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Interpretive Structural Modeling of Barriers to Knowledge Commercialization¹

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Abstract

Purpose: The present research aimed to develop an interpretive structural model of the barriers to knowledge commercialization (KC) in Payame Noor University (PNU) of Iran.

Method: The present research is an applied research of mixed method types in terms of objectives and it is conducted based on confirmatory factor analysis. Fuzzy Delphi method was used for validation and variable screening, and barriers to KC were prioritized using fuzzy analytical hierarchy process (AHP). Moreover, fuzzy DEMATEL technique and interpretive structural modeling were used for the identification and development of a model for the relationship between variables. The research community was experts of KC at PNU and given the research approach, 30 people were selected among them based on purposive sampling.

Findings: Given the amount of effectiveness and affectability of the variables in the interpretive structural model, the variables such as weak legal framework for supporting idea people at the university, inefficiency and ineffectiveness of the rules and regulations for commercialization, lack of regulation for the apportionment of financial gain from commercialization among scholars, lack of skilled and expert human resources, lack of financial resources and facilities for commercialization of research results, and the weakness in the mutual recognition between university and industry, are the most affectable; they are in fact the dependent variables of the model. On the other hand, the variables such as inadequate knowledge of the faculty members, poor fund management in the university, weakness of universities in wealth creation, absence of university entrepreneurial missions, the absence of up-to-date and effective idea banks and databases in the university, and the lack of effective communication between students and industry sector's activists, are the most effective.

Discussion and Conclusion: The attention and reinforcement given to the independent variables in KC can improve the status of the dependent variables and eventually it results in successful KC.

Keywords: Knowledge Commercialization; Knowledge management; Commercialization of research results; Barriers to knowledge commercialization.

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1. Introduction and the Statement of the Problem

A potential source of income for universities and other research institutions is provided through the preparation of condition for raising capital from the knowledge produced in these centers. Given the mission of the universities as custodians of knowledge production and distribution in the society, they have made a lot of efforts to transfer and use knowledge in the economic, social and industrial sectors; this process is known as the commercialization of research results.

Commercialization of knowledge reduces the universities' dependence to public sector budget. On the other hand, the attention cast upon the commercialization of research results and innovations is the manifestation of recognizing the importance of science and technology and assuming their direct effect on economic, social, cultural, and political development. Adoption of this approach is promising in the elimination of barriers to knowledge-based economy formation. The advancement of academic sectors in commercialization of research results requires the provision of the necessary prerequisites in the academic and industry sectors and the dominant socioeconomic environment.

The trend of the business environment and the global economy over the last few decades suggests that the advancement and development of any society is due to the scientific researches and their application. The hidden economic potential in research findings will become practical when the findings effectively turn into innovation (Daynich & Wang, 2016). Thus, the growth rate of science over the past few decades and the world's rapid movement on the basis of knowledge, has drawn attentions to the science more than ever and the need for the conversion of knowledge into commercial products has become an essential issue; moreover, the development of science and technology is an inevitable requirement in achieving knowledge-based economy (Roknijo, Jafari, Yazdani, & Alvani, 2017).

The commercialization of knowledge in any society is influenced by the political, economic, cultural, and social structures of that society, and the relationship among the university, industry, and the government. Debacker and Veugelers (2005) considered the diverse inclination of universities towards the commercialization of knowledge and, consequently, various commercialization patterns in academic environments to be the result of various organizational structures in the universities (Debackere & Veugelers, 2005). Therefore, universities that intend to increase their efficiency, effectiveness and competitiveness in KC process are forced to reconsider the shape and size of their structures (Debackere & Veugelers, 2005). Pourezzat et al. (2010) also considered the presence of professional bureaucratic structures with traditional organizational boundaries to be the reason of reduced KC inclination in universities; they claimed that an appropriate solution for KC in universities is to change management and structural policies of the universities, to encourage the relationship between universities and the industry, to consider time requirement, and to change the management style. Therefore, in order to develop the commercialization of university research products, it is necessary to build and reinforce the appropriate culture of the trend at the university (Pourezzat, Gholipour, & Nadirkhanloo, 2010).

