Clustering and Ranking University Majors using Data Mining and AHP algorithms: A case study in Iran

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Abstract

Although all university majors are prominent and the necessity of their presences is of no question, they might not have the same priority basis considering different resources and strategies that could be spotted for a country. Their priorities likely change as time goes by; that is, different majors are desirable at different times. If the government is informed of which majors could tackle today existing problems of the world and the country, it surely would esteem those majors more. This paper considers the problem of clustering and ranking university majors in Iran. To do so, a model is presented to clarify the procedure. Eight different criteria are determined and 177 existing university majors are compared on these criteria. First, by K-means algorithm, university majors are clustered based on similarities and differences. Then, by AHP algorithm, we rank university majors.

Keywords: data mining; clustering; K-means algorithm; multi-criteria decision making; analytic hierarchy process; university major ranking problem

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Introduction

University major choice is an important decision to make for anybody seeking professional/higher education. It is a decision that will influence the way people look at the world around themselves (Porter & Umbach, 2006). The future occupation of people is closely related to their education. Given this importance, it is always of interest to find the guidance in collaboration with making aforementioned choices about which major to select. It is known that students should draw on available resources to ultimately pick a path that is right for them (Boudarbat, 2008). Nowadays, due to the creation of numerous undergraduate majors, the need for having a more precise approach becomes increasingly necessary. Besides individual reasons, governments could be another client of university major choice. They might look for a way to supply their professional labors as one of the most influential factors in their national future. To manage this and to find which majors are of more importance in future, they require a systematic approach to have a deeper view about majors. For example, they entail to know areas each major affects, how majors can affect, to what extent each major is influential in a given area. Although all university majors are prominent, and the necessity of their presences is of no question, they might not have the same priority basis considering different strategies that could be spotted for a country. Their priorities likely change as time goes by; that is, different majors are desirable at different times. If the government is informed of which majors could tackle today existing problems of the world and the country, it surely would esteems those majors more. By investing more on those majors or providing greater grants for those studying the majors, they intend to motivate more talented students to study them.

Therefore, with reference to the given explanations, it is a handy contribution to construct a model for such a decision-making process. To this end, we define eight different Main Specialization Groups (MSG). We first group university majors based on their similarities and differences which are obtained by their magnitude of influence on MSGs. The values of different major group can then be calculated and evaluated to provide useful decisional information for the government to utilize resources rationally. Among available grouping methods, data mining approaches have attracted more attention. Given different data mining models, clustering is regarded as the art of systematically finding groups in a data set (Fayyad, Piatetsky-Shapiro, & Smyth, 1996). In this paper, to cluster the university majors, we utilize the *k-means* algorithm as the most widely used method that has shown much success in different applications such as market segmentation, pattern recognition, information retrieval, and so forth (Cheung, 2003; Kuo, Ho, & Hu, 2002). Besides its high performance, it is a very popular approach for clustering because of its simplicity of implementation and fast execution.

Ranking/ordering university majors is a multi-criteria problem; that is, different criteria should be taken into account. For example, one major might be very important for industrial setting while another one is appropriate for improving social culture. Armed with this, we apply the Analytic Hierarchy Process (AHP) as a simple Multi Criteria Decision Making (MCDM) method for dealing with unstructured, multi-attribute problems. AHP is developed by Saaty and widely studied by other authors (Bolloju, 2001; Kablan, 2004; Lipovetsky & Conklin, 2002). It consists of breaking down a complex problem into components, which are then organized into levels in order to generate a hierarchical structure. The aim of constructing this hierarchy is to determine the impact of the lower level on an upper level, and this is achieved by paired comparisons provided by the decision-maker. The hierarchical structure of the AHP model attempts to estimate the impact of each alternative on the overall objective of the hierarchy. Another advantage of the AHP is that it uses a consistency test to filter inconsistent judgments. Taking into account these advantages, many outstanding works have been published based on AHP. They include applications of AHP in different fields, such as planning, selecting the best alternative, ranking alternatives as in our case, resource allocation, resolving conflicts, optimization, etc., as well as numerical extensions of AHP (Chatzimouratidis & Pilavachi, 2009; García-Cascales & Lamata, 2009). An important bibliographic review of MCDM tools was carried out by Steuer (2003). Our objective is to employ an AHP application in the problem of ranking university majors.

