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Investigating priorities of engineering disciplines for addressing the technical needs of Iranian society using the Analytic Hierarchy Process

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Abstract

Iranian society needs a trained expert workforce in light of the rapid advances in science and technology. This is as important as natural needs for community survival, and having an expert workforce leads to independence and power for the society. To this end, governments can facilitate social progress through appropriate and comprehensive planning, training young talent, and optimal use of the available tools and capacities. Considering the importance of expertise in engineering fields for industrialization, this paper investigates the importance and priority of the common engineering disciplines in Iran. To achieve this goal, several criteria must be considered simultaneously, which we did using the Analytic Hierarchy Process. Our findings include a prioritization of the disciplines in this branch of science.

Keywords: engineering disciplines, ranking, Analytic Hierarchy Process (AHP), higher education, Iranian society

Introduction

Today, the traditional boundaries between university, industry, and government have disappeared to the point of being almost indistinguishable in most cases. This is known as the Triple Helix of university-industry-government (Viale & Etzkowitz, 2010). Part of the university domain is considered as industry, and part of the industry domain is regarded as the university (Bagherinejad, 2008). The knowledge generated in universities may be regarded as a competitive advantage for industry (Salter & Bruneel, 2009) and economic success in any country is largely dependent on scientific and academic research (Brown, 2006). Higher education in different communities typically seeks the following general and basic objectives (Madhoushi & Niazi, 2010):

A. Conducting fundamental, scientific, and applied research for knowledge development;
B. Training and providing skilled, efficient, and professional manpower required by different sectors of society;
C. Facilitating the fulfillment of cultural and social goals.

Most universities do not have a clear vision of the strategies needed to make students aware of industry's current and future needs (Moubayed, Bernard, & Jammal, 2009). Since training and providing skilled and professional manpower can reduce poverty and unemployment, meet community needs, reduce dependency, prevent exploitation and dominance, and so on, investigating this issue is of high importance. Thus, this paper investigates the priorities of the engineering field’s specialties to advance our understanding of society’s needs for these specialties.

Having a job which is valuable to society depends on accurate and extensive studies by governments. Individuals then make informed decisions for their employment. Thus, governments announce society’s need for specific jobs, based on their assessment, and the job seeker selects his/her desired job from the options provided, according to his/her interest, talent, and capacities. Governments therefore seek an optimal way to identify specific professional jobs as one factor affecting the future of their nations. However, governments must be aware of the expertises’ various influences to identify and meet the needs of the profession (Rad, Naderi, & Soltani, 2010). Of course, the need for various specialties varies in different communities and changes over the time. On the other hand, a government can help to establish communication between universities and the community, to help meet its needs, through motivating structures (Cao, Zhao, & Chen, 2009). Being aware of the needs, a government is able to support respective specialties and help overcome community problems by encouraging people to study in the respective needed specialties. Therefore this study attempts to provide an appropriate method for identifying this need, with the ultimate goal of helping both the government and individual future job seekers as they make educational decisions.

All sciences and professions are important for societal progress. However, taking into account the exponential growth of science, society's progress in industrial areas, and the human need for new technologies, engineering disciplines have a special role. Considering the social needs for technical and engineering branches in Iran, this study focuses on the priorities of the common engineering disciplines to achieve an industrialized society.

A decision maker may face different criteria in a decision making process, and he or she may be forced to choose the best among several options. In these conditions, one popular decision-making method is Analytic Hierarchy Process (AHP). AHP is one of the most well known techniques for multipurpose decision making, developed originally by Saaty (1980, 1989). This method can be used when the decision making process includes several competing decision-making options and criteria (Cao et al., 2009). AHP allows a combination of qualitative and quantitative criteria simultaneously. In this case, qualitative criteria are the needed engineering disciplines, and quantitative criteria are the number and conditions of the manpower. AHP is based on the pair-wise or binary comparisons of options and decision criteria. Collecting data from decision makers is needed for such comparisons, and it allows decision makers to concentrate only on the comparison of two criteria or options, free from any external intrusions.