Today, there are many barriers, including political, legal, economic, structural and organizational aspects, communicative, environmental, lack of market understanding and inadequate skilled human resources, to the development and commercialization process in Iran (Biranvand, Seif, Safa, & Mazlounian, 2019) this issue necessitate us to conduct university research in order to reinforce and to establish a connection to industry and to maximize business opportunities. Acceptance of the responsibility for the KC by academics due to the increasing demand in society is necessary in order to attract other branches of science and examine different strategies so that they can promote the successful commercialization process, and improve the advancement and the rate of the process. To this end, we reviewed the previous research to identify

barriers to commercialization in PNU, to develop an interpretive structural model of these barriers in PNU, and to present appropriate strategic recommendation.

The design of KC mechanisms and its operationalization, in the first phase, requires the identification of effective factors on KC in the universities. To this end, using expert opinions in the present research, we aimed to identify the most important barriers to KC in PNU for the presentation of strategic recommendation, and for the introduction of effective factors on KC through the recognition of available grounds in this area. Therefore, in order to provide the main purpose of the research as "Identification of barriers to KC in PNU in order to present strategic recommendation in this area" tries to answer the following questions:

1. What are the barriers to KC in PNU?
2. How to prioritize barriers to KC in PNU?
3. What cause-and-effect relationships exist between the barriers to KC in PNU?
4. What strategic recommendation can be presented for KC in PNU?

2. Literature Review

Commercialization is a challenging problem in universities since business activities stand in contrast to the traditional role of the universities in the provision of education and research. However, it should be considered as a new goal in gaining economic benefits. The commercialization of knowledge in universities is influenced by the two categories of preventive and progressive impact. Among preventive forces, we can mention challenges and barriers to KC in universities. Many studies have identified the barriers to KC and minor issues related to this area. Factors such as lack of sufficient capital(Biranvand et al., 2019; Jung, Lee, & Lee, 2015), lake of policy(Costa Neto, Perin, & Ferreira, 2019; Heidari & Pourezzat, 2011; Hmieleski & Powell, 2018; Pourezzat et al., 2010), Lack of commercialization culture(Costa Neto et al., 2019; Biranvand & Seif, 2018; Hmieleski & Powell, 2018; Zahra, Kaul, & Bolivar, 2018; Irani, hayak, & Asetmal, 2018; Abbasi Esfanjani & Foruzandeh Dehkordi, 2015), Restrictive policies(Jahed, 2011; Pourezzat et al., 2010; Pourezzat & Heidari, 2011; Zahra et al., 2018), Lack of connection between university and industry(Costa Neto et al., 2019; Vick & Robertson, 2018; Biranvand, 2018; Rajalo & Vadi, 2017; Abasi, 2017; Pazhouhesh Jahromi, 2016; Pourezzat et al., 2010; Bruneel, D'Este, & Salter, 2010).

3. Methodology

The present research is an applied research in terms of objectives and it is conducted based on confirmatory factor analysis. Data were collected through the review of previous studies and Delphi method. Fuzzy Delphi method was used for validation and variable screening; and fuzzy AHP was used for prioritizing barriers to KC. Moreover, fuzzy DEMATEL technique, and interpretive structural modeling were used for the development of the model and the identification of the relationship between variables. The research questionnaire based on fuzzy DEMATEL technique aimed to identify the causal relationship pattern between the research variables. A pairwise comparison questionnaire was used to prioritize the factors.

Given the library study phase, the research community was all previous sources in the area of KC. We reviewed the sources until theoretical saturation so that we could ensure all components were extracted from previous sources. In the fuzzy Delphi phase, the research community was all experts of KC at PNU; they all had theoretical knowledge, practical experience, intention and ability to participate in the research. Despite quantitative surveys, members of the Delphi panel are not selected on the basis of probability sampling. Because Delphi is a mechanism for group decision making and requires qualified specialists who have deep knowledge of the subject.

