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Intellectual capital management with Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Analytic Network Process (FANP) in Payame Noor University[1]

Zahra Rajaei,
Assistant Professor, Public Administration, Payame Noor University, Tehran, Iran
Corresponding Author Email: ZahraRajaei@pnu.ac.ir
Mohammad Hadi Moslehi,
Assistant Professor, mathematics, Payame Noor University, Tehran, Iran
Zahra Heidarnia
Faculty member, Public Administration, Payame Noor University, Tehran, Iran

ABSTRACT
Intellectual capital assessment for higher education system in the knowledge based economy era is an important and crucial issue for producing effective science and maximally applying capacities and capabilities of the universities and higher education institutes. Attaining this targetneeds standards and guidelines appropriate to the objectives and missions of the universities specially the Payame Noor University; therefore, in the current study, we pursue identification of an appropriate structure for intellectual capital in Payame Noor University. Statistical population in this paper includes the experts and faculty members of the South Khorasan Payame Noor University who have organizational positions and managerial work experiences. Two questionnaires were used in this study: Questionnaire I: Pairwise comparisons in Secundo model criteria regulated based on Saaty 9 scale and Questionnaire II: Dematel questionnaire to determine the relationship between the criteria and sub-criteria in Secundo model.This study has been done from March 2015 through March 2016; pairwise comparison ratio of inconsistency was between 0.002 and 0.009 and all were in threshold value 0.1.The results show that from the viewpoint of the experts, human capital with normal weight 0.515 gets the most priority, the organizational capital with normal weight 0.301 gets the average priority and the relational capital with normal weight 0.184 gets the last priority weight
Keywords: Intellectual Capital, Fuzzy Analytic Hierarchy Process (FAHP), Fuzzy Analytic Network Process (FANP)

Introduction

Today, the higher education system, especially Payame Noor University, faces many challenges, and to meet these challenges, the university must seriously manage the processes of creating its knowledge assets and the value of its intellectual capital and its role in society. To know. Prioritization and management of intellectual capital helps managers to better understand the internal and external issues of the organization, and knowledge assets as the main capacity of universitieswith a strategic and key role in need of prioritization and measurement (Secundo, 2010).The university is recognized as an institution in which intangible assets are vital and important, and the management of intellectual capital contributes to the success of the organization in the competitive arena (Arenas & Lavanderos, 2008). In addition, since the most important targetof universities today is the production and dissemination of knowledge, intellectual capital management can be used as a valid strategic management framework (Kong, E. and Prior, D, 2008). The issue of evaluating intellectual capital is influenced by various factors. The current paper aims at identifying the appropriate structure of intellectual capital in Payame Noor University of South Khorasan. Accordingly, it can be solved by multi-criteria decision making. The current paper first determines the appropriate criteria of intellectual capital, then the specified criteria are ranked using the fuzzy hierarchical analysis and fuzzy network analysis. This research seems necessary from two points of view:

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A) The absence of an appropriate intellectual capital management system in Iranian universities.
B) Simultaneous use of two network techniques and fuzzy hierarchy. This method has not been used in intellectual capital management research. The network analysis method was proposed by Taki Zawa and saaty in 1986. The generalized network analysis method is a hierarchical method. In many cases, hierarchical relationships do not necessarily prevail, and there are internal relationships between and within clusters. As a result, it shows more complex relationships between different levels of decision-making in a network and considers the interactions and feedback between criteria and alternatives (Meade, L.M., &Sarkis, 1999).
The current paper aims at answering the question of how to prioritize the basic criteria of intellectual capital (and its sub-criteria) in universities in Payame Noor University experts opinon?

Theoretical Foundations and Research Background

Intellectual capital is a set of collective knowledge, information, technology, skills, customer loyalty and management teams that can lead to value creation in products and services in the organization. In other words, intellectual capital is "information and knowledge used to create value" (Delgado, Miriam, 2011: 4). The elements of intellectual capital play an important role in the processes of innovation, learning and supporting the dissemination of knowledge (Kong et al., 2009).
knowledge, participation in research results, publications, graduate education, and stakeholder communication constitute the intellectual capital of universities. Intellectual capital is categorized into three categories: human capital, structural or organizational capital, and customer or communication capital (Khalique. et al., 2011: 343). Human capital represents the share of knowledge workers in the organization (Bontis, 2000). Human capital forms the basis of intellectual capital and without it, intellectual capital can not be implemented (Hung et al., 2006). Human capital refers to the competence of employees, skills, experience and their relationships. For example, an organization trains its employees is in fact developing its human capital (Wang, 2011: 5).
Structural or organizational capital refers to the structures and processes within an organization that employees use to apply their knowledge and skills (Bontis, 2000).
Relational capital is the knowledge available in marketing channels and relationships with stakeholders and customers. Customer capital represents the potential capability of an organization due to external intangible factors (Bontis, 1999).
Many universities today are looking for ways to exploit their intellectual assets that are more oriented towards income and funding rewards related to their work (Bezhani Ivoni, 2010), which can be mentioned as follows.
Borhani (2010), found that the amount of intellectual capital information disclosed by UK universities in annual reports is low and are intensely controlled and have less awareness of intellectual capital, using content analysis in testing the amount and nature of intellectual capital disclosure and determining its relationship with performance in the annual reports of 30 UK universities. Thus, it is necessary to take preliminary steps to better understand the characteristics and function of UK universities.
Mirkamali and Zohor (2010) examined the components of intellectual capital, namely human capital, structural capital and relational capital among managers and experts of Ferdowsi University of Mashhad to develop a model for measuring intellectual capital in Iranian universities, based on a theoretical study. They found that it is almost impossible to provide a single formula for calculating the economic value of intellectual capital, but this does not mean that designing a tool for measuring intellectual capital is insignificant, but designing a set of qualitative measurement indicators that can identify the current position of organizations is useful. The overall results indicate the importance of taking into account all components to grow and develop the current position of the university. In addition, the correlation shows that there are interrelationships between different components of intellectual capital, which in turn affects the management of the organization as well as the management of intellectual capital.
Nazaripour et al. (2010) found that intangible assets play a decisive role in the value creation process of an organization to provide a framework for identifying and classifying the main components of intellectual capital (ie human capital, structural capital and communication capital) at the university level. Arbab Shirani and Abbasi (2009) found that no university alone has been able to provide intellectual capital to attract multidimensional knowledge in the international dimension by analyzing the intellectual capital of universities to provide a clear picture of universities from the perspective of knowledge management. they also added thar ntellectual capital is one of the most effective concepts of strategic management in non-profit sectors, including universities.
Hosseinpour and Azar (2011) conducted a study entitled "Study of the relationship between intellectual and social capital with organizational performance from the perspective of managers and employees". The results showed that there is a positive and significant relationship between intellectual capital and organizational performance.
Secundo et al. (2010) examined the current theories and practical experiences and the basic conceptual model developed by combining the measurement indicators of intellectual capital in itely to provide a framework for measuring intangible assets in Italian higher education and research institutes and found that the development of intangible assets is at the heart of the mission of educational and research organizations. Therefore, identification and measurement of intellectual capital is an operational priority in assessing the alignment between strategic