In this study, respondents performed comparisons between technical and engineering disciplines. It was done based on shortages and potential professionals available in society, not based on individuals' personal interests. To this end, the respondents were selected from faculty members with more than ten years of academic background, and administrative managers in academic affairs or experts in various industries. In addition to binary comparison, AHP provides valuable information on the issue and makes the decision making process logical, since the respondent in AHP measures only two factors toward each other and does not consider any other factors. Also, the decision making process with the analysis of different opinions is used with high quality (Mohammadi & Yadegarzade, 2002).

This study required extensive research among university faculty and experts in the field. Finding people in different fields of engineering who had sufficient information was challenging and time consuming. Responses from participants with insufficient information about different fields of engineering were excluded from analysis.

To focus on just one branch of science, this paper is limited to the fields within engineering. While this is desirable, allowing for a specific focus on engineering and technical fields, it is also a limitation because the medical fields and humanities are unrepresented. Of course, however, this technique is extendible to all fields.

The remaining part of the paper is organized as follows: we first provide a literature review and research methodology. Then we present the data analysis before turning to the process of implementation on a real case. We close with a summary of the results and recommendations for future work.

Literature review

We here review literature on two topics: studies that introduced and ranked the higher education system, faculties, educational departments, and educational branches; and studies that investigated the selection of disciplines, especially in engineering. The first includes studies on Iran's position in global academic rankings, such as Madhoushi and Niazi (2010). They emphasized the necessity of paying attention to academic status and its place in the world, and studied the educational and academic conditions in 31 other countries.

There are different views on university rankings and the associated methodologies. Some authors argue that ranking causes unhealthy competition among universities and that institutions attempt to organize their activities based on ranking criteria. In contrast, some authors, including Dadras (2002), maintain that ranking leads to improved quality of higher education institutions and universities, and believe that qualitative ranking should be done according to the objectives of the higher education institutions and universities. Another group of authors considers ranking as a factor of acceleration and movement by universities toward a competitive context, which thus increases their efficiency (Mohammadi & Yadegarzade, 2002).

After ranking the universities, it is common to rank the faculties or schools within each university. It should be noted that comprehensive studies have been conducted on ranking medical faculties in Iran since 1998, based on 149 criteria for 38 universities. The other study in this field is ranking educational departments. Ranking mathematics department (34 groups) at the undergraduate level used different data envelopment analysis models to determine their effectiveness (Parand, 2002). In the other study by Tasshiri and Rahbari (2009), ranking and classification of specialized capabilities of industrial engineering graduates was done using the AHP method. They ranked specialties of this field based on Industrial Engineering curriculum content (Tasskhiri & Rahbari, 2009).

Ranking using the AHP method was done in Chinese universities in 2001. The strength of this type of ranking is that it uses two surveys on indices and their weights (Madhoushi & Niazi, 2010). Separately, Gorman determined top academic institutions in terms of educational disciplines, 1987-2002. Additionally, Rad et al., (2010) and Soltani (2010) classified all academic disciplines using a data mining method and then ranked them using AHP algorithm.

The second set of studies includes the effects of engineering disciplines. Engineering education is commonly categorized into three periods (Apelian, 2007): the 19th century and the first half of the 20th century is known as the "professional engineering" era, the second half of the twentieth century is known as the "scientific engineering" era, and the 21st century is known as "productive entrepreneurial engineering."

In Finland, engineering education reorganization has been emphasized since 1990s to meet European industry requirements (Lehto, 2006). In Sweden, this task was undertaken by representatives from industry, the community, and professional organizations at different levels of engineering education planning and management, and through direct presentation in the academic curriculum (Nilson, 1985). The experience of Eastern Washington University and Polytechnic University of Helsinki indicated that the only way to satisfy new requirements in engineering education is a systematic and long term cooperation between industry and universities (Lehto, 2006; Loendorf & Richter, 2006).

Motaharinejad, Yaghoubi, and Davami (2011) investigated the engineering education requirements, considering the industrial needs in Iran. They examined problems in the relationship between industry and universities, characteristics and competencies of engineering graduates, and university-industry relations.

