9	Expanding the science and technology parks, development centers and national laboratories	SS25
			Market demand and demand for research results	SS26
			Capacity of receiving and transferring research results	SS27
			Risk taking capacity, venture capitalist	SS28
	Commercialization culture	S10	Expansion and promotion of commercialization and entrepreneurship culture	SS29

Prioritizing the criteria, sub-criteria and ultimate indexes affecting knowledge commercialization at Isfahan University.

The fuzzy analytic hierarchy process is used to determine the priority of criteria, sub-criteria and effective indexes on knowledge commercialization. The analytic process is as follows:

1. Pairwise comparison of main criteria according to the purpose and determining the weight of main criteria;
2. Pairwise comparison of the sub criteria of each criteria and determining the weight of the sub criteria of each cluster;
3. Determine the weight of the ultimate indexes of each sub-criteria;
4. Calculate the final weight of the criteria, sub-criteria and final ultimate indexes.
Nine-point scale is used for pairwise comparison of the elements. Likewise, the fuzzy approach is used to quantify the values in this study.

Table3. The Fuzzy Scale Equal to Nine-point Scale in an AHP Technique (Sarafrazi, Izadiyar & Habibi, 2014, p. 77)

Verbal phrase	Fuzzy equivalent	Reverse fuzzy equivalent
Preferred Equally	(1, 1, 1)	(1,1,1)
Midway	(1, 2, 3)	$\left(\frac{1}{3},\frac{1}{2},1\right)$
Preferred moderately	(2, 3, 4)	$\left(\frac{1}{4},\frac{1}{3},\frac{1}{2}\right)$
Midway	(3, 4, 5)	$\left(\frac{1}{5},\frac{1}{4},\frac{1}{3}\right)$

Preferred Strongly	(4, 5, 6)	$\left(\frac{1}{6},\frac{1}{5},\frac{1}{4}\right)$
Midway	(5, 6, 7)	$\left(\frac{1}{7},\frac{1}{6},\frac{1}{5}\right)$
very strongly Preferred	(6, 7, 8)	$\left(\frac{1}{8},\frac{1}{7},\frac{1}{6}\right)$
Midway	(7, 8, 9)	$\left(\frac{1}{9},\frac{1}{8},\frac{1}{7}\right)$
Extremely Preferred	(9, 9, 9)	$\left(\frac{1}{9},\frac{1}{9},\frac{1}{9}\right)$

Determining the priority of the main criteria according to the purpose

In order to perform the analytic hierarchy process, first the main criteria were pairwise compared according to the purpose.

Table 4. The Pairwise Comparison Matrix of the Main Criteria.

	C1	C2	C3	Fuzzy expansion	Normal
C1	(1, 1, 1)	(0.45, 0.59, 0.83)	(0.45, 0.55, 0.74)	(1.9, 2.14, 2.57)	(0.15, 0.21, 0.31)
C2	(1.2, 1.7, 2.23)	(1, 1, 1)	(0.4, 0.51, 0.76)	(2.6, 3.21, 3.99)	(0.21, 0.32, 0.49)
C3	(1.36, 1.83, 2.23)	(1.32, 1.94, 2.52)	(1, 1, 1)	(3.68, 4.77, 5.75)	(0.3, 0.47, 0.7)

The results of normalization of criteria are presented in Table 4.

Table5. Defuzzification of the Ultimate Weights of the Main Criteria

	Crisp	**X1max**	**X2max**	**X3max**	**Deffuzy**	**Deffuzy**
Structural	0.226	0.223	0.219	0.226	0.226
Content	0.339	0.334	0.328	0.339	0.339
Contextual	0.491	0.486	0.481	0.491	0.491

Accordingly, the priority Eigen vector of the main criteria will be as (W_1).

$$W_1 = \begin{bmatrix} 0.214 \\ 0.321 \\ 0.465 \end{bmatrix}$$

According to the obtained Eigen vector:

- The contextual factor with a normal weight of 0.465 has the highest priority.
- The content factor with a normal weight of 0.321 is in the middle.
- The last one is the structural factor with a normal weight of 0.214.

The inconsistency rate of the performed comparisons is 0.073, which is less than 0.1 and therefore the comparisons are reliable.

Determining the priority of the sub criteria of the investigated factors

In the second step of the fuzzy AHP the sub-criteria related to each of the main criteria are compared pairwise. The pairwise comparison of each cluster is investigated separately.

- Pairwise comparison of the structural sub-criteria

Structural sub-criteria include "financial and informational resources", "strategic links", "networking" and "hard capabilities, processes, technology, capabilities". Fuzzy value of the mean of the experts' opinion is presented in Table 6 to determine the priority of the structural sub-criteria.

Table 6. Determining the Priority of Structural Sub-criteria.