Therefore, 30 people were selected based on purposive sampling with respect to the research approach; these people met at least one of the following criteria:

- Individuals who have commercialized their research finding or they had the intention to commercialize but failed to do so.
- Individuals who are familiar with the commercialization of university research, the process of obtaining a patent, and academic enterprises.
- Individuals who have accomplished at least one phase relevant to the process of research commercialization.

4. Research Findings

To evaluate the specified research objectives, using research findings, barriers to commercialization were first identified, and then, they were prioritized so that the driving and dependence power of each index could be measured through the interpretive structural equation modeling. Determining the driving and dependence power of the indices helps to partition them in the proposed model.

4.1. Identification of Barriers to KC

In the first step, we identified and screened barriers to KC in the universities. Based on literature review and specialized interviews, 28 indices were identified. In the next step, fuzzy Delphi method was used for identifying and screening the ultimate indices. Based on fuzzy 7 point scale (Table 1), the fuzzy mean and the defuzzified output values relevant to indices were calculated (Table 2). The defuzzified value above 0.7 is acceptable and any index scored less than 0.7 is eliminated.

Table1: Fuzzy 7 Point Scale for Rating the Indices

Definitive equivalent	Language variable	Fuzzy Number Scale
1	Absolutely trivial	(0, 0, 0.1)
2	Very trivial	(0, 0.1, 0.3)
3	Trivial	(0.1, 0.3, 0.5)
4	Average	(0.3, 0.5, 0.75)
5	Important	(0.5, 0.75, 0.9)
6	Very important	(0.75, 0.9, 1)
7	Absolutely important	(0.9, 1, 1)

- To Calculate the Fuzzy Mean of Expert Opinions

To find the sum of the respondents' opinions and to compute the fuzzy mean of their opinions, the following equation is used:

$$F_{AGR} = \left(\min\{l\}, \left\{ \frac{\sum m}{n} \right\}, \max\{u\} \right)$$

Each triangular fuzzy number, the sum of expert opinions for the jth index, is represented as follows:

$$\tau_j = (L_j, M_j, U_j)$$

$$L_j = \min(X_{ij})$$

$$M_j = \sqrt[n]{\prod_{i=1}^n X_{ij}}$$

$$U_j = \max(X_{ij})$$

The subscript i refers to the expert, thereby

- X_{ij} : The value of the ith expert's assessment for the jth criterion
- L_j : The minimum assessment value obtained for the jth criterion
- M_j : The geometric mean of the experts' assessment value for the jth criterion function
- U_j : Maximum assessment value obtained for the jth criterion

- **Defuzzification of Values**

Generally, the summation of triangular and trapezoidal fuzzy numbers can be summed up by a crisp value which is the best corresponding mean. The operation is called defuzzification. There are several defuzzification methods. In the present study, the center-of-area method is used for defuzzification, as follows:

$$DF_{ij} = \frac{[(u_{ij} - l_{ij}) + (m_{ij} - l_{ij})]}{3} + l_{ij}$$

The fuzzy mean and the defuzzified output of the values relevant to the indices, extracted from the review of the previous sources, are represented in Table 2.