Appreciating the previous studies, our current work is mostly focused on the technical and engineering disciplines and their relative position toward each other in the current status. In other words, considering society's needs and the shortage of expert manpower in each of the engineering fields, and its importance in the current condition in Iran, priorities of this field lies in student admissions and directing them toward community needs is determined. The reason for this emphasis is to avoid wasting time and cost for education in those fields which are not mostly demanded by the society, or have become saturated in the current conditions, and to direct students toward the most demanding fields. As a result, the unemployment rate in the educated class can be reduced. In addition, the most appropriate state for ranking in the higher education system is ranking educational groups (Mohammadi & Yadegarzade, 2002). Findings in this area suggest that if ranking is done based on the academic educational groups (disciplines) in the universities, their results can be used in the optimal way (Madhoushi & Niazi, 2010).

Methods

This is a descriptive field study of an implementation instance in the technical and engineering branch. The sample includes eight main groups, determined based on the literature and government reports. The validity of these criteria has been confirmed by a series of structured reports. These groups equate to academic disciplines and sub-disciplines. For example, pharmacy is a sub group of the medical group, or mechanical engineering is a sub group of the industrial group. The eight groups are: financial and economic, social and religious, industrial, political, services, agriculture, environment and natural resources, and hygiene/therapy. The groups were weighted using data from a questionnaire. The position of each group was specified using the weights and they were ranked. Fifteen popular technical and engineering branches in Iran also were compared to each other using another questionnaire. Each was compared with the main groups to determine the appropriate position of each technical and engineering field and the relationship among them all. A pair-wise comparison of the disciplines was also done. For instance, in current circumstances we need to train specialists in the computer engineering or agricultural engineering field. Common technical and engineering disciplines that have been reviewed in this paper are shown in Table 1.

Table 1. Technical and engineering fields

Electronic engineering
Industrial engineering
Chemical engineering
Computer engineering
Information technology engineering
Mechanical engineering
Material engineering
Biomedical engineering
Robotics engineering
Mining engineering
Civil engineering
Oil engineering
Architectural engineering
Aerospace engineering
Agriculture engineering

Finally, after comparing multiple factors with the desired goals, we created a hierarchy based on eight criteria and fifteen fields (Figure 1). We used Expert Choice (EC) software, version 11 (Arlington, VA) (Motaharinejad, Yaghoubi, & Davami, 2011) to perform this hierarchical analysis.

We used questionnaires and interviews to gather data. Participants had considerable experience and knowledge, in both what society needs, and about their field. For example, managers of large organizations know what technical deficiencies exist in each section of society, or university leadership is aware of the status of each field. Participants included professionals such as managers of large organization, faculty members, directors of educational groups, engineers with at least Master of Science. degree and 10 years of experience, and so on.

Data analysis

For our hierarchical model, we calculated the weight of criteria and disciplines and entered them into EC. One strength of AHP and EC is using pair-wise comparison of two elements to obtain exact rates of excellence for each level of elements, instead of using traditional methods of weight allocation (Steuer & Paul, 2003).

Following the model development, we next evaluated the elements using pairwise comparison, which is the process of identifying the relative importance or probability of two elements in relation to another element at a higher level. Three evaluation models for pairwise comparisons include verbal judgment, graphical judgment, and numerical judgment. For our comparison, we used the numerical judgment method, using nine scoring scales to determine the extent of superiority for each element over the other. Since our decision tree has eight criteria that must be compared with each other in a pairwise manner, there were 24 comparisons, according to the following equation, where "n" is the number of comparisons and "r" is the number of nodes (comparison elements):

$$n = \frac{r(r-1)}{2}$$

At the second level, our model gave us 15 options, which would produce over 111 comparisons. This number of option comparisons would be very time consuming, since a large number of pair-wise comparisons would have to be run for the options toward each criterion. Therefore, instead of pairwise comparisons for the options, we used a data network. A data network integrates the ability of hierarchical and pairwise comparison to evaluate hundreds or thousands criteria. The options are prioritized based on each criterion in the data network and a priority is assigned to each option. The data network uses an increasing utility curve, with a possible value range of 1-8; the curve type is specified as linear, and larger values have higher priorities. We analyzed the priorities for each group, and specified as a criterion the effect of each group on the engineering fields. Another outcome was the ranking of technical and engineering disciplines according to current conditions in Iran.