Looking into the literature, there is no paper published dealing with the major choice as a nationwide problem. They almost tackle the problem as just an individual assistance model. These papers usually propose regression models that guide a student to know which major is the best choice regarding her/his personal conditions, characteristics and interests (Berger, 1988; Boudarbat, 2008; Crampton, Walstrom, & Schambach, 2006; Porter & Umbach, 2006). As far as we reviewed, this paper is the first work exploring this problem as a nationwide one, and clustering university majors using a data mining method called *k-means*. Moreover, university majors are ranked by a MCDM method, called AHP algorithm.

In the following parts of this paper, first university majors are clustered, and then the conceptual model of university major ranking is provided. Finally, AHP algorithm is applied to order university majors.

University major ranking model

This section presents a conceptual model to describe the decision making procedure of university major clustering and ranking. In fact, we employ a Flow Chart (FC) model to show the whole procedure. This diagram is to clarify each step of the whole procedure regardless of its details. Figure 1 presents the FC model. The procedure could be divided into three main phases: data gathering, data preparation, and decision making.

In the first phase, the list of existing university majors is solicited from Iranian Ministry of Science, Research, and Technology. University majors in Iran are presented in five main groups each of which covers an educational background from high school. These five groups are: fine arts, mathematics and physics, empirical sciences, human sciences, and foreign languages. Finally, 177 university majors presented in Iran are identified. Then, MSGs are determined. Doing so, this paper intends to consider eight highlighted main specialization groups with due considerations to Iran’s own attributes and special areas are needed in order to ease the design process of sustainable development. These eight MSGs were extracted after a review of the literature of the problem and the reports published by the local government for achieving sustainable development, and the validity and reliability of these MSGs have been verified and confirmed by a number of structured interviews. At this time, additional rules and constraints taken from Iran’s strategies and views are to be considered as well. Finally, the following eight MSGs are considered as decision criteria:

- financial/economical
- industrial
- service
- therapy/health
- social/religious
- political
- agricultural
- environmental/natural resources

In the second phase, regarding the data gathered in previous phase, two suitable questionnaires are designed. The first one is to compare university majors on their magnitude of influence on abovementioned MSGs. The second one is to compare the importance/weight of each MSG for Iran's current situation. The questionnaires are sent to 64 experts whose definition is set in this research as follows: An expert is a person who has at least an MS degree in one of the official university majors along with at least three-year working experience in his/her specialization field. After data collection, some qualification tests, such as consistency in AHP algorithm, are utilized to verify the results of questionnaires.

If all the requirements are met, the third phase starts. First, we employ one of the well-known data mining approaches to cluster university majors based on their similarities and differences on the results. This step is explained in more details in the next section. Then, we rank university majors by means of a MCDM algorithm. There are two options to employ: Multi-Objective Decision Making (MODM), or Multi-Attribute Decision-Making (MADM) approaches. MODM models are those searching a continuous/integer space to find optimal solutions. The most commonly used type of these models is linear programming.