Table 2: Results Obtained from Index Screening

Code	Indexes	L	M	U	Crisp	Results
S01	Weak legal framework for supporting idea people at the university	0.58	0.75	0.88	0.74	Accept
S02	Inefficiency and ineffectiveness of the rules and regulations for commercialization, researchers	0.59	0.77	0.89	0.75	Accept
S03	Lack of regulation for the apportionment of financial gain from commercialization among scholars	0.62	0.80	0.92	0.78	Accept
S04	Lack of intellectual property rights ownership rights derived from joint research with industry	0.57	0.74	0.88	0.73	Accept
S05	Lack of effective policies to improve the quality of academic research	0.67	0.83	0.93	0.81	Accept
S06	Law intention towards commercialization	0.68	0.85	0.95	0.83	Accept
S07	Lack of skilled and expert human resources	0.60	0.78	0.90	0.76	Accept
S08	Weakness of the university with high motivation for human capital	0.61	0.80	0.92	0.78	Accept
S09	Inadequate knowledge of the faculty members	0.60	0.78	0.91	0.77	Accept
S10	The inadequacy of the scholar's share in the commercialization revenues	0.61	0.79	0.91	0.77	Accept
S11	Poor fund management in the university	0.66	0.82	0.92	0.80	Accept
S12	Weakness of universities in wealth creation	0.59	0.77	0.90	0.75	Accept
S13	Lack of financial resources and facilities for commercialization of research results	0.62	0.80	0.92	0.78	Accept
S14	Lack of university sponsorship from researchers to exploit production know-how	0.72	0.87	0.95	0.85	Accept
S15	Lack of organized organization for the commercialization of academic research	0.65	0.81	0.92	0.79	Accept
S16	Lack of bureaucratic flexibility	0.60	0.78	0.91	0.76	Accept
S17	Absence of university entrepreneurial missions	0.59	0.75	0.87	0.74	Accept
S18	Lack of a research leading university document	0.67	0.83	0.93	0.81	Accept
S19	Lack of effective policies to improve the quality of academic research	0.62	0.79	0.91	0.77	Accept
S20	The absence of up-to-date and effective idea banks and databases in the university	0.62	0.80	0.92	0.78	Accept
S21	Weakness in mutual recognition of university and industry	0.63	0.81	0.92	0.78	Accept
S22	Weakness in the mutual recognition between university and industry	0.64	0.81	0.93	0.79	Accept
S23	Lack of communication and networks between investors, industry activists and academics	0.65	0.83	0.94	0.81	Accept
S24	Weakness of university consulting services to the community	0.61	0.79	0.91	0.77	Accept
S25	Weak research culture	0.59	0.77	0.90	0.75	Accept
S26	Existence cultural differences between university and industry	0.55	0.75	0.89	0.73	Accept
S27	Weakness of entrepreneurship culture	0.65	0.80	0.90	0.78	Accept
S28	Uncompromising collective sensitivity to the commercialization of knowledge generated at universities	0.57	0.75	0.88	0.73	Accept

Accordingly, 28 indices have been approved and studied as barriers to KC in PNU.

4.2. Prioritization of the Indices of KC

The fuzzy AHP has been used to prioritize the identified indices. Thus, 28 indices were identified and classified into 6 main criteria (Table 4). The main criteria are: legal barriers, human resource barriers, economic barriers, structural and policy barriers, communication and information barriers, and cultural barriers. Some sub-criteria (indices) are defined for each main criterion based on the main criteria mentioned in the literature and in the specialized interviews. The criteria and barriers (indices) of the research are named with a numerical index to be easily detected and studied during the research.

The analysis was carried out in 3 steps, as follows:

- Prioritizing the main barriers based on the objective through a pairwise comparison;
- Prioritizing the sub-criteria in the relevant cluster through a pairwise comparison;
- Calculating the ultimate weight of indices.

Saaty's 9 point scale was used for pairwise comparison of the components. In the present study, a fuzzy method was used to quantify the values; therefore, Saaty's fuzzy scale was used (Table 3).

Table 3: Triangular Fuzzy Pairwise Comparison

Definition	Fuzzy equivalent	Revers fuzzy equivalent
Equally Preferred	(1, 1, 1)	(1,1,1)
Moderate Preferred	(1, 2, 3)	$(\frac{1}{3}, \frac{1}{2}, 1)$
Moderately Preferred	(2, 3, 4)	$(\frac{1}{4}, \frac{1}{3}, \frac{1}{2})$
Moderate Preferred	(3, 4, 5)	$(\frac{1}{5}, \frac{1}{4}, \frac{1}{3})$
Strongly Preferred	(4, 5, 6)	$(\frac{1}{6}, \frac{1}{5}, \frac{1}{4})$
Moderate Preferred	(5, 6, 7)	$(\frac{1}{7}, \frac{1}{6}, \frac{1}{5})$
Very strongly Preferred	(6, 7, 8)	$(\frac{1}{8}, \frac{1}{7}, \frac{1}{6})$
Moderate Preferred	(7, 8, 9)	$(\frac{1}{9}, \frac{1}{8}, \frac{1}{7})$
Extremely Preferred	(9, 9, 9)	$(\frac{1}{9}, \frac{1}{9}, \frac{1}{9})$