	S1	S2	S3	Fuzzy expansion	Normal
S1	(1, 1, 1)	(0.97, 1.23, 1.52)	(0.77, 1.04, 1.41)	(2.74, 3.27, 3.93)	(0.25, 0.36, 0.52)
S2	(0.66, 0.81, 1.04)	(1, 1, 1)	(0.65, 0.91, 1.19)	(2.3, 2.72, 3.22)	(0.21, 0.3, 0.42)
S3	(0.71, 0.96, 1.3)	(0.84, 1.1, 1.55)	(1, 1, 1)	(2.55, 3.06, 3.85)	(0.23, 0.34, 0.51)

The results of the Defuzzification of the structural sub-criteria are as follows:

Table7. Fuzzy Values of Structural Sub-criteria.

Crisp	X1max	X2max	X3max	Deffuzy	Normal
S1	0.376	0.372	0.369	0.376	0.359
S2	0.312	0.309	0.306	0.312	0.298
S3	0.359	0.354	0.349	0.359	0.343

According to the obtained normal weight:

- The S1 index with a weight of 0.359 has the highest priority.
- The S3 index with a weight of 0.343 is in the second priority.
- And the last one is the S2 index with a weight of 0.298.

The inconsistency rate of the comparisons is also 0.001 and is at the tolerance threshold of 0.1.

- A pairwise comparison of content subcategories

Content sub-criteria include: knowledge base and research quality, soft capabilities: human skills and marketing, internal management of the organization. Fuzzy values of the mean of experts' opinion are calculated to determine the priority of content sub-criteria.

Table8. Determining the Priority of Content Sub-criteria

	S4	S5	S6	Fuzzy expansion	Normal
S4	(1, 1, 1)	(2.19, 2.7, 3.19)	(1.27, 1.86, 2.55)	(4.46, 5.56, 6.74)	(0.34, 0.51, 0.75)
S5	(0.31, 0.37, 0.46)	(1, 1, 1)	(1.37, 1.95, 2.5)	(2.69, 3.32, 3.96)	(0.2, 0.3, 0.44)
S6	(0.39, 0.54, 0.79)	(0.4, 0.51, 0.73)	(1, 1, 1)	(1.79, 2.05, 2.52)	(0.14, 0.19, 0.28)

The Defuzzification results of the content sub-criteria are as follows:

Table9. Fuzzy Values of Content Sub-criteria.

Crisp	X1max	X2max	X3max	Deffuzy	Normal
S4	0.533	0.527	0.521	0.533	0.507
S5	0.317	0.314	0.310	0.317	0.301
S6	0.201	0.198	0.194	0.201	0.192

Based on the obtained normal weight:

- The S4 index with a weight of 0.507 has the highest priority.

- The S5 index with a weight of 0.301 has the second priority.
- And the last one is the S6 index with a weight of 0.192.
The inconsistency rate of the performed comparisons is also 0.078 and is at the tolerance threshold of 0.1.

- **Pairwise comparison of the contextual sub-criteria**

Contextual sub-criteria include "Innovative infrastructure in the national information system", "political and legal environment", "Technical, economic, and market environment", and "Commercialization Culture". Fuzzy values of the mean of experts' opinion is presented in Table 10 to determine the priority of sub-criteria. Since four indexes are used, therefore six pairwise comparisons are performed.

Table10. Determining the Priority of Contextual Sub-criteria.

	S7	S8	S9	S10	Fuzzy expansion	Normal
S7	(1, 1, 1)	(1.05, 1.41, 1.76)	(0.55, 0.72, 0.97)	(0.53, 0.72, 0.99)	(3.13, 3.86, 4.72)	(0.14, 0.22, 0.32)
S8	(0.57, 0.71, 0.95)	(1, 1, 1)	(0.73, 0.98, 1.29)	(0.44, 0.55, 0.72)	(2.74, 3.23, 3.97)	(0.12, 0.18, 0.27)
S9	(1.03, 1.39, 1.82)	(0.77, 1.02, 1.36)	(1, 1, 1)	(0.27, 0.35, 0.43)	(3.08, 3.76, 4.62)	(0.14, 0.21, 0.32)
S10	(1.01, 1.38, 1.89)	(1.38, 1.82, 2.28)	(2.31, 2.87, 3.67)	(1, 1, 1)	(5.7, 7.07, 8.84)	(0.26, 0.39, 0.6)

The Defuzzification results of the contextual sub-criteria are as follows:

Table11. Fuzzy values of contextual Sub-criteria.

Crisp	X1max	X2max	X3max	**Deffuzy**	**Normal**
S7	0.226	0.223	0.221	0.226	0.214
S8	0.192	0.189	0.186	0.192	0.181
S9	0.221	0.218	0.216	0.221	0.209
S10	0.419	0.412	0.406	0.419	0.396

According to the obtained normal weight:

- The S10 index with a weight of 0.396 has the first priority.
- The S7 index with a weight of 0.214 is in the second priority.
- The S9 index with a weight of 0.209 is in the third priority.
- And the last one is the S2 index with a weight of 0.181.
The inconsistency rate of the performed comparisons is 0.043 and is at the tolerance threshold of 0.1.