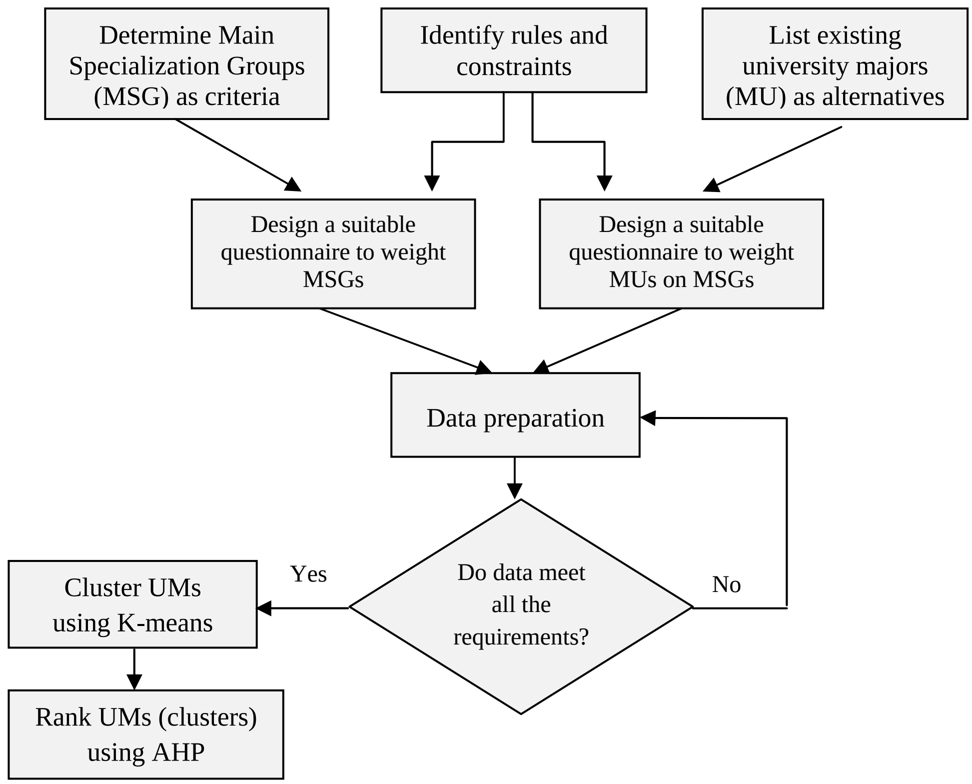

Figure 1 - General model of clustering and ranking university majors

Since the problem of ranking university majors is not a continuous problem, the MODM model is not the best choice. Our purpose to present the model is to mathematically characterize the problem. A MADM model could be more effective. Among the MADM approaches, AHP has shown many successful applications in such ranking problems (Chen & Cheng, 2009; Hsu & Pan, 2009). Therefore, we have been thinking of ranking the university majors by AHP algorithm. The details and results are presented further in the paper.

University Major Clustering Problem (UMCP) in Iran

The background of clustering and K-means algorithm

In today's world, data are considered as one of the most valuable assets. With the current dramatic increase in magnitude of available data and also their low cost storage, it became interesting to discover knowledge in these data. Therefore, the importance of how to effectively process and use data more and more soars. This calls for new techniques to help analyze, understand the huge amounts of stored data (Liao & Chen, 2004). Among the new techniques developed, data mining is the non-trivial extraction of hidden and potentially useful information from large sets of data. In other words, data mining is the process of discovering significant knowledge, such as patterns, associations, changes, anomalies and significant structures from large amounts of data stored in databases, data warehouses, or other information repositories (Liao, Chen, & Wu, 2008). In the literature, there are many data mining models such as classification, estimation, predictive modeling, clustering, affinity grouping or association rules, description and visualization, as well as sequential modeling.

Clustering is a widely used technique, whose goal is to provide insight into the data by partitioning the data (objects) into disjoint and homogeneous groups (clusters) of objects, such that objects in a cluster are more similar to each other than to objects in other clusters. According to Boutsinas and Gnardellis (2002), clustering algorithms have been frequently studied in various fields including machine learning, neural networks and statistics, among others (Corcho, Lopez, & Perez, 2003; Davies & Fensel, 2003; Fensel, 2001).

The *k-means* algorithm, first proposed by MacQueen (1967), is the most popular partition-clustering method that has attracted great interest in the literature. The goal of the *k-means* algorithm is to partition the objects into *k* clusters so that the within-group similarity is maximized. The procedure of *k-means* methods could be described as follows.

- Place *k* points into the space represented by the objects that are being clustered. These points represent initial group centroids.
- Assign each object to the group that has the closest centroid.
- When all objects have been assigned, recalculate the positions of the *k* centroids.
- Repeat Steps 2 and 3 until the centroids no longer move. This produces a separation of the objects into groups from which the metric to be minimized can be calculated.

The applications of K-means for university major clustering problem

This study employs *k-means* in cluster analysis and partitions 177 university majors into ten clusters. The distance between each major and centeriod is calculated using Euclidean distance as the most commonly used distance measure in *k-means* method (Huang, Chang, & Wu, 2009). Again, each major is assigned to the nearest cluster, and the new centeriod dimension *j* of cluster *l* is the arithmetic mean of the influence degree of the majors belonging to the cluster *l*. This procedure iterates until no new cluster is obtained when majors are reassigned. To run the procedure, the algorithm was coded in MATLAB 7.