orientation and performance within such institutions. Besides, the set of assumed comprehensive indicators can provide a useful context for refining them and establishing a link between indicators and issues of strategy and management. On the other hand, its practical application is that the set of indicators can be used as a communication tool and support for strategic decisions related to the structural, social and human capital of educational and research organizations.
Canibano et al. (2009) conducted a review research method in response to the question of whether the mechanisms used in the evaluation and management of intangibles in companies can be applied in universities and other research institutes; they found that some of the frameworks used in companies could also be used in universities. The current paper aims at analyzing and prioritizing the factors affecting intellectual capital in Payame Noor University. The current paper main criteria include: human capital (c1), organizational capital (c2) and relational capital (c3). Human capital itself includes attractiveness (s11) and efficiency (s12). Organizational capital also includes innovation and knowledge coding (s21) and infrastructure development (s22). Relational capital also includes international scope (s31), research and development networks (s32) and client respect (s33). indicators have been selected per sub-criteria, that according to Secundo model, each element includes sub-criteria based on the strategic goals of higher education institutions (Secundo et al., 2010, 145). Of course, in reference to the litreatur, the criteria of client respect and its sub-criteria have been added to the relational capital. Consequently, the subsets of each of the elements of organizational, human and relational capital have been identified and prioritized based on its compliance with the strategic goals of Payame Noor University. A total of 47 final indicators have been selected. The criteria, sub-criteria and final indicators of the research are listed in Table 11.

Research method

1. The study population and sample

The study population consists of experts and faculty members of Payame Noor University of South Khorasan who have executive positions with work and managerial experiences[1]. Having formed the operational headquarters and made the decision, the experts should be selected and the issue should be justified to them[2]. Here are some key characteristics for selecting experts: be involved with the issue at hand, have ongoing information about the issue to collaborate, be motivated to participate in the analysis process, and feel that the information gained from a group agreement will be valuable to them (Asgharpour, 2009). The experts in this study had these characteristics and cooperated with full insight. the expert selection was very limited with the number of 45 people, but the return rate was 34 questionnaires, and as a result, 34 people qualified as the sample. In fact, Saaty (1990) believes that ten experts are enough for studies based on pairwise comparisons. The pairwise comparison questionnaire is commonly referred to as the expert questionnaire because the respondents to the decision-making issues are experts, managers, and professors who are experts in the field in question. Therefore, qualified people are inherently limited. The time frame of the research was from March to 2015 to 2020. Using different tools in the analysis can also be effective in the accuracy of the analysis method. That is, while using the best method, it should be used with the most appropriate tools, because the choice of method and tools is of particular importance and the results of the analysis depend entirely on the methods and tools. (Ezzati, 2007: 74). To design the questionnaire 1, the Secundo model and the Saaty 9- scale pairwise comparison techniques have been used to prioritize the main criteria and sub-criteria relative importance.

Table 1- Fuzzy spectrum equivalent to a Saaty 9-scale; Khorshid and Zabihi, 2010: 41; Lee et al., **2008: 101**

Inverse fuzzy equivalent	Fuzzy equivalent	Verbal phrase Comparison status of i with j
(1,1,1)	(1, 1, 1)	Same preference
$\left(\frac{1}{3},\frac{1}{2},1\right)$	(1, 2, 3)	Somewhat preferred
$\left(\frac{1}{4},\frac{1}{3},\frac{1}{2}\right)$	(2, 3, 4)	A little preferred
$\left(\frac{1}{5},\frac{1}{4},\frac{1}{3}\right)$	(3, 4, 5)	

1 Including the director of Payame Noor University of South Khorasan, the deputy of Payame Noor University of South Khorasan, the director of the provincial groups of South Khorasan, the director of security and the head of the units and centers of South Khorasan, etc.
2 Because the researcher himself was in charge of distributing the questionnaire, although it was sent by the provincial research with automation, first the researcher explained the intellectual capital in Secundo model and its criteria to complete experts and the experts completed the questionnaires with full insight.

$\left(\frac{1}{6},\frac{1}{5},\frac{1}{4}\right)$	(4, 5, 6)	Somewhat preferred
$\left(\frac{1}{7},\frac{1}{6},\frac{1}{5}\right)$	(5, 6, 7)	Very preferred
$\left(\frac{1}{8},\frac{1}{7},\frac{1}{6}\right)$	(6, 7, 8)	Somewhat preferred
$\left(\frac{1}{9},\frac{1}{8},\frac{1}{7}\right)$	(7, 8, 9)	Very much preferred
$\left(\frac{1}{9},\frac{1}{9},\frac{1}{9}\right)$	(9, 9, 9)	Somewhat preferred

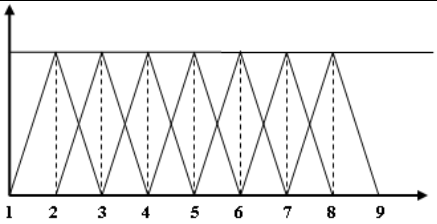

Figure 1- Evaluation of indices relative to each other using triangular fuzzy numbers

Demetel questionnaire was used as Questionnaire 2 to determine the relationships between criteria and sub-criteria of Secundo intellectual capital (Table 2).