Determining the priority of the ultimate criteria

Since the present study is a four-level hierarchical research, therefore in the third step of the Fuzzy AHP, the ultimate indexes related to each of the sub-criteria is compared pairwise.

- **Pairwise comparison of the financial and informational indexes**

The financial and informational indexes include "providence of the required financial resources" and "access to the informational resources". Fuzzy values of the mean of the experts' opinion are

presented in Table 12 to determine the priority of the indexes of the financial and informational resources.

Table12. Prioritizing of the financial and informational indexes.

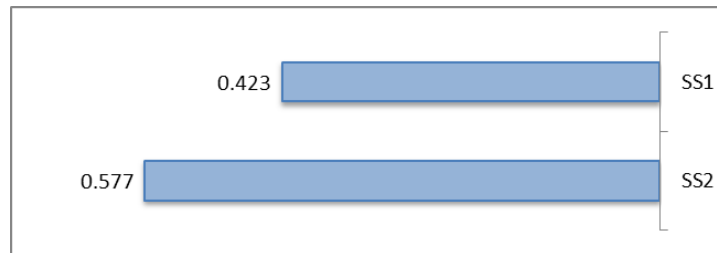|	SS1	SS2	Fuzzy expansion	Normal
SS1	(1, 1, 1)	(0.95,0.73, 0.580)	(1.95, 1.72, 1.58)	(0.54, 0.42, 0.34)
SS2	(1.71, 1.39, 1.05)	(1, 1, 1)	(2.71, 3.39, 2.05)	(0.74, 0.58, 0.44)

Fig1. Fuzzy values of the financial and informational indexes.

The SS2 index with a weight of 0.577 is the most important one. Since only one comparison is performed, so there is no need to calculate the inconsistency rate.

- **Pairwise comparison of strategic links**

Indexes of the strategic links include "creating strategic relations between university and industry", and "communication between the researchers, inventors and executives of the business plans". The fuzzy values of the mean of the experts' opinion is presented in Table 13 to determine the priority of strategic link indexes.

Table13. Prioritizing of the strategic links indexes.

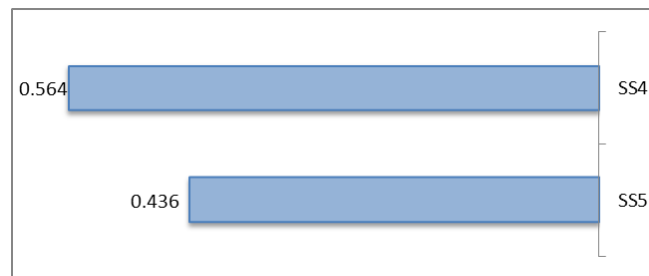|	SS1	SS2	Fuzzy expansion	Normal
SS1	(1,1,1)	(1.57, 1.32, 1.04)	(2.57, 2.32, 2.04)	(0.7, 0.57, 0.45)
SS2	(0.96, 0.76, 0.64)	(1,1,1)	(1.96, 1.76, 1.64)	(0.53, 0.43, 0.36)

Fig2. Fuzzy values of the strategic links indexes.

SS4 index with a weight of 0.564 is the most important. Since only one comparison is performed, so there is no need to calculate the inconsistency rate.

- **Pairwise comparison of the indexes of the hard abilities**

The indexes of hard capabilities include, "strategic programming of the researches", "the alignment of policies and rules with commercialization purpose", "establishment of a commercialization center/ institution", "documenting and introducing successful experiences of commercialization", "having lab, workshop and equipment". Fuzzy values of the mean of experts' opinions are calculated to determine the priority of the indexes of hard capabilities.

Table14. Prioritizing the of hard capabilities indexes.

|	SS5	SS6	SS7	SS8	SS9	Fuzzy expansion	Normal
SS5	(1, 1, 1)	(0.6, 0.74, 0.95)	(0.49, 0.59, 0.73)	(1.72, 2.13, 2.52)	(0.5, 0.62, 0.75)	(4.31, 5.08, 5.94)	(0.12, 0.17, 0.23)
SS6	(1.06, 1.35, 1.67)	(1, 1, 1)	(1.02, 1.23, 1.5)	(1.35, 1.63, 1.93)	(0.5, 0.58, 0.67)	(4.92, 5.78, 6.77)	(0.14, 0.2, 0.26)
SS7	(1.38, 1.69, 2.04)	(0.67, 0.81, 0.98)	(1, 1, 1)	(2.78, 3.29, 3.8)	(0.38, 0.48, 0.61)	(6.2, 7.27, 8.43)	(0.18, 0.25, 0.33)
SS8	(0.4, 0.47, 0.58)	(0.52, 0.62, 0.74)	(0.26, 0.3, 0.36)	(1, 1, 1)	(1.7, 2.03, 2.44)	(3.88, 4.42, 5.12)	(0.11, 0.15, 0.2)
SS9	(1.34, 1.62, 1.98)	(1.49, 1.74, 2.02)	(1.64, 2.08, 2.66)	(0.59, 0.49, 0.59)	(1, 1, 1)	(6.06, 6.93, 8.25)	(0.18, 0.24, 0.32)
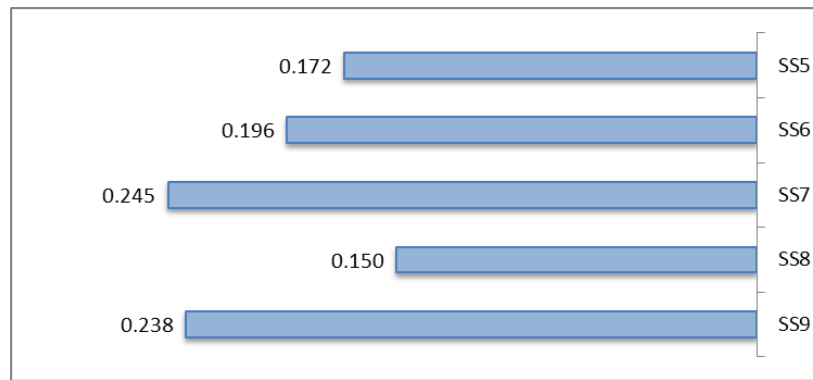
Fig3. Fuzzy values of the hard capabilities indexes.