The results of UMCP and the final centriods of the ten clusters are presented in Tables 1 and 2, respectively. Centeriods of each cluster are its average magnitude of influence on each MSG. Cluster 1 includes the majors concerning more on financial and economical MSG, and slightly on social and religious MSG. Cluster 2 consists of engineering majors; therefore, they clearly focus on the industrial MSG. Majors in Cluster 3 are those relating to individual therapy and health, whereas majors of Cluster 4 are those focusing on public health. Cluster 5 covers majors training social related courses such as social, political, religious and military affairs. Cluster 6 involves majors providing services for civilians. Cluster 7 includes majors relating to agriculture and natural resources MSG. Cluster 8 consists of majors that their aspects of social services are more influential than the other aspects. Cluster 9 involves majors that could almost affect all the eight criteria; although they are more important on economical, social and religious, political, and service criteria. Cluster 10 apparently covers majors that have been given lower values by the involved decision makers. Based on results collected, they might be comparatively less influential.

Table 2 - The centriods of university major clusters in each MSG in percentage

	MSG							
cluster	financial/ economical	social/ religious	industry	politics	services	therapy/ health	agriculture	environment/ natural resources
1	44	28	18	4	11	2	5	10
2	59	9	70	6	41	18	21	16
3	11	14	0	0	47	4	58	15
4	16	54	4	5	25	8	37	27
5	7	37	4	41	8	1	2	1
6	18	5	18	1	20	8	10	10
7	29	2	23	4	16	44	35	54
8	6	20	4	10	8	2	5	3
9	41	59	19	50	24	6	5	6
10	4	2	3	2	6	1	3	3

University Major Ranking Problem (UMRP) in Iran using AHP

The first step in using the AHP is to construct a hierarchy structure of the UMRP. Figure 2 depicts how the problem mentioned above can be modeled using the AHP. This hierarchical structure offers a natural way to divide and conquer the complexity of UMRP; without it, decision makers may simply be overwhelmed. The hierarchy structure of the UMRP is three-level one. The first is final problem's goal "ranking university majors".

The second includes the involved criteria which are those eight MSGs mentioned earlier, and the third consists of the problem's alternatives which are the 177 official university majors in Iran. Figure 2 shows the hierarchy structure of the UMRP. It is necessary to indicate that the consistency of each comparison matrix of each decision maker is tested in data preparation phase. In the case of inconsistency proceeding, the decision maker is requested to revise the judgments.

Since UMRP is a group decision making process and many judgments are involved, we need to utilize an indicator combining the judgments. To this end, we use an approach with following two steps:

- The weights for each decision maker are obtained. Due to high complexity size and excessive number of required computations, utilization of standard form (i.e. Eq. (5)) to calculate the weights seems ineffective. To effectively obtain the weights, we employ an approximation method as follows. First, the summation of each row of the comparison matrix is calculated. Therefore, we have an $n \times 1$ matrix. Then, the normalized form of this matrix gives the weights.
- To combine the weights obtained for each decision maker, the arithmetic mean is used. These means represent the final weight of each alternative in a given criterion. The final results for weights of the eight criteria are as follows: finance and economics (0.346), society and religion (0.196), industry (0.131), politics (0.041), services (0.070), agriculture (0.070), medicine (0.072) and environments and natural sources (0.074).

All the other steps of AHP are implemented and the final results of the UMRP (majors' ranks) are presented in Table 3. Management, mechanical and information technology engineering are three top majors, based on view of the decision makers. After these three majors, engineering majors, such as industrial and civil engineering along with medicine, film and video production and law are more influential majors.

Sensitivity analysis allows us to verify the results of the decision. A sensitivity analysis can be performed to see how sensitively the alternatives change with the importance of the criteria. To implement AHP analysis, we use specialized software, called Expert Choice version 2000. The implementation of AHP provides four graphical sensitivity analysis modes: dynamic, gradient, performance and two-dimensional analysis. Performance sensitivity analysis has been employed here. It depicts how well each alternative performs on each criterion by increasing or decreasing the importance of the criteria.