Table 2 - Fuzzy spectrum equivalent to verbal expressions of Demethel technique (Habibi et al., 2014)

Fuzzy equivalent	Definitive equivalent	Linguistic variable
(0.0, 0.1, 0.3)	0	No effect
(0.1, 0.3, 0.5)	1	Low effect
(0.3, 0.5, 0.7)	2	Medium effect
(0.5, 0.7, 0.9)	3	High effect
(0.7, 0.9, 1.0)	4	Too much effect

2- Validity and reliability of the expert questionnaire

Validity shows that the measuring instrument measures what it is trying to measure. In the expert questionnaire, which is based on a pairwise comparison of all elements with each other, the probability that a variable is not considered is zero. Therefore, because all the criteria have been considered in this assessment and the designer is not able to provide a specific bias in the design of questions, so questionnaires based on pair comparison per se have validity (Ghodsipour, 2002: 66). To inconsistency index is used to examine the questionnaire. These indicators indicate that if the rate of inconsistency of pairwise comparisons is greater than 0.1, it is better to reconsider the comparisons. Given that the questionnaire considers and compares all the factors of the model, so all the probabilities related to not considering a variable will be eliminated. On the other hand, because the questionnaire compares and measures all the criteria in pairs, so the maximum possible questions are asked from the audience with the desired structure, and given that all the criteria have been considered in this measurement and the designer is not able to design specific questions, there will be no need to measure reliability. (Mehregan, 2004: 170) Consistency test: In the pairwise comparison technique, this test is performed based on the Consistency ratios (C.R) of the comparison matrix that includes the following process:

Weighted Sum Vector calculation: We multiply the matrix of pairwise comparisons on the column vector "relative weight". The new vector obtained is called the Weighted Sum Vector=WSV.

Consistency vector calculation: The elements of the weighted vector are divided by the relative priority vector, and the resulting vector is called the Consistency vector.

Obtaining λmax: Averaged Consistency vector elements values is λmax .

Consistency Index (CI) calculation: Consistency index is defined as follows:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

n is the number of options in the problem.

Instead of calculating λmax, the approximate method of geometric mean is often used.

$$L = \frac{1}{n}\left[\sum_{i=1}^{n}(AW_i / W_i)\right]$$

- The parameter L is the approximate value of λmax.
- AWi vector is equal to the product of the pairwise comparison matrix of the criteria multiplied by the eigen vector (preferences)
- The Wi vector is the same as the eigen vector or criterion priority vector. Therefore, after calculating the AWi, it is enough to divide each of the values of this vector by the corresponding value of the Wi vector and then add the obtained values. By dividing the resulting number by the number of criteria (n), the value of L is obtained.

-Random Index (RI)calculation: Random index (RI); Extracted from Alonso & lamata random index table. (Alonso & lamata, 2006: 449).

Consistency ratio calculation: Consistency ratio is obtained by dividing the Consistency index by a random index. Consistency ratio of 0.1 or less expresses consistency in comparisons (Mehregan, 2004: 173-170) CR = CI / RI which was less than 0.1 in all comparisons.

3-Information analysis method

The current paper uses fuzzy hierarchical analysis process (AHP) and the combined approach of (DEMATEL) and fuzzy network analysis process (ANP) technique to prioritize the indices.

1- A: **Hierarchical Analysis Process (AHP)**

2- In the first stage, it is assumed that there is no relationship between the elements. In this case, the hierarchical model of criteria, sub-criteria and final indices of the research will be as in Figure 2.

Figure 2- Hierarchical pattern of variables

3- The priority of elements using the Fuzzy Hierarchical Analysis Process (FAHP) technique is as follows:

1- The pairwise comparison of main criteria based on the purpose and determining the weight of the main criteria
2- The pairwise comparison of sub-criteria of each criterion and determining the weight of sub-criteria of each cluster
3- The pairwise comparison of the indicators of each sub-criterion and determining the weight of the final indices
4- Multiply the weight of the sub-criteria by the weight of the relevant criterion and determine the final weight of the sub-criteria and indices.

The first step is pairwise comparison of the main criteria based on the goal.

The pairwise comparison is very simple and all elements of each cluster should be compared in pairs. Therefore, if there are n elements in a cluster, a n(n-1)/2 comparison will be made. Therefore, in this step, three pairwise comparisons are performed from a group of experts' opinions. Experts' opinions have been quantified using the fuzzy scale. Experts opinion was collected using the Saaty 9- scale. The experts opinion was made fuzzy based on

Table 2. Therefore, ten pairwise comparisons for the main criteria have been done fuzzily based on the experts' opinion.

- Aggregation of experts' opinion: To aggregate the experts' opinion, it is better to use the geometric mean of each of the three triangular fuzzy numbers. (Equation 1)

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

The pairwise comparison matrix is based on the fuzzy geometric mean of the experts' opinion. This matrix, which is represented by the symbol $\tilde{X}$, is presented in Table 3 of the Appendix.

After forming the matrix of paired comparisons, the eigen vector $\tilde{X}$ is calculated. First, the fuzzy expansion of each row is calculated. Each pair of matrix comparisons is displayed as $\tilde{x}_{ij}\,\tilde{X}$. The fuzzy expansion of each row is also represented by a symbol $\tilde{S}_i$. Therefore, the fuzzy expansion of each row will be calculated as follows: $\tilde{S}_i = \sum_{j=1}^{n} x_{ij}$ (Equation 2)

Therefore, the fuzzy expansion of the elements of each row will be as follows:

Fuzzy expansion row 1 (1, 1, 1) $\oplus$ (1.69, 2.05, 2.4) $\oplus$ (1.99, 2.54, 3.04) = (4.68, 5.59, 6.44)

Fuzzy expansion row 2 (0.42, 0.49, 0.59) $\oplus$ (1, 1, 1) $\oplus$ (1.38, 1.74, 2.14) = (2.8, 3.22, 3.73)