Therefore the SS7 index with a weight of 0.245 is in the top priority. The SS9 index with a weight of 0.238 is in the second priority. The SS6 index with a weight of 0.196 is in the third priority and the SS8 index with a weight of 0.150 is the last one. The inconsistency rate is obtained 0.019 and is less than tolerance threshold of 0.1. So the results are reliable.

- **Pairwise comparison of the knowledge base indexes**

The knowledge base indexes are: "paying attention and focusing on the needs of the market and customer", "management of research and commercialization projects" and "processing the results for different purposes". The fuzzy values of the mean of experts' opinions is calculated to determine the priority of the base knowledge indexes.

Table15. Prioritizing of the base knowledge indexes.

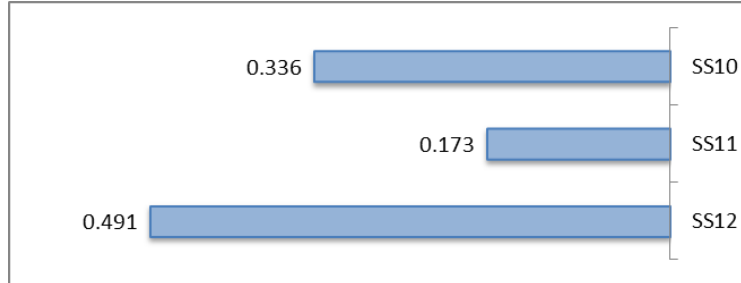|	SS6	SS7	SS8	Fuzzy expansion	Normal
SS10	(1, 1, 1)	(1.62, 2.21, 2.84)	(0.35, 0.46, 0.65)	(2.97, 3.67, 4.5)	(0.23, 0.33, 0.5)
SS11	(0.35, 0.45, 0.62)	(1, 1, 1)	(0.37, 0.45, 0.55)	(1.72, 1.9, 2.16)	(0.13, 0.17, 0.24)
SS12	(1.53, 2.17, 2.84)	(1.83, 2.22, 2.69)	(1, 1, 1)	(4.37, 5.4, 6.53)	(0.33, 0.49, 0.72)

Fig4. Fuzzy values of the base knowledge indexes.

Therefore, the SS12 index with a weight of 0.491 is in the first priority. The SS10 index with a weight of 0.336 is in the second priority and the SS11 index with a weight of 0.173 in in the last priority. The inconsistency rate is 0.064 and is less than tolerance threshold of 0.1, so the results are reliable.

- Pairwise comparison of the indexes of soft capabilities

The indexes of soft capabilities include: "enriching the universities with research base and position", "ability to execute and operationalization of the research results", "Users' knowledge and belief of the research results". Fuzzy values of the mean of experts' opinions is calculated to prioritize the indexes of soft capabilities.

Table16. Prioritizing of the soft capabilities indexes.

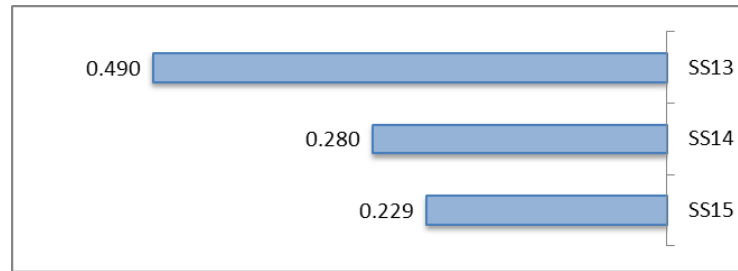|	SS6	SS7	SS8	Fuzzy expansion	Normal
SS13	(1, 1, 1)	(1.53, 1.95, 2.5)	(1.43, 1.95, 2.53)	(3.96, 4.9, 6.03)	(0.33, 0.49, 0.73)
SS14	(0.4, 0.51, 0.66)	(1, 1, 1)	(0.96, 1.32, 1.71)	(2.36, 2.83, 3.36)	(0.19, 0.28, 0.41)
SS15	(0.39, 0.51, 0.7)	(0.59, 0.76, 1.05)	(1, 1, 1)	(1.98, 2.27, 2.74)	(0.16, 0.23, 0.33)

Fig5. Fuzzy values of the soft capabilities indexes.