The geometric mean method is used to find the sum of expert opinions in the fuzzy AHP.

$$F_{AGR} = \left(\prod (l), \prod (m), \prod (u) \right)$$

After forming the matrix of pairwise comparisons, the eigenvector was calculated. First, the fuzzy expansion of each row is computed. Each element of pairwise comparison matrix \tilde{X} is represented as \tilde{x}_{ij} . The fuzzy extension of each row is represented by \tilde{S}_i symbol. Therefore, the fuzzy expansion of each row will be calculated as follows:

$$\tilde{S}_i = \sum_{j=1}^n x_{ij}$$

Then the fuzzy summation is computed as the sum of elements in the column of preferences:

$$\sum \tilde{S}_i = \sum_{i=1}^n \sum_{j=1}^n x_{ij}$$

To normalize the preferences of each criterion, the total values of that criterion must be divided by the sum of all preferences (column elements). Since the values are fuzzy, the fuzzy summation

of each row is multiplied by the inverse of summation. The inverse of summation must be calculated.

$$\text{if } \tilde{F} = (l, m, u) \text{ then } \tilde{F}^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l} \right)$$

Table 4: Indices of KC in PNU Represented in the Ultimate Order of Priority

Main criteria	W	Indexes	W1	W2	PE	
Legal barriers	0.231	S01	Weak legal framework for supporting idea people at the university	0.293	0.0676	1
		S02	Inefficiency and ineffectiveness of the rules and regulations for commercialization, researchers	0.271	0.0626	2
		S03	Lack of regulation for the apportionment of financial gain from commercialization among scholars	0.216	0.0500	6
		S04	Lack of intellectual property rights ownership rights derived from joint research with industry	0.114	0.0265	19
		S05	Lack of effective policies to improve the quality of academic research	0.106	0.0244	21
Human resource barriers	0.184	S06	Law intention towards commercialization	0.310	0.0568	3
		S07	Lack of skilled and expert human resources	0.245	0.0450	9
		S08	Weakness of the university with high motivation for human capital	0.258	0.0474	8
		S09	Inadequate knowledge of the faculty members	0.187	0.0343	15
Economic barriers	0.231	S10	The inadequacy of the scholar's share in the commercialization revenues	0.264	0.0529	4
		S11	Poor fund management in the university	0.171	0.0344	14
		S12	Weakness of universities in wealth creation	0.241	0.0483	7
		S13	Lack of financial resources and facilities for commercialization of research results	0.181	0.0362	13
		S14	Lack of university sponsorship from researchers to exploit production know-how	0.144	0.0288	18
Structural and policy barriers	0.132	S15	Lack of organized organization for the commercialization of academic research	0.279	0.0368	11
		S16	Lack of bureaucratic flexibility	0.286	0.0377	10
		S17	Absence of university entrepreneurial missions	0.171	0.0225	22
		S18	Lack of a research leading university document	0.154	0.0203	25
		S19	Lack of effective policies to improve the quality of academic research	0.110	0.0145	28
Communication and information barriers	0.114	S20	The absence of up-to-date and effective idea banks and databases in the university	0.271	0.0308	16
		S21	Weakness in mutual recognition of university and industry	0.190	0.0216	23
		S22	Weakness in the mutual recognition between university and industry	0.228	0.0259	20
		S23	Lack of communication and networks between investors, industry activists and academics	0.176	0.0200	26
		S24	Weakness of university consulting services to the community	0.135	0.0153	27
Cultural barriers	0.139	S25	Weak research culture	0.369	0.0514	5
		S26	Existence cultural differences between university and industry	0.261	0.0363	12
		S27	Weakness of entrepreneurship culture	0.217	0.0301	17
		S28	Uncompromising collective sensitivity to the commercialization of knowledge generated at universities	0.153	0.0213	24