Fuzzy expansion row 3 (0.33, 3.9, 0.5) $\oplus$ (0.47, 0.58, 0.72) $\oplus$ (1, 1, 1) = (1.8, 1.97, 2.23)

Therefore, the fuzzy expansion of the preferences of each of the main criteria will be as follows:

$\sum_{j=1}^{3} x_{1j}$ = (4.68, 5.59, 6.44)

$\sum_{j=1}^{3} x_{2j}$ = (2.8, 3.22, 3.73)

$\sum_{j=1}^{3} x_{3j}$ = (1.8, 1.97, 2.23)

Then the fuzzy sum of the elements of the column of preferences is calculated: (Equation 3)

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

The sum of the elements of the main criteria preferences column will be as follows:

$\sum_{i=1}^{3}\sum_{j=1}^{3} x_{ij} = (9.28, 10.78, 12.39)$

To normalize the preferences of each criterion, the sum of the values of that criterion must be divided by the sum of all the preferences (column elements). Because the values are fuzzy, the fuzzy sum of each row is multiplied by the inverse of the sum. The inverse sum must be calculated. (Equation 4).

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

So based on Equation 4 we have:

$\left(\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}\right)^{-1}$ = (0.08, 0.09, 0.11)

$S_k = \sum_{i=1}^{n} M * \left(\sum_{i=1}^{n}\sum_{j=1}^{n} M_g^j\right)^{-1}$

Therefore, the results of normalization of the obtained values will be as follows:

(0.38, 0.52, 0.69)= $\tilde{W}_{C1}$

(0.23, 0.3, 0.4)= $\tilde{W}_{C2}$

(0.14, 0.18, 0.24)= $\tilde{W}_{C3}$

Each of the obtained values are the fuzzy and normalized weight corresponds to the main criteria.

De- fuzzification [1]: In this study, the center of gravity method proposed by [1] Bojadziev, George; Bojadziev, Maria is used for de- fuzzification. (Table 4 de-fuzzification of final weight values of main criteria)

$$x^1_{\max} = \frac{l+m+u}{3};\ x^2_{\max} = \frac{l+2m+u}{4};\ x^3_{\max} = \frac{l+4m+u}{6}$$

$$\text{Crisp number} = Z^* = \max\{x^1_{\max}, x^2_{\max}, x^3_{\max}\}$$

It should be noted that the calculated weights are non-fuzzy but should be normalized (Table 5 Appendix). Accordingly, the eigen vector of preferences of the main criteria will be W_1.

1 There are several methods for de-fuzzification, such as the Chang Degree Method, the Surface Center Method, and the Minkowski Method.

$$W_1 = \begin{bmatrix} 0.515 \\ 0.301 \\ 0.184 \end{bmatrix}$$

Given the obtained eigen vector, human factors with a normal weight of 0.515 have the highest priority. Organizational capital with a normal weight of 0.301 is in the middle grade. The relational capital with a normal weight of 0.184 is in the third priority. The inconsistency rate of the comparisons made is 0.012 which can be trusted.

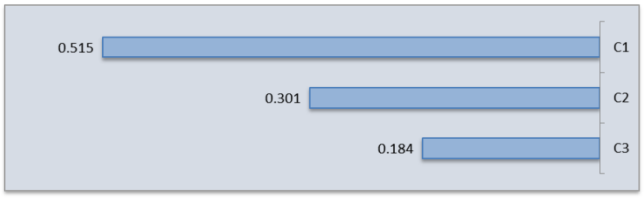

Figure 3- Graphic representation of the main criteria based on purpose

The second step is to prioritize the sub-criteria of the main research criteria

In the second step of the FAHP technique, the sub-criteria related to each of the main criteria are compared in pairs. The pairwise comparison of each cluster is examined separately. Given the lengthy calculations as in the first step, the results are summarized.

2-1 Pairwise comparison of sub-criteria of human capital

The sub-criteria of human capital are: attractiveness and efficiency. According to the obtained eigen vector, attractiveness with a weight of 0.596 is more important. Of course, only one comparison has been made and there is no need to calculate the inconsistency.

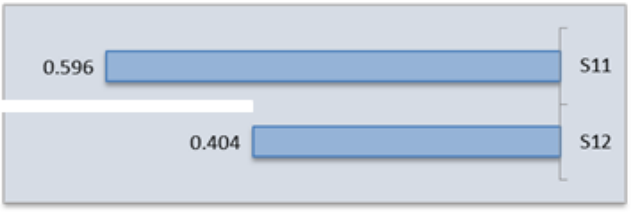

Figure 4- Graphic representation of human capital sub-criteria

2-2- Pairwise comparison of sub-criteria of organizational capital

The sub-criteria of organizational capital are: "Innovation and knowledge coding" and "Infrastructure development". Based on the obtained eigen vector, the development of infrastructure with a weight of 0.564 is more important. Of course, only one comparison has been made and there is no need to calculate the inconsistency.

Figure 5- Graphic representation of sub-criteria of organizational capital

2-3- Pairwise comparison of sub-criteria of relational capital

The sub-criteria of relational capital are: international domains, R&D networks and client respect. Based on the obtained eigen vector, research and development networks with a weight of 0.433 are more important than other indicators. The inconsistency rate of the comparisons is 0.002 and is at the tolerance threshold of 0.1.

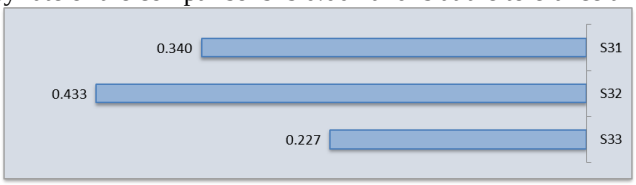

Figure 6- Ranking of sub-criteria of relational capital

Step 3: Prioritize the sub-criteria of the research sub-criteria

In the third step of the FAHP technique, the sub-criteria related to each category of sub-criteria are compared in pairs. Then the results of de- fuzzification and extraction of preferences eigen vector weight are done. It should be

noted that due to the long calculations[1], the final results are summarized in Figure 7. Also, the inconsistency rates of the comparisons were between 0.002 and 0.009, all of which are at the tolerance threshold of 0.1.