Therefore, the SS13 index with a weight of 0.490 is in the first priority. The SS14 index with a weight of 0.280 is in the second priority and the SS15 index with a weight of 0.229 is in the last priority. The inconsistency rate is obtained 0.008, so the results are reliable.

- **Pairwise comparison of internal management indexes**

Internal management indexes include: "incentive supporting system of commercialization", "Strengthening and promoting commercialization culture in universities", "Training courses of teachers and higher education students", "Training and attracting people with commercialization skills". The fuzzy values of the mean of the experts' opinions to prioritize the indexes of internal management are presented in Table 17.

Table17. Prioritizing of the internal management indexes.

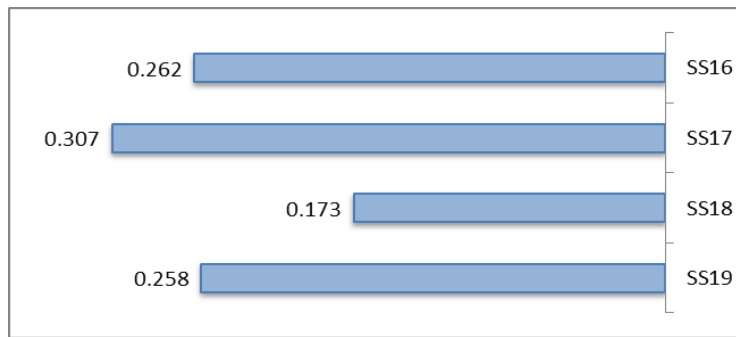|	SS16	SS17	SS18	SS19	Fuzzy expansion	Normal
SS16	(1, 1, 1)	(0.75, 0.94, 1.2)	(1.37, 1.9, 2.45)	(0.5, 0.69, 0.92)	(3.62, 4.53, 5.57)	(0.17, 0.26, 0.39)
SS17	(0.83, 1.06, 1.34)	(1, 1, 1)	(1.05, 1.3, 1.61)	(1.5, 1.99, 2.49)	(4.39, 5.35, 6.44)	(0.21, 0.31, 0.45)
SS18	(0.41, 0.53, 0.73)	(0.62, 0.77, 0.95)	(1, 1, 1)	(0.53, 0.69, 0.91)	(2.56, 2.99, 3.59)	(0.12, 0.17, 0.25)
SS19	(1.08, 1.45, 1.98)	(0.4, 0.5, 0.66)	(1.1, 1.44, 1.89)	(1, 1, 1)	(3.58, 4.4, 5.54)	(0.17, 0.25, 0.39)

Fig6. Fuzzy values of the internal management indexes.

Therefore, the SS17 index with a weight of 0.307 is the first priority. The SS16 index with a weight of 0.262 is in the second priority. The SS19 index with a weight of 0.258 is in the third priority and the SS18 index with a weight of 0.173 is the last one. The inconsistency rate is obtained 0.054 and is less than 0.1 tolerance threshold. So the results are reliable.

- **Pairwise comparison of the indexes of innovative infrastructures**

Performance indexes include: "creation and expansion of communication circles between institutions and related organizations", "infrastructures of communication", "comprehensive information network of research results". The fuzzy values of the mean of experts' opinions are calculated to determine the priority of performance indexes.

Table18. Prioritizing of the innovative infrastructure indexes.

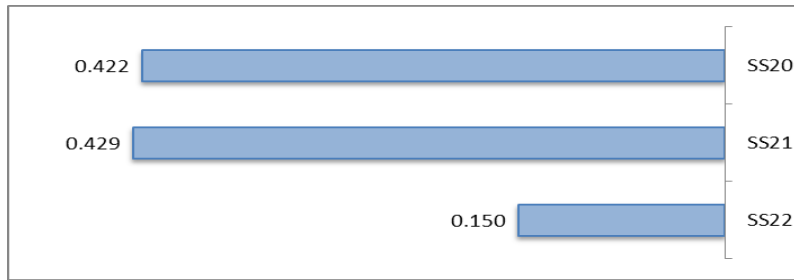|	SS20	SS21	SS22	Fuzzy expansion	Normal
SS20	(1, 1, 1)	(0.42, 0.52, 0.67)	(2.59, 3.45, 4.26)	(4.02, 4.97, 5.93)	(0.29, 0.42, 0.6)
SS21	(1.48, 1.93, 2.36)	(1, 1, 1)	(1.71, 2.11, 2.61)	(4.19, 5.03, 5.97)	(0.3, 0.43, 0.61)
SS22	(0.23, 0.29, 0.39)	(0.38, 0.47, 0.58)	(1, 1, 1)	(1.62, 1.76, 1.97)	(0.12, 0.15, 0.2)

Fig7. Fuzzy values of the innovative infrastructure indexes.