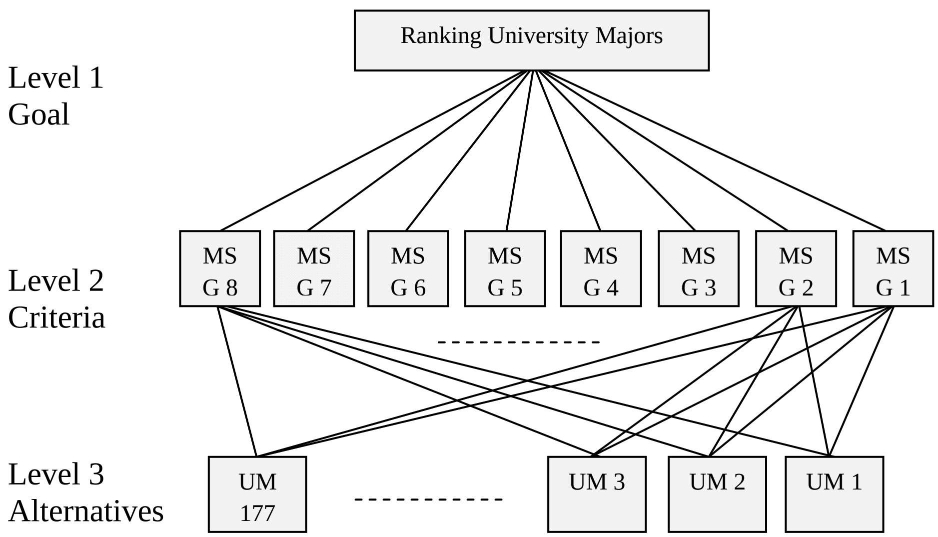

Figure 2 - Hierarchy structure of the UMRP

In view of the above, we consider that a sensitivity analysis is necessary in order to analyze decision-making if the condition is changed over time. Sensitivity analysis identifies the impact of changes in the priority of criteria. It is clear that there are variations in the relative importance/weights of the criteria. Due to numerous number of university majors, we just continue the sensitivity analysis with 11 first majors whose importance ratios are significantly different from the others: management, mechanical eng., information technology eng., industrial eng., medicine, film and video production, petroleum eng., law, electrical eng., civil eng., and bio eng. majors.

With regard to financial/economical MSG, mechanical eng. goes to the top if the FEG importance decreases; while management keeps the top rank if financial/economical MSG's importance increases. If the relative importance becomes greater than 0.5, information technology eng. obtains the second rank. Considering social/religious MSG, film and video production is highly sensitive towards social/religious MSG's importance weight. More precisely, its priority soars if social/religious MSG's importance weight increases to 0.55 while in lower weights, its rank deteriorates. The same trend could be also seen from law. Engineering-based majors show the opposite trend, meaning that they go down versus greater weight of social/religious MSG's importance. Taking into account industrial MSG, as expected, engineering-based majors' ranks soar while higher weight is given industrial MSG importance. This time, medicine, law, and film and video production lose their ranks and fall down to lower priorities.

Regarding political MSG analysis, we can see film and video production taking over all the other majors if decision makers when political MSG importance is adjusted upwards the current weight. Law is also granted the second rank if PG importance becomes greater than 0.6. Considering Service MSG sensitivity analysis, it seems medicine, information technology eng., and law are those majors gaining higher priorities while increasing service MSG importance. In therapy/health MSG analysis, medicine and bio. eng. move to upper ranks if the decision makers give greater relative importance to therapy/health MSG than that of the other criteria. Actually, they have direct correlation with the importance. The results of sensitivity analysis of agricultural criterion shows that mechanical eng. is granted the first priority among these 11 majors when we consider a possible greater influence of this MSG. Management degrades to fourth rank in the relative importance greater than 0.57. In environmental/natural resources MSG, petroleum eng. goes up to the first rank if the importance of this MSG is decided to be greater than 0.22.

Conclusion and Suggestions for Future Studies

This paper dealt with university majors ranking problem. UMRP is an important problem since university majors might not have the same priority basis with due considerations to different resources and strategies that a country has, though they are all eminent. UMRP is a dynamic problem; therefore, a general model is needed to clarify the whole procedure. In this case, we employed a Flow Chart model which has three phases: data gathering, data preparation, and decision making. In the first two phases, all the data needed for the third phase are collected and tested for the necessary requirements. In the third phase, the all the majors are clustered according to their similarity and differences by *k-means* algorithm. Since UMRP is an MADM problem, we employ an application of AHP algorithm to rank university majors.