Another advantage of the AHP method is "decision" compatibility control. It is always possible to compute a number of incompatible decisions in AHP and reach an estimated result (Moshref Javadi & Azmoon, 2011). For example, if A is twice B, and B is three times C, then A equals six times C. This is said to be a compatible estimation. However, human estimations are not always compatible in practice. Therefore, the incompatibility rate was calculated for each matrix separately, and matrices with incompatibility rates above 0.1 were monitored after entering data into EC software to obtain compatibility.

Results

Our hierarchical structure (see Figure 1) has 3 levels. The first consists of the main problem or the goal, the second level has the eight criteria, and third includes the desired options (the 15 technical and engineering fields).

Table 2 gives the final results for the weights of the eight criteria in the second level. The values indicate the importance of each group, presented in descending order, with the financial and economic group at the top. The industrial, hygiene/therapy, and services groups are next. These results show that the financial and economic group has special importance and is in even more demand in the

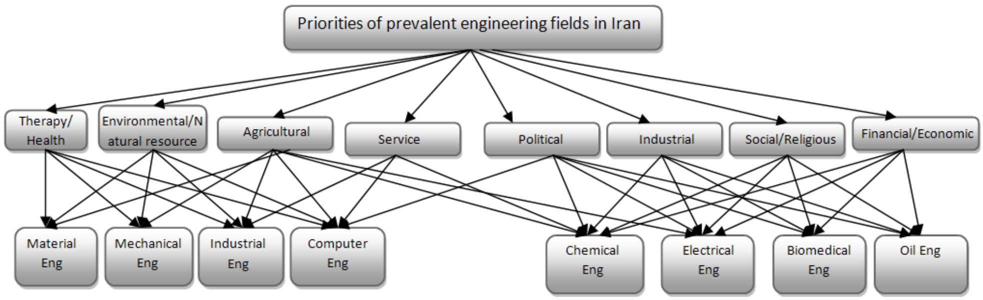

Figure 1. Analytic Hierarchy Process (AHP)

current economic conditions. The industrial group is in second place, which is represented by the technical and engineering group in our study. It is at the second level, which suggests the need for trained experts in both groups, so that society is directed toward economic and industrial activities. This finding is supported by the focus of developed and advanced countries' economies. Economically strong countries that have professionals in this field encounter fewer economic problems such as unemployment, poverty, and so on. For example, countries such as Germany that have parent industries like automobile manufacturing have strong economies.

Table 2. Weights of the second level's criteria

Criteria	Weight
Financial/Economical	0.259
Industrial	0.207
Health/Therapy	0.144
Service	0.134
Agricultural	0.074
Social/Religious	0.067
Political	0.061
Environmental/Natural resources	0.054

The medical group is ranked third. Iran has made significant progress in medical sciences in recent years, but this rank still does not fulfil expectations considering the history of medicine in Iran. Unfortunately, there are still shortages of pharmaceuticals and new medical technologies. The service group is fourth, suggesting the need to train specialists in this field. Given that it takes considerable time to emerge with a professional skill set in the services field, it makes sense to provide technical and vocational training for students from an early age. Simultaneously, it would be beneficial to equip schools with practical and applied instruments to satisfy this requirement.

The fifth, sixth, and seventh ranks were filled by the agriculture, social/religious, and political groups with little differences between each other. Since Iran has an Islamic culture and historical background in Islam, the influence of Islam is apparent in these fields. This is also true about political groups. However, a need to train more professional people in the agricultural group is still felt. Considering the environmental conditions and climatic diversity of Iran, which makes it suitable for agriculture, this group is expected to act more effectively. More intense shortages in the four first groups could explain agriculture's lower ranking. The environment and natural resources group has the lowest priority. One interpretation of this position is that the importance of this group and its effects on other groups are still unknown. Hence, it should be introduced better to the community and people, because a country's resources allow industry to prosper. They are used in medical products, develop the economy, advance the agriculture, and have other similar advancing effects in the economy.

The ranking of the engineering disciplines and the incompatibility rates at the third level are shown in Figure 2.