Table 8: The Driving and Dependence Power of the Research Variables

Code	Indexes	Driving Power	Dependence Power
S01	Weak legal framework for supporting idea people at the university	2	5
S02	Inefficiency and ineffectiveness of the rules and regulations for commercialization, researchers	2	4
S03	Lack of regulation for the apportionment of financial gain from commercialization among scholars	1	6
S04	Lack of intellectual property rights ownership rights derived from joint research with industry	9	11
S05	Lack of effective policies to improve the quality of academic research	5	11
S06	Law intention towards commercialization	2	9
S07	Lack of skilled and expert human resources	1	8
S08	Weakness of the university with high motivation for human capital	7	10
S09	Inadequate knowledge of the faculty members	20	6
S10	The inadequacy of the scholar's share in the commercialization revenues	5	7
S11	Poor fund management in the university	21	8
S12	Weakness of universities in wealth creation	13	4
S13	Lack of financial resources and facilities for commercialization of research results	3	8
S14	Lack of university sponsorship from researchers to exploit production know-how	12	8
S15	Lack of organized organization for the commercialization of academic research	2	7
S16	Lack of bureaucratic flexibility	9	6
S17	Absence of university entrepreneurial missions	16	6
S18	Lack of a research leading university document	4	11
S19	Lack of effective policies to improve the quality of academic research	6	7
S20	The absence of up-to-date and effective idea banks and databases in the university	21	5
S21	Weakness in mutual recognition of university and industry	1	8
S22	Weakness in the mutual recognition between university and industry	6	3
S23	Lack of communication and networks between investors, industry activists and academics	7	7
S24	Weakness of university consulting services to the community	7	7
S25	Weak research culture	3	8
S26	Existence cultural differences between university and industry	7	11
S27	Weakness of entrepreneurship culture	6	8
S28	Uncompromising collective sensitivity to the commercialization of knowledge generated at universities	6	5

6. Finding the Relationships and Level Partitioning the Dimensions and Indices

To find the relationships and to partition the criteria, the output and input sets should be extracted for each criteria of the access matrix.

- Reachability set (row elements, outputs, or those that affect): Reachability set of a variable is a set of Variables that can be reached through this variable.
- Antecedent set (column elements, inputs, or those that are affected): Antecedent set of a variable is a set of variables through which this variable can be reached.

To find the relationship and to partition the criteria, the output and input sets should be extracted for each criteria of the access matrix. For the variable C_i , the reachability set (output or those that

affect) includes variables that can be reached through the variable C_i . The antecedent set (input or those that are affected) includes variables through which the variable C_i can be reached.