As a direction for future research, one might work on application of other multi objective decision making procedure for the problem under consideration. It is also interesting to present other criteria that can influence the university major ranking. Another impressive stream for future research is to introduce a model for how to assign grants for the research projects defined for each majors according to their ranks.

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Appendixes

Table 1 – The results of university major ranking problem

Clusters		Majors				
1	1	Historical construction renovation	2	historical facility renovation	3	architecture
	4	handcraft industry	5	fashion and textile design	6	textile eng.
	7	architecture eng.	8	urbanization	9	economical sci.
	10	industrial economics	11	theoretical economics		
2	1	electrical eng.	2	industrial eng.	3	civil eng.
	4	computer eng.	5	information tech. eng.	6	mechanical eng.
	7	material eng.	8	biomedical eng.	9	electronic eng.
3	1	medicine	2	dentistry	3	physiotherapy
	4	midwifery	5	nursing	6	radiology
	7	radiation therapy	8	dental nursing	9	curator in medicine
	10	medical services man.	11	work therapy		
4	1	nutrition	2	environmental health	3	professional health
	4	public health	5	psychology	6	clinical psychology
5	1	journalism	2	judiciary sciences	3	Islamic jurisprudence exp.
	4	law affairs exp.	5	Islamic wisdom	6	social sci.
	7	Islamic sci.	8	theology	9	Quran sci.
	10	art and cultural man.	11	political relations	12	political sci.
	13	national security	14	security sci.	15	military information

	16	political geography	17	military sci.	18	training political teachers
6	1	photography	2	industrial design	3	railroad eng.
	4	clerical affairs	5	banking affairs man.	6	rural civil eng.
	7	food industry	8	insurance man.	9	accounting
	10	physical sci.	11	chemical sci.	12	mathematical sci.
	13	clinical laboratory sci.	14	aerospace eng.	15	polymer eng.
	16	statistical sci.	17	nuclear tech.	18	robotics eng.
7	1	agricultural eng.	2	veterinarian	3	agricultural machine tech.
	4	mining eng.	5	petroleum eng.	6	oil eng.
	7	oil Exploration eng.	8	biotechnology	9	biological Sci.
	10	chemical eng.	11	emergency medical affairs	12	herbaceous production tech.
	13	geology	14	pharmacology	15	animal production tech.
	16	forestry tech.	17	fishing tech.	18	tore tech.
	19	environmental tech.	20	urban forestry eng.	21	general biological Sci.
	22	medicinal plant production	23	entomology	24	natural resources eng.
8	1	traditional arts	2	theatre	3	portrait
	4	Iranian music	5	universal music	6	social activism

	7	social relations sci.	8	guidance & consultation	9	tourist services
	10	Persian lan. & lit.	11	Arabic lan. & lit.	12	Arabic translation
	13	audiology	14	taxation affairs	15	ECO insurance man.
	16	national operations	17	geography	18	history
	19	archaeology	20	cultural sci.	21	speaking therapy
	22	family studies	23	postal sci.	24	weaponry
	25	physical training & sports sci.	26	organizational psychology	27	childhood studies
	28	philosophy				
9	1	cinema	2	film & video production	3	law
	4	management				
10	1	graphic design	2	museums guidance	3	museums keeping
	4	sculpture	5	carpet expertise	6	visual arts
	7	printmaking	8	marine eng.	9	aircraft maintenance eng.
	10	aviation	11	shipping navigation	12	technical excavation
	13	pilot	14	computer sci.	15	aircraft navigation
	16	helicopter pilot	17	transportation eco.	18	non-coal mineral extraction
	19	wood industry	20	water sci. eng.	21	seeing ponder
	22	prosthetics	23	medical documents	24	anesthesia
	25	surgery room	26	teeth	27	teeth health

			prosthetics		
28	marine commissar man.	29	marine business man.	30	marine security
31	curator	32	custom affairs	33	Turkish lan. & lit.
34	English lan. & lit.	35	English translation	36	English training
37	English news translation	38	German lan. & lit.	39	German translation
40	French lan. & lit.	41	French translation	42	Russian lan. & lit.
43	Armenian lan. & lit.	44	Ordo lan. & lit.	45	Japanese lan. & lit.
46	Italian lan. & lit.	47	Spanish lan. & lit.	48	Chinese lan. & lit.