Therefore, the SS21 index with a weight of 0.429 is in the top priority. The SS20 index with a weight of 0.422 is in the second priority and the SS22 index is with a weight of 0.150 is the last one. The inconsistency rate is obtained 0.098, so the results are reliable.

- Pairwise comparison of the indexes of political and legal environment
Indexes of the political and legal environment include: "supportive policies", "rules and regulations of supporting the commercialization". The fuzzy values of the mean of experts' opinions are calculated to determine the priority of the indexes of political and legal environment.

Table19. Prioritizing the indexes of political and legal environment.

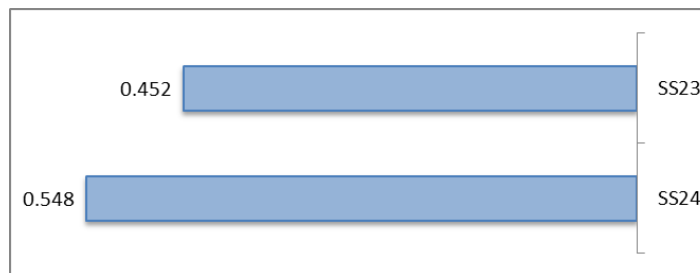|	SS23	SS24	Fuzzy expansion	Normal
SS23	(1, 1, 1)	(0.65, 0.82, 1.06)	(1.65, 1.82, 2.06)	(0.36, 0.45, 0.57)
SS24	(0.95, 1.22, 1.53)	(1, 1, 1)	(1.95, 2.22, 2.53)	(0.42, 0.55, 0.7)

Fig8. Fuzzy values of the innovative infrastructure indexes.

Therefore, the SS24 index with a weight of 0.548 has the highest importance. Since one pairwise comparison is performed, there is no need to calculate the compatibility.

- Pairwise comparison of the indexes of technical, economic and market environment
The indexes of the technical, economic, and market environment include: "expanding the science and technology parks, development centers and national laboratories", "market demand and demand for research results", "capacity of receiving and transferring research results", "risk taking capacity, and venture capitalist". The fuzzy values of the mean of the experts' opinions are calculated to prioritize the performance indexes.

Table20. Prioritizing the indexes of technical, economic and market environment.

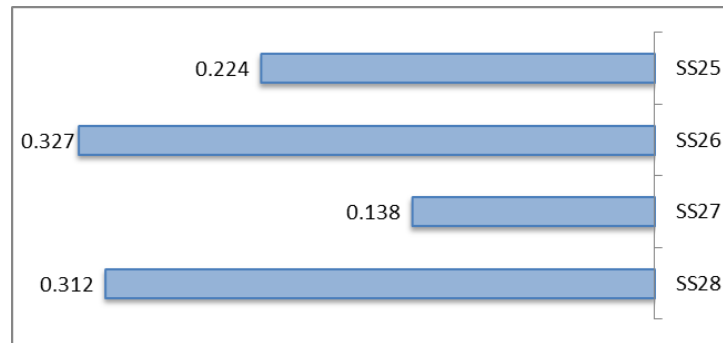|	SS25	SS26	SS27	SS28	Fuzzy expansion	Normal
SS25	(1, 1, 1)	(0.59, 0.75, 0.93)	(1.28, 1.73, 2.27)	(0.45, 0.59, 0.79)	(3.33, 4.07, 4.99)	(0.15, 0.22, 0.34)
SS26	(1.08, 1.34, 1.69)	(1, 1, 1)	(1.6, 1.99, 2.39)	(1.18, 1.69, 2.17)	(4.86, 6.02, 7.24)	(0.22, 0.33, 0.49)
SS27	(0.44, 0.58, 0.78)	(0.42, 0.5, 0.63)	(1, 1, 1)	(0.33, 0.42, 0.59)	(2.19, 2.5, 3)	(0.1, 0.14, 0.2)
SS28	(1.26, 1.69, 2.2)	(0.46, 0.59, 0.85)	(1.69, 2.4, 3.05)	(1, 1, 1)	(4.41, 5.68, 7.09)	(0.2, 0.31, 0.48)

Fig9. Fuzzy values of the technical, economic and market environment indexes.

Therefore, the SS26 index with a weight of 0.327 is in the top priority. The SS28 index with a weight of 0.312 is in the second priority. The SS25 index with a weight of 0.224 is in the third priority and the SS27 index with a weight of 0.138 is the last one. The inconsistency rate is 0.028, so the results are reliable.