Step 4: Determine the final preferences with FAHP technique

To determine the final preferences of the main criteria using the FAHP technique, the weights related to the main criteria (W_1) and the weight of the indicators based on each criterion (W_2) should be available. The results of the comparison of the research sub-criteria and their related weights constitute the W_2 matrix. To determine the final preferences of the indicators with AHP technique, it is enough to multiply the weight of the indices based on each criterion (W_2) by the weight of the main criteria (W_1). Each of these matrices is calculated in the previous steps. The results of the calculation and the weights related to the indices and determining the final preferences of the elements with the FAHP technique are shown in Table 11 and Figure 7.

B- Determining the preferences of elements by The analytic network process (ANP)

The analytic network process (ANP) is a generalization of the Analytic Hierarchy Process or AHP. In many cases, hierarchical relationships do not necessarily prevail, and there are internal relationships between and within clusters. In this case, the simple hierarchical pattern transforms into a network of relationships. In Demetel technique, experts are able to express their views on the effects (direction and intensity of effects) between factors with more mastery. It should be noted that the matrix obtained from the Demetel technique (internal communication matrix) shows both the causal relationship between the factors and the effectiveness of the variables. Determining the preferences of elements with the Fuzzy Network Analysis Process (FANP) technique requires the following steps:

1- Parallel comparison of the main criteria based on the targetand determining the weight of the main criteria (W_{21})

2- Identifying the relationships between the main criteria with the Demetel technique (W_{22})

3- Pairwise comparison of sub-criteria of each criterion and determining the weight of sub-criteria of each cluster (W_{32})

4- Identifying the relationships between sub-criteria with Demetel technique (W_{33})

A- Pairwise comparison of the indices of each sub-criterion and determining the weight of the final indices (W_{43})

B- Pairwise comparison of the indices of each sub-criterion and determining the weight of the final indices

To achieve the ultimate preferences in a system with interactions, the internal preferences vectors (ie the calculated ws) must be inserted into the appropriate columns of a matrix. The result is a supermatrix (actually a partitioned matrix). (Zebardast, 2010: 81)[2]

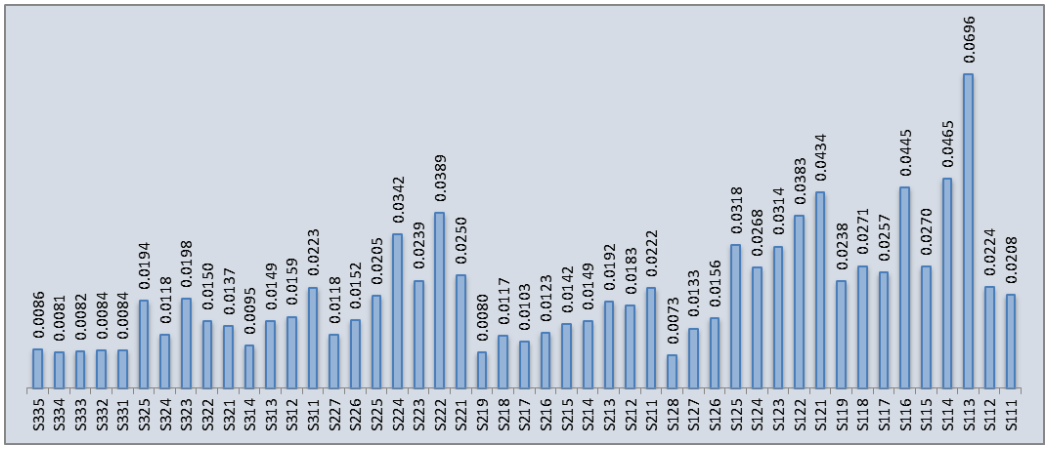

Figure 7- Final priority of the main criteria using the AHP technique

1 All long calculations related to the criteria and sub-criteria are detailed in the plan submitted to Payame Noor University.

2 Zebardast, Esfandiar. (2001). Application of Hierarchical Analysis Process in Urban and Regional Planning, University of Tehran Electronic Journals Database, Fine Arts, Fourteenth Year, Issue: 10.

Figure 8- Network model of research variables

According to the relationships identified in the present study, the initial supermatrix of this study is as follows

$$\begin{matrix} Goal \\ Critera \\ Sub\ criteria \\ Indices \end{matrix}\begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & 0 \\ 0 & W_{32} & W_{33} & 0 \\ 0 & 0 & W_{43} & I \end{bmatrix}$$

In this supermatrix, the W21 vector indicates the importance of each of the main criteria based on the target. The W22 vector represents a pairwise comparison of the relationships between the main criteria derived from the output of the Demitel technique. The W32 vector indicates the importance of each of the sub-criteria in its respective cluster. The W33 vector represents a pairwise comparison of the relationships between the sub-criteria. Zero values also indicate that the factors are ineffective at the intersection of rows and columns. The network pattern of the model is designed using the ANP technique in the superdesign software. Using the concept of normalization, the unbalanced supermatrix is transformed into a balanced supermatrix (normal). In a balanced supermatrix, the sum of the elements of all the columns is equal to one. The next step is to calculate the limit supermatrix. The limit supermatrix is obtained by empowering all the elements of the rhythm supermatrix. This operation is repeated until the elements of the supermatrix converge to the same value. In this case, all the elements related to each criterion will be a fixed number and the same. Based on the calculations made and the limit supermatrix, the output of the Supersigen software is determined (W_{43}, W_{32}, W_{21}). The final preferences of the criteria are possible. The internal relationships pattern of each cluster (W_{22}, W_{33}) is calculated using the Demetel technique. The figure shows the execution algorithm of the DANP technique.

Step 1 - Identify the pattern of relationships of the main criteria

The Demetel technique has been used to reflect the internal relationships between the main criteria. The fuzzy range used is given in Table 2.