Table 3 - University majors' ranks using AHP

Rank	Major	Rank	Major
1	management	2	mechanical eng.
3	information tech. eng.	4	industrial eng.
5	medicine	6	film & video production
7	petroleum eng.	8	law
9	electrical eng.	10	civil eng.
11	biomedical eng.	12	environmental health
13	material eng.	14	urbanization
15	biotechnology	16	chemical eng.
17	oil eng.	18	computer eng.
19	urban forestry eng.	20	historical construction renovation
21	agriculture eng.	22	historical facility renovation
23	textile eng.	24	pharmacology
25	mining eng.	26	public health
27	handcraft industry	28	economical sci.
29	cinema	30	veterinarian

31	architecture	32	architectural eng.
33	aerospace eng.	34	accounting
35	clinical psychology	36	psychology
37	nutrition	38	fashion and textile design
39	theology	40	industrial design
41	oil exploration eng.	42	herbaceous production technology
43	animal production technology	44	theoretical economics
45	shipping navigation	46	forestry technology
47	environmental technology	48	Quran sci.
49	Islamic sci.	50	industrial economics
51	polymer eng.	52	dentistry
53	biological sci.	54	insurance management
55	rural civil eng.	56	nursing
57	general biological sci.	58	geology
59	journalism	60	railroad eng.
61	professional health	62	fishing technology
63	tore technology	64	Persian lan. & lit.
65	art & cultural management	66	banking affair management
67	Islamic jurisprudence expertise	68	Islamic wisdom
69	political relations	70	political sci.
71	historical arts	72	natural resources eng.
73	social sci.	74	midwifery
75	law affairs expertise	76	social activism
77	nuclear technology	78	national security
79	photography	80	agricultural machines technology
81	judiciary sciences	82	robotics eng.
83	chemical sci.	84	medical services management
85	food industry	86	entomology
87	organizational	88	clerical affairs

	psychology		
89	emergency medicine	90	social relations sci.
91	political geology	92	physical sci.
93	statistical sci.	94	prosthetics
95	guidance & consultation	96	family studies
97	graphical design	98	work therapy
99	medicinal plant production	100	country operations
101	Iranian music	102	universal music
103	physiotherapy	104	speaking therapy
105	audiology	106	clinical laboratory sci.
107	pilot	108	taxation affairs
109	ECO insurance man.	110	military information
111	philosophy	112	theatre
113	portrait	114	water sci. eng.
115	radiology	116	radiation therapy
117	geography	118	curator
119	postal sci.	120	tourist services
121	museum guidance	122	museum keeping
123	mathematical sci.	124	arsenal
125	cultural sci.	126	physical training & sports sci.
127	transportation economics	128	printmaking
129	computer sci.	130	electronic eng.
131	custom affairs	132	marine eng.
133	non-coal mineral extraction	134	seeing ponder
135	curator in medicine	136	history
137	archaeology	138	wood industry
139	childhood studies	140	Arabic lan. & lit.
141	Arabic translation	142	military sci.
143	training political teachers	144	dental nursing
145	carpet expertise	146	security sci.
147	English lan. & lit.	148	English translation
149	English training	150	English translation news expertise

151	medical documents	152	marine commissar man.
153	marine business man.	154	sculpture
155	visual arts	156	aircraft maintenance eng.
157	aviation	158	marine security
159	technical excavation	160	teeth health
161	anesthesia	162	surgery room
163	aircraft navigation eng.	164	helicopter pilot
165	teeth prosthetics	166	German lan. & lit.
167	German translation	168	French lan. & lit.
169	French translation	170	Russian lan. & lit.
171	Armenia lan. & lit.	172	Spanish lan. & lit.
173	Chinese lan. & lit.	174	Japanese lan. & lit.
175	Turkish lan. & lit.	176	Italian lan. & lit.
177	Ordo lan. & lit.		