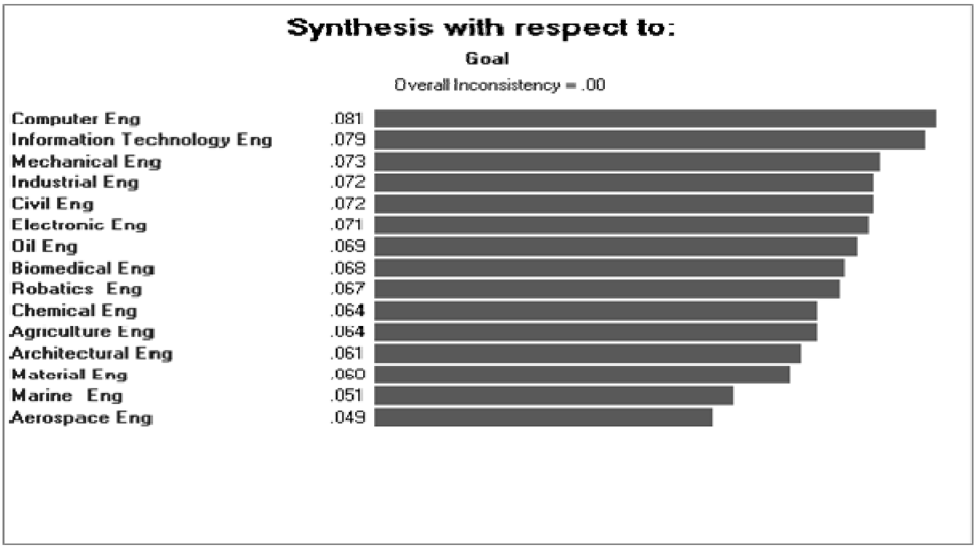

Figure 2. Ranking of technical and engineering fields

In this ranking, computer engineering is first, followed by IT engineering. Promoting and developing these fields helps us take steps toward achieving a modern and advanced society, with the goal of developing e-governance and e-society. Mechanical and Industrial Engineering are the next priorities. The ranking represents society's needs; the government can use the priorities to plan and recruit human resources in these areas. Doing so helps to reduce unemployment rates among college graduates, and prevents unnecessary costs for studying fields with limited job opportunities. The incompatibility rate in this study was less than 0.1 (see Figure 2), showing the compatibility and accuracy of respondents' answers.

We now review the results of the sensitivity analysis. Sensitivity analysis allows us to evaluate the results of decision making, showing how the sensitivity of the options (fields) varies by the criteria's (groups) importance. There are five types of sensitivity analysis: dynamic, performance, gradient, head to head, and two-dimensional. We selected a gradient sensitivity analysis (Figures 3 to 10). These diagrams show the impact of each group on the fields (or disciplines); a change in each group's impact changes the overall importance of the group. The importance of the groups is shown with a vertical line, such as that at 0.259 for the financial and economic group. For example, if the financial and economic group is needed by society and its effect is increased, petroleum engineering will be the first priority and civil and computer engineering will be ranked second and third, respectively. If we raise the value of industrial group, then, mechanical engineering will move to the top and computer and electrical engineering will be next. Thus, by increasing or decreasing the importance of each group, the priority of fields changes.

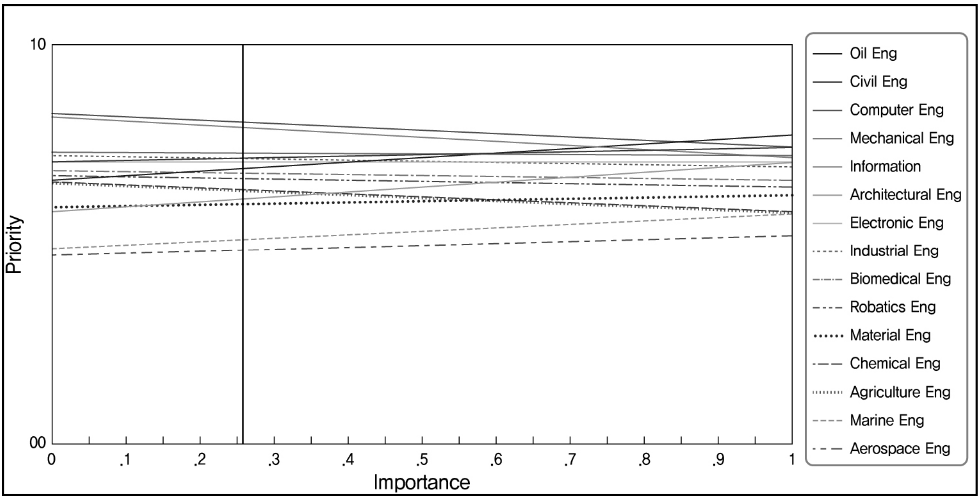

Figure 3. Priority of fields (Financial/Economical group)