1- Calculation of direct communication matrix **$(\tilde{X})$**

First, the experts' opiniov have been collected and fuzzfied with the appropriate fuzzy range (Chapter 3). First, the views of experts are collected and fuzzy with the relevant fuzzy spectrum. If the n-criterion relations have been examined by k experts, the initial matrix for examining the n-criteria relations from the k's expert opinion will be as follows: (Equation 1)

$$\begin{bmatrix} 0 & \tilde{X}_{12}^{(k)} & \cdots & \tilde{X}_{1n}^{(k)} \\ \tilde{X}_{21}^{(k)} & 0 & \cdots & \tilde{X}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{X}_{n1}^{(k)} & \tilde{X}_{n2}^{(k)} & \cdots & 0 \end{bmatrix}$$

So that each element of this initial matrix is a triangular fuzzy number as follows: (Equation 2)

$$\tilde{X}_{ij}^{(k)} = \left(\tilde{l}_{ij}^{(k)}, \tilde{m}_{ij}^{(k)}, \tilde{u}_{ij}^{(k)}\right)$$

When using the opinion of several experts, a simple arithmetic mean of the comments is used and we form a fuzzy or $\tilde{X}$ direct correlation matrix. The fuzzy mean n of the triangular fuzzy number will be calculated as follows : (Table 6 Appendix Calculate the fuzzy direct connection matrix)

$$F_{AVE} = \frac{\sum l}{n}, \frac{\sum m}{n}, \frac{\sum u}{n}$$

2- Calculation of normal direct connection matrix

To normalize values, the $\tilde{a}_i^{(k)}$values should be calculated (Equation 3) and $\tilde{b}^{(k)}$ (Equation 4). Dividing the $\tilde{X}$ matrix elements by the $\sum u_{ij}$maximum values of the $\tilde{N}$normal fuzzy matrix will give:

$$\tilde{a}_i^{(k)} = \sum \tilde{X}_{ij}^{(k)} = \left(\sum_{j=1}^{n} \tilde{l}_{ij}^{(k)}, \sum_{j=1}^{n} \tilde{m}_{ij}^{(k)}, \sum_{j=1}^{n} \tilde{u}_{ij}^{(k)} \right)$$

$$\tilde{b}^{(k)} = max\left(\sum_{j=1}^{n} u_{ij}^{(k)} \right); 1 \le i \le n$$

Therefore, the normalized matrix will be as follows: (Equation 5)

$$\begin{bmatrix} \tilde{N}_{11}^{(k)} & \tilde{N}_{12}^{(k)} & \cdots & \tilde{N}_{1n}^{(k)} \\ \tilde{N}_{21}^{(k)} & \tilde{N}_{22}^{(k)} & \cdots & \tilde{N}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{N}_{n1}^{(k)} & \tilde{N}_{n2}^{(k)} & \cdots & \tilde{N}_{nn}^{(k)} \end{bmatrix}$$

So that each element of the normal matrix will be as follows: (Equation 6)

$$\tilde{N}_{ij}^{(k)} = \left(\tilde{X}_{ij}^{(j)} \right) \Big/ \tilde{b}^{(k)} = \left(\frac{\tilde{l}_{ij}^{(k)}}{\tilde{b}^{(k)}}, \frac{\tilde{m}_{ij}^{(k)}}{\tilde{b}^{(k)}}, \frac{\tilde{u}_{ij}^{(k)}}{\tilde{b}^{(k)}} \right)$$

Based on equations 3 and 4 we will have:

$$\tilde{b}^{(k)} = 2.14$$

Therefore, the resulting normal matrix is as follows:

To normalize the values, each row $\sum u_{ij}$must be calculated. By dividing the $\tilde{X}$matrix elements by the $\sum u_{ij}$ maximum values the $\tilde{N}$normal fuzzy matrix will be obtained: (Table 5 Calculation of the direct relation matrix of the fuzzy normal)

$$k = max\left(\sum_{j=1}^{n} u_{ij} \right) = 2.14$$

$$\tilde{N} = \frac{1}{k} * \tilde{X}$$

3- Calculate the complete connection matrix

The relation $\mathrm{N} \times (I - N)^{-1}$ is used to calculate the complete correlation matrix. In the fuzzy Demetel method, the normal fuzzy matrix is divided into three matrices (according to Equation 5), so by dividing the fuzzy matrix for the lower bound values we have:

$$N_l = \begin{vmatrix} 0.00 & 0.22 & 0.25 \\ 0.24 & 0.00 & 0.16 \\ 0.16 & 0.19 & 0.00 \end{vmatrix}$$

So by dividing the fuzzy matrix by the possible values we have:

$$N_m = \begin{vmatrix} 0.05 & 0.31 & 0.36 \\ 0.35 & 0.05 & 0.26 \\ 0.25 & 0.30 & 0.05 \end{vmatrix}$$

So by dividing the fuzzy matrix for the upper boundary values we have:

$$N_u = \begin{vmatrix} 0.16 & 0.39 & 0.44 \\ 0.44 & 0.16 & 0.36 \\ 0.35 & 0.39 & 0.16 \end{vmatrix}$$

Then the I_{n*n} Identity Matrix is formed:

$$I = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

Finally, the following operation is performed to obtain the complete correlation matrix:

$$T_l = N_l \times (I - N_l)^{-1}$$

$$T_m = N_m \times (I - N_m)^{-1}$$

$$T_u = N_u \times (I - N_u)^{-1}$$

$$\tilde{t}_{ij} = (t_{ij}^l, t_{ij}^m, t_{ij}^u)$$

Values de-fuzzification can be started after calculating the complete correlation matrix (Table 7 Appendix shows the calculation of the complete fuzzy correlation matrix). the method proposed by Boujadzief is used for de-fuzzification.