Table 9: level partitioning based on Input and Output Sets

Level	Output or those that affect	Input or those that are affected
C01	S01,S02	S01,S02,S11,S15,S20
C02	S01,S02	S01,S02,S11,S17
C03	S03	S03,S09,S11,S12,S17,S20
C04	S04,S05,S06,S08,S18,S23,S24,S25,S26	S04,S09,S10,S11,S14,S16,S18,S20,S23,S24,S25
C05	S05,S08,S13,S15,S21	S04,S05,S08,S09,S12,S17,S20,S23,S24,S27,S28
C06	S06,S07	S04,S06,S09,S10,S11,S23,S24,S27,S28
C07	S07	S06,S07,S08,S09,S12,S17,S20,S26
C08	S05,S07,S08,S10,S13,S15,S21	S04,S05,S08,S10,S12,S20,S23,S24,S27,S28
C09	S03,S04,S05,S06,S07,S09,S10,S11,S12,S13,S14,S16,S17,S18,S19,S21,S23,S24,S26,S27	S09,S11,S12,S13,S17,S19
C10	S04,S06,S08,S10,S14	S08,S09,S10,S11,S14,S20,S22
C11	S01,S02,S03,S04,S06,S09,S10,S11,S12,S13,S14,S15,S16,S17,S18,S19,S20,S23,S24,S25,S27	S09,S11,S12,S13,S14,S16,S17,S20
C12	S03,S05,S07,S08,S09,S11,S12,S16,S17,S19,S21,S26,S28	S09,S11,S12,S17
C13	S09,S11,S13	S05,S08,S09,S11,S13,S17,S20,S26
C13	S04,S10,S11,S14,S15,S16,S19,S23,S24,S25,S27,S28	S09,S10,S11,S14,S16,S19,S20,S22
C14	S01,S15	S05,S08,S11,S14,S15,S20,S26
C15	S04,S11,S14,S16,S23,S24,S25,S27,S28	S09,S11,S12,S14,S16,S22
C16	S02,S03,S05,S07,S09,S11,S12,S13,S17,S18,S19,S20,S22,S23,S25,S27	S09,S11,S12,S17,S20,S22
C17	S04,S18,S21,S26	S04,S09,S11,S17,S18,S20,S23,S24,S26,S27,S28
C18	S09,S14,S19,S25,S27,S28	S09,S11,S12,S14,S17,S19,S20
C19	S01,S03,S04,S05,S07,S08,S10,S11,S13,S14,S15,S17,S18,S19,S20,S21,S22,S24,S25,S26,S27	S11,S17,S20,S22,S26
C20	S21	S05,S08,S09,S12,S18,S20,S21,S26
C21	S10,S14,S16,S17,S20,S22	S17,S20,S22
C22	S04,S05,S06,S08,S18,S23,S26	S04,S09,S11,S14,S16,S17,S23
C23	S04,S05,S06,S08,S18,S24,S26	S04,S09,S11,S14,S16,S20,S24
C24	S04,S25,S26	S04,S11,S14,S16,S17,S19,S20,S25
C25	S07,S13,S15,S18,S20,S21,S26	S04,S09,S12,S18,S20,S23,S24,S25,S26,S27,S28
C26	S05,S06,S08,S18,S26,S27	S09,S11,S14,S16,S17,S19,S20,S27
C27	S05,S06,S08,S18,S26,S28	S12,S14,S16,S19,S28
C28	S01,S02	S01,S02,S11,S15,S20

Having determined the reachability and antecedent sets, intersection of the two sets is calculated. The first variable which is obtained from the intersection of the two sets and is equal to the reachability set (outputs) will be in the first level. Therefore, the elements of level 1 will be the most affectable in the model. After determining the level, the criterion whose level has been identified is removed from the entire set and then we form the input and output sets again, and we obtain the subsequent variable level (Faraji and Azar, 2010). Consequently, the variables are partitioned into 6 levels:

- Level 1 variables: S01, S02, S03, S07, S13, S20
- Level 2 variables: S06, S15, S18

- Level 3 variables: S05, S08, S26
- Level 4 variables: S04, S23, S24, S25, S27, S28
- Level 5 variables: S10, S14, S16, S19
- Level 6 variables: S09, S11, S12, S14, S17, S21, S22

7. Conceptual Model Developed by Interpretive Structural Technique

The ultimate pattern of the identified variable levels is represented in Figure 1. In this graph, the significant relationships between the elements of each level and the elements of the level below and the significant internal relationships between the elements of each row are considered.

Considering the amount of effectiveness and affectability of each variable in relation to variables in the analysis, the level partitioning of the variables and graph of the relationships between them is shown in Figure 1. The variables of level 1 are the most affectable and have the least effect and the variables of Level 6 are the least affectable and have the most effect on the process of KC in PNU.