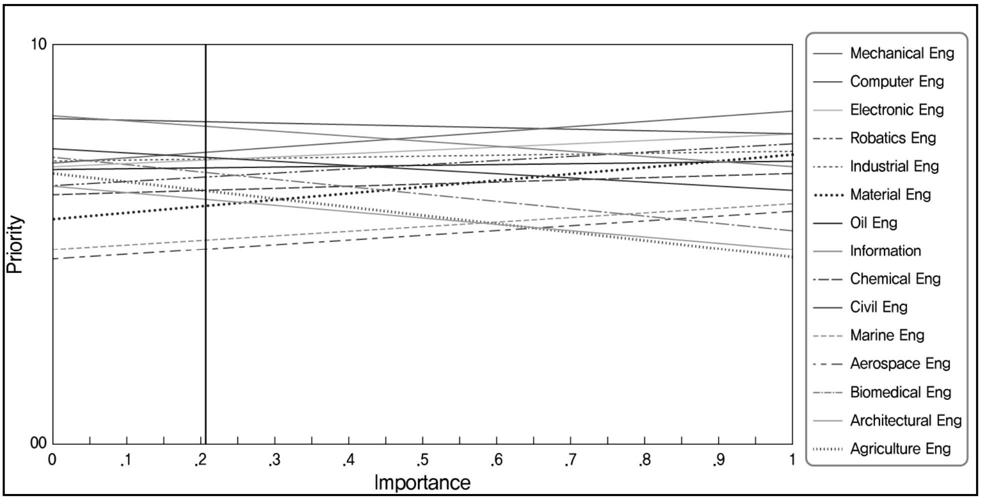

Figure 4. Priority of fields (Industrial group)

Figure 4 illustrates that if there is a higher demand for professionals in the industrial group, the electrical and computer engineering will move to be the highest priorities. Figure 5 shows that if religious and social sciences are needed in society, computer and architecture move up in the rankings. Figure 6 shows a scenario where the political group has greater demand, in which case technical fields such as oil, information technology and the computer will move to higher priority.

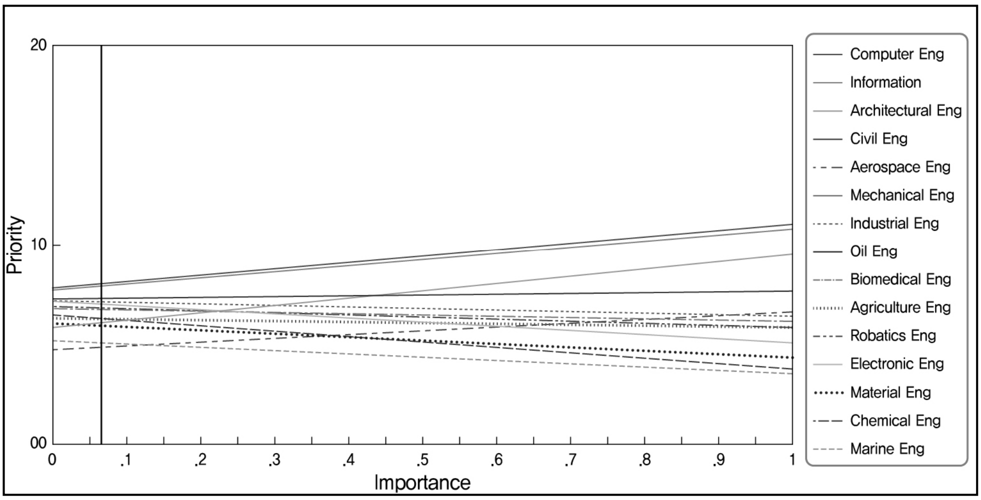

Figure 5. Priority of fields (Social/Religious group)