Table 3- De-fuzzificated complete correlation matrix: (definite)

	Human Capital	Organizational capital	Relational capital
Human Capital	2.021	2.229	2.214
Organizational capital	2.167	1.966	2.024
Relational capital	2.002	2.045	0.268

4- Network relations map (NRM)

The threshold value must be calculated to determine the network relationship map (NRM). Thus, minor relationships can be ignored and a network of significant relationships can be drawn. Only relationships whose values in the T matrix are greater than the threshold value will be displayed in the NRM. To calculate the threshold value of the relations, it is sufficient to calculate the average values of the T matrix. Once the threshold intensity is determined, all values of the matrix T that are smaller than the threshold are zero, ie that causal relationship is not considered. In this study, the threshold value is 1.88. Therefore, the pattern of meaningful relationships is as follows:

Table 4 – Significant relationship pattern of the main criteria of the model

	C1	C2	C3
C1	2.021	2.229	2.214
C2	2.167	1.966	2.024
C3	2.002	2.045	×

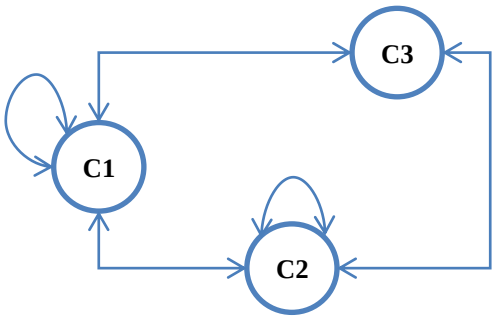

Figure 9 - The internal relationships of the main criteria

According to the pattern of relationships, the causal diagram can be drawn. (Table 10 of the appendix, pattern of effectiveness and effectiveness of research criteria)

The sum of the elements of each row (D) indicates the extent to which that factor influences other factors in the system. Human capital has the greatest impact on other elements. Organizational capital is the middle priority and relational capital has the least impact.

The sum of the elements of the column (R) for each factor indicates the degree to which that factor is affected by other factors in the system. Organizational capital is most affected by other elements. Human capital is the middle priority and capital has the least impactful relationship.
The horizontal vector (D + R) is the degree of influence of the desired factor in the system. Human capital has the most interaction with other elements. Organizational capital is in the middle priority and capital has the least interaction relationship.
The vertical vector (D-R) indicates the power of each factor. In general, if the D-R is positive, the variable is a causal variable, and if it is negative, it is a disability. Human capital is considered a causal variable and relationship capital and organizational capital are considered disabled.

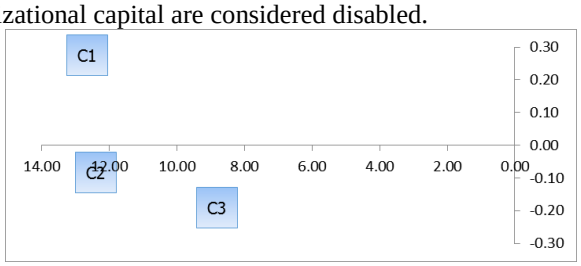

Figure 10 - Cartesian coordinate diagram of variables

The result of pairwise comparison of elements in Super Decision software

As previously explained, pairwise comparisons of elements in their respective clusters (W_{43}, W_{32}, W_{21}) have already been performed in the calculations of the hierarchical analysis process. The results of these pairwise comparisons in Super Decision software are shown in Figure 11:

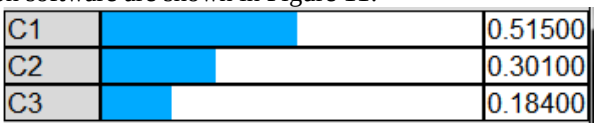

Figure 11 - Prefence of main criteria based on target

Thus, the pattern of the relations of the sub-criteria is obtained and then the unbalanced supermatrix, the balanced supermatrix and the limit supermatrix are extracted. The final prefence of the main criteria is plotted in Figure 12 by adapting the limit matrix.

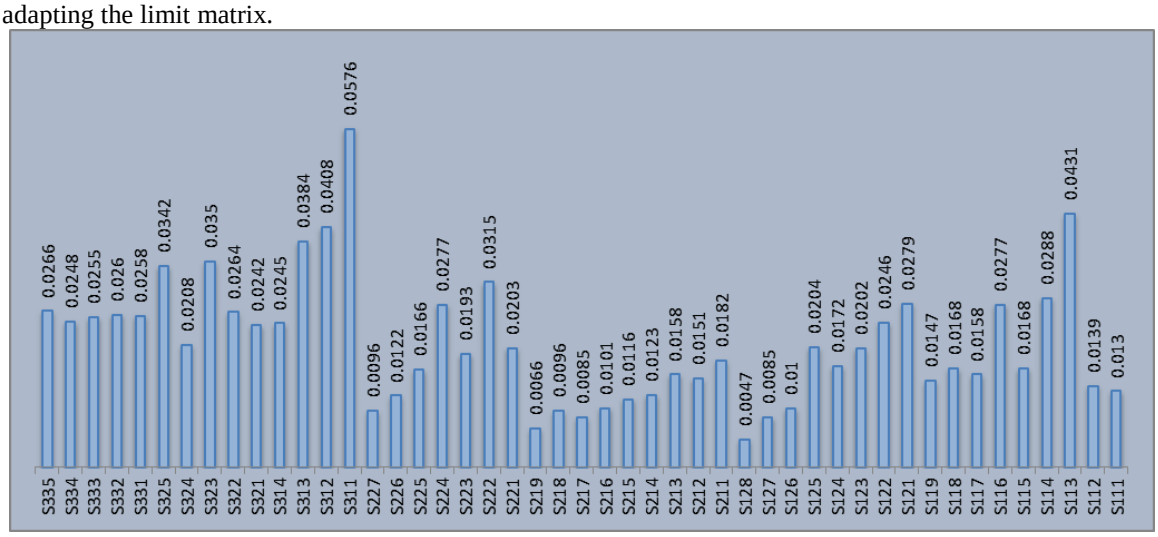

Figure 12 - Final priority of the main criteria using ANP technique

Discussion and conclusion

Given the emphasis and importance in recent years on the quality of the higher education system, the use of prioritized indicators of intellectual capital can improve quality in the university in general and Payame Noor University education and research, in particular. And will be able to more effectively design and implement the strategies needed to achieve the goals.

✓ Since human capital with a normal weight of 0.515 has the highest priority as the largest capital, in terms of slightly more than any other factor affects the growth, survival, dynamism, as well as improving the efficiency and attractiveness of the university.