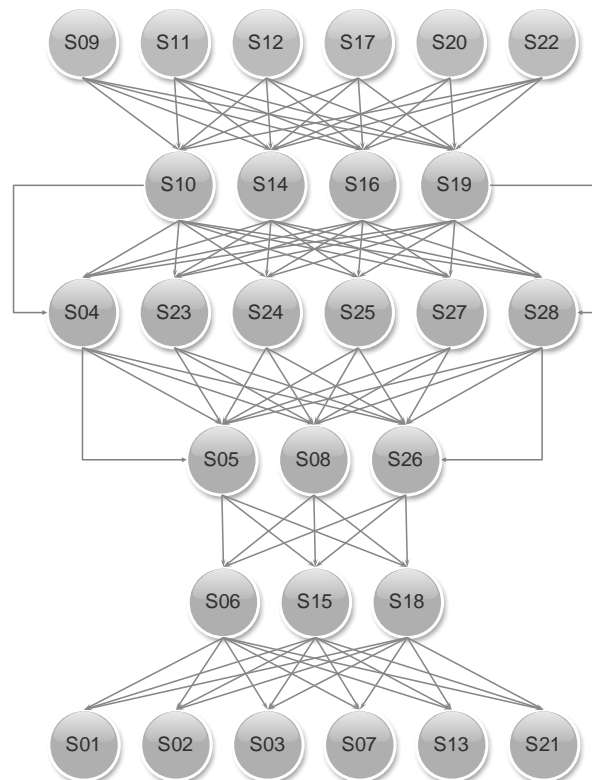


Figure 1: The Interpretive Structural Model

8. Discussion and Conclusion

The knowledge-based economic system would be beyond our reach if we have no knowledge-based industry and entrepreneurial universities. An established relationship between industry and higher education and its continuity based on their coexistence and mutual cooperation can make a knowledge-based economy via the mediating role of the government. The establishment of knowledge-based enterprises, science and technology parks, and entrepreneurship centers in the universities will be effective if the commercialized product or knowledge is in demand in Iran and international markets. The concept of KC is not just about a single brand registration and holding a production license for the product; it is the ability to raise capital from the knowledge produced by a research project.

The design of KC mechanisms and its operationalization, in the first phase, requires the identification of effective factors on KC in the universities. To this end, in the present research, having identified the barriers to KC through the study of previous sources, we classified them into 6 main criteria. The fuzzy AHP used to prioritize the 6 criteria and the main criteria were listed in their order of importance: legal barriers, economic barriers, human resource barriers, cultural barriers, structural and policy barriers, and communication and information barriers. Moreover, the research results by (Irani et al., 2018; Biranvand, 2018; Abasi, 2017; Pazhouhesh Jahromi, 2016) showed that among barriers to commercialization, the legal barrier is the first on the list of priorities. The ultimate weight of each index was calculated using fuzzy AHP; and the indices were listed in their order of importance, as follows, weak legal framework for supporting idea people at the university, inefficiency and ineffectiveness of the rules and regulations for commercialization, researchers' law intention towards commercialization, the inadequacy of the scholar's share in the commercialization revenues, weak research culture, lack of regulation for the apportionment of financial gain from commercialization among scholars, and weakness of universities in wealth creation. The results obtained from the prioritization of barriers identified in this research along with managerial decisions can help improve the status quo.

Given the interpretive structural model developed based on partitioning the indices in the present research, the variables including, weak legal framework for supporting idea people at the university, inefficiency and ineffectiveness of the rules and regulations for commercialization, lack of regulation for the apportionment of financial gain from commercialization among scholars, lack of skilled and expert human resources, lack of financial resources and facilities for commercialization of research results, and the weakness in the mutual recognition between university and industry, are the most affectable. In other words, these variables are dependent variables of the model. On the other hand, the fundamental and effective variables of the model are: inadequate knowledge of the faculty members, poor fund management in the university, weakness of universities in wealth creation, absence of university entrepreneurial missions, the absence of up-to-date and effective idea banks and databases in the university, and the lack of effective communication between students and industry sector's activists.

Paying attention to effective variables can help us improve the variables in the affectable levels of the proposed model and, as a result, improve the KC. Regarding the variable levels represented in the model (Figure 1), it is recommended that university administrators take measures for the elimination of barriers to KC based on effectiveness and affectability level of the variables in order to improve the KC at PNU.

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