The ultimate priority of the effective indexes on knowledge commercialization using fuzzy AHP technique

In order to determine the final priority of the factors using the fuzzy AHP technique, the weights related to the main criteria (W_1) and the weight of the indexes based on each criteria should be obtained (W_2). The comparison results of the sub-criteria of the research and their weights form the (W_2) matrix. In order to determine the ultimate priority of the indexes with AHP technique, it is enough to multiply the weight of the indexes based on each criterion (W_2) to the weight of the main criteria (W_1). Each of these matrixes are calculated in previous steps. The calculation results out and the weights related to the indexes are given in Table 21:

Table 21. Determining the ultimate priority of criteria, Sub-criteria, and indexes using Fuzzy AHP Technique.

| Criteria	W	Sub-criteria	W1	W2	Ultimate Criteria	W1	W2
Structural	0.214	Financial and informational resources	0.359	0.077	Providence of the required financial resources	0.423	0.0326
					Access to the informational resources	0.577	0/0444
		Strategic links, networking	0.298	0.064	Creating strategic relations between university and industry	0.564	0.0360
					Communication between the researchers, inventors and executives of the business plans	0.436	0.0278
		Hard abilities, processes, and capabilities	0.434	0.073	Strategic programming of the researches	0.172	0.0126
					The alignment of policies and rules with commercialization purpose	0.196	0.0144
					Establishment of a commercialization center/ institution	0.245	0.0180
					Documenting and introducing successful experiences of commercialization	0.154	0.0110
					Having lab, workshop and equipment	0.238	0.0175
Content	0.321	Knowledge base and research quality	0.507	0.163	Paying attention and focusing on the needs of the market and customer	0.336	0.0547
					Management of research and commercialization projects	0.173	0.0281
					Processing the results for different purposes	0.491	0.0799
		Soft capabilities; human skills and marketing	0.301	0.097	Enriching the universities with research base and position	0.490	0.0474
					Ability to execute and operationalization of the research results	0.280	0.0271
					Users' knowledge and belief of the research results	0.229	0.0221
		Internal management of the organization	0.192	0.061	incentive supporting system of commercialization	0.262	0.0161
					Strengthening and promoting commercialization culture in universities	0.307	0.0189
					Training courses of teachers and higher education students	0.173	0.0106
					Training and attracting people with commercialization skills	0.258	0.0158
Contextual	0.546	Innovative infrastructures in national information system	0.214	0.099	Creation and expansion of communication circles between institutions and related organizations	0.422	0.0419
					Infrastructures of communication	0.429	0.0426
					Comprehensive information network of research results	0.150	0.0149
		Political and legal environment	0.181	0.084	Supportive policies	0.452	0.0380
					Rules and regulations supporting the Commercialization	0.548	0.0462
		Technical, economic and market environment	0.209	0.097	Expanding the science and technology parks, development centers and national laboratories	0.224	0.0218
					Market demand and demand for research results	0.327	0.0318
					Capacity of receiving and transferring research results	0.138	0.0134
					Risk taking capacity, venture capitalist	0.423	0.0326
		Commercialization culture	0.396	0.184	Expansion and promotion of commercialization and entrepreneurship culture	0.577	0.0444
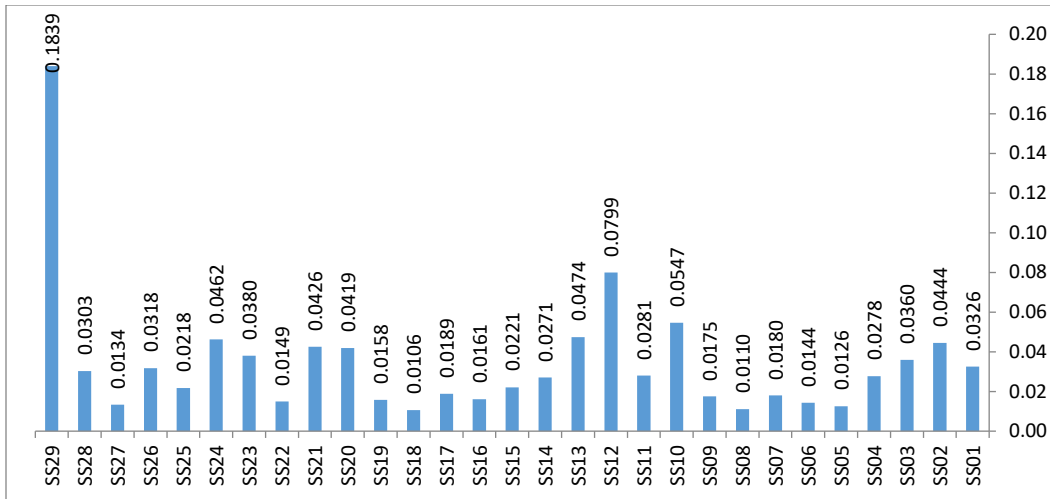
Figure 10. Output of the Fuzzy AHP Technic.

According to the data of Table 21 and Figure 10, based on the obtained weight by calculating with the fuzzy technique, the contextual criteria among the main criteria, and the sub criteria of commercialization culture, the knowledge base and the research quality among the sub-criteria, respectively, are in the first and second priorities. The prioritization of the indexes indicated that the expansion and promotion of the commercialization and entrepreneurial, processing the results for different purposes and the focusing and paying attention to the needs of market and customer are respectively in the first to third priorities.