✓ Human capital in terms of quality also moves towards a dynamic, learner and knowledge-based university that has the ability to adapt to change, which plays a key role in promoting the attractiveness and work of the university, therefore, high levels of organizational support for this human capital demands in various ways, such

as financial support for training and retraining courses. In knowledge economy, learning new knowledge and applying them determines the competitive advantage of an organization (Sarlak, 2007: 170).

✓ Organizational capital with a normal weight of 0.301 is in the middle grade. Payame Noor University by providing organizational contexts and platforms and appropriate technology infrastructure and information systems as well as by establishing a suitable structure and organic environment to create an open atmosphere and thus support novel ideas, innovations and encouraging research should be at the top of the work of Payame Noor University administrators

✓ Relational capital with a normal weight of 0.184 is in the third priority. University administrators should strengthen formal and informal channels with their stakeholders and by highlighting the educational brand to strengthen and develop Payame Noor's cooperation with research centers, industry and universities. For example, in holding joint graduate courses with foreign universities in national priority fields and student exchange, as well as scientific and research cooperation to strengthen indicators and criteria of communication capital.

✓ It should be noted that each organization has a unique culture and atmosphere, so the findings of this study have been developed only with a practical approach for Payame Noor University and can not be easily generalized to other educational centers. Table 11 provides a comparison of the summary of prioritization of indicators with AHP analysis technique and ANP technique.

Table 5 - Summary of prioritization of indicators with AHP analysis technique and ANP technique

Criteria	Final indices	The acronym for sub-criteria in this research	Final weight with FAHP technique	Normal weight with FANP technique	Rank with FAHP technique	Rank with FANP technique
C1 Human capital: Sub-criteria Attractiveness index (S11) includes:	Number of graduates	S111	0.0208	0.013	20	36
	Number of new people hired	S112	0.0224	0.0139	17	35
	Percentage of students with a technology or business background	S113	0.0696	0.0431	1	2
	Number of graduate students	S114	0.0465	0.0288	2	8
	Number of class hours per day	S115	0.027	0.0168	11	28
	Percentage of previous students with the status of academic staff or faculty	S116	0.0445	0.0277	3	11
	Percentage of students accepted and total number of students	S117	0.0257	0.0158	13	31
	Number of undergraduate students	S118	0.0271	0.0168	10	29
	Percentage of learners' complaints	S119	0.0238	0.0147	16	34
C1 Human capital: Sub-criteria of S12 efficiency index	Number of faculty members	S121	0.0434	0.0279	4	9
	Percentage of faculty members compared to the number of students	S122	0.0383	0.0246	6	18
	Evaluation of faculty members from the perspective of students	S123	0.0314	0.0202	9	24
	Average age of faculty members	S124	0.0268	0.0172	12	27
	Number of hours devoted to faculty for seminars	S125	0.0318	0.0204	8	22
	Percentage of staff compared to the total number of students	S126	0.0156	0.01	27	41
	Number of employees (research, administrative)	S127	0.0133	0.0085	34	44
	Percentage of faculty members compared to the total number of staff	S128	0.0073	0.0047	47	47
C2 Organizational Capital Sub-criteria of Innovation and Knowledge Coding Index S21	Percentage of success in obtaining projects relative to the total	S211	0.0222	0.0182	19	26
	Number of international awards received	S212	0.0183	0.0151	25	33
	Number of inventions	S213	0.0192	0.0158	24	32
	Number of ongoing research projects	S214	0.0149	0.0123	30	37
	Number of books published by faculty members	S215	0.0142	0.0116	32	39
	Number of publications in international journals and books	S216	0.0123	0.0101	35	40
	Number of publications in the international journals of each faculty member	S217	0.0103	0.0085	39	45
	Number of papers presented at conferences	S218	0.0117	0.0096	38	43
	Number of applications submitted in the field of innovation	S219	0.008	0.0066	46	46
	Technology costs per faculty	S221	0.025	0.0203	14	23
	Number of software for teaching / research	S222	0.0389	0.0315	5	7
	Number of books available in the library	S223	0.0239	0.0193	15	25
C2 Organizational Capital: Sub-Criteria of Infrastructure Development	Percentage of technology costs relative to total costs	S224	0.0342	0.0277	7	10
	Technology costs per employee	S225	0.0205	0.0166	21	30
	Technology costs per student	S226	0.0152	0.0122	28	38
	Percentage of teamwork use	S227	0.0118	0.0096	37	42

Criteria	Final indices	The acronym for sub-criteria in this research	Final weight with FAHP technique	Normal weight with FANP technique	Rank with FAHP technique	Rank with FANP technique
Index S22						
Relational capital C3: Sub-criteria of research and development networks S31	Number of university agreements signed by other scientific-research or industrial centers in relation to scientific members	S311	0.0223	0.0576	18	1
	Percentage of speakers invited to learning programs	S312	0.0159	0.0408	26	3
	Number of faculty members participating in international conferences	S313	0.0149	0.0384	31	4
	Number of students with international experience	S314	0.0095	0.0245	40	19
Relational capital: Sub-criteria International Scopes S32	Number of visits to the university site	S321	0.0137	0.0242	33	20
	Number of research institutes involved in research activities	S322	0.015	0.0264	29	13
	Number of members referring to scientific websites and e-business management	S323	0.0198	0.035	22	5
	Number of emails received and sent	S324	0.0118	0.0208	36	21
	Number of research institutes involved in educational activities	S325	0.0194	0.0342	23	6
C3 Relational capital: Sub-criteria the client respect S33	Client Affairs Department	S331	0.0084	0.0258	43	15
	Creating platforms and infrastructure for sending client complaints through the website	S332	0.0084	0.026	42	14
	Establishment of free telephone lines to raise customer complaints	S333	0.0082	0.0255	44	16
	Providing electronic services to clients	S334	0.0081	0.0248	45	17
	Communicating continuously with clients and knowing their level of satisfaction by creating a system for creating a system of complaints and suggestions	S335	0.0086	0.0266	41	12

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