Conclusion

In the first step, Defuzzification of the ultimate weights of the main criteria indicates that the contextual factors with a weight of 0.456 are the first priority, content factors with a weight of 0.339 are in the second priority, and structural factors with a weight of 0.226 are in the third priority of the effective factors on the commercialization of knowledge.

In the second step, using the fuzzy AHP technique, the sub-criteria related to each of the main factors were compared pairwise. The results of Defuzzification of structural sub-criteria indicates that the "financial and informational resources" sub- criteria with a weight of 0.359 is of prime importance. The "hard capabilities, processes, technology, and capacities" sub-criteria with a weight of 0.343 is in the second priority, and the sub-criteria of "strategic links, networking" with a weight of 0.298 is in the third priority. The results of Defuzzification of content sub-criteria show that the "knowledge base and research quality" sub-criteria with a weight of 0.507 is of the first priority. The "soft capabilities; human skills and marketing" sub-criteria with a weight of 0.301 is in the second priority and the "internal management of the organization" sub-criteria with a weight of 0.192 is in the third priority. The Defuzzification results of contextual sub-criteria indicate that the "commercialization culture" sub-criteria with a weight of 0.396 is the first priority. The "innovative infrastructure in the national information system" sub-criteria with a weight of 0.214 is in the second priority, the "technical, economic and market environment" sub-criteria with a

weight of 0.209 is in the third priority, and the "political and legal environment" sub-criteria with a weight of 0.181 is in the fourth priority.

In the third step, the pairwise comparison of the indexes in each sub-criteria determines the ultimate priority of the effective indexes on knowledge commercialization at the Isfahan University. Results indicate that:

Among the indexes related to the sub-criteria of financial and informational resources, the "providence of the required financial resources" with a weight of 0.577 is the most important one. The "access to the informational resources" index, with a weight of 0.423, is in the second priority. Among the indexes of the strategic links, the "establishing strategic relations between university and industry" index with a weight of 0.564 is in the first priority and the index of "interaction between researchers, inventors and managers of business plans" with a weight of 0.436 is in the second priority.

Among the five indexes related to hard capabilities sub-criteria, the "creating a commercialization center / institution" index with a weight of 0.245 is in the first priority, the "having laboratory" index is in the second priority, the "alignment of policies and rules with commercialization purpose" index is in the third priority, "strategic programming of the researches" index is the fourth priority and the "documentation and introduction of successful commercialization experiences" is in the fifth priority.

Pairwise comparison of the indexes of knowledge base indicate that the "processing the results for different purposes" index with a weight of 0.491 is in the first priority, the "focusing and paying attention to market and customer needs" index is in the second priority and the index of "management of the research and commercialization projects" is in the third priority of importance.

The fuzzy values of the experts' opinions to prioritize the soft capabilities index indicates that the "enriching the universities with research base and position" with a weight of 0.490 is in the first priority. The "ability to execute and operationalization of research results" and "users' knowledge and belief of the research results" are in the second and third priorities.

Among the four indexes of internal management, the index of "developing and promoting commercialization culture in universities" with a weight of 0.307 is in the first priority. Other indicators of the "incentive supporting system of commercialization", "training courses of teachers and higher education students", and "Training and attracting people with commercialization skills" are in the second to fourth priority.

Pairwise comparison of the sub-criteria of innovative infrastructures indicate that the index of "infrastructures of communication" with a weight of 0.429 is in the first priority, and the indexes of "creating and expansion of communication circles between institutions and related organizations" and "comprehensive information network of research results" are in the second and third priority.

The Defuzzification values related to the sub-criteria of the political and legal environment confirm that the index of "rules and regulations supporting the commercialization" with the weight of 0.548 is in the first priority and the index of "supportive policies" is in the second priority.

Among the four indexes of the "technical, economic and market environment" sub-criteria, the "market demand and demand for research results" index is in the first priority and other indexes of "risk taking capability, venture capitalist", "expanding the science and technology parks, development centers and national laboratories", and "capacity of receiving and transferring research results" are respectively, in the next priorities.

In the fourth step, the ultimate weight of the criteria, the sub-criteria and the ultimate indexes are calculated. The results of this part of the fuzzy AHP indicate that the index of "expansion and promotion of commercialization and entrepreneurship culture" is in the first priority of the effect of commercialization of knowledge. The result is that in order to commercialize knowledge at Isfahan University, the indexes of "expansion and promotion commercialization and entrepreneurship culture", "processing the results for different purposes" and "focusing and paying attention to the needs of the market and customer" should be the priorities for the authorities, respectively. The expansion of commercialization culture leads to carry out researches with the goal of producing capital and profitability and prevention of research without the purpose of capital production. Paying attention to the processing of research results for different purposes makes it possible to avoid single-dimensionality and single-product production. Because single-dimensionality in some cases may lead to failure and waste of costs. The next priority is paying attention to the needs of the market and customer. Paying attention to the need of the market prevents the researches and production of products that do not have any customer, and directs the cost and human resources to conduct researches that is required by the customer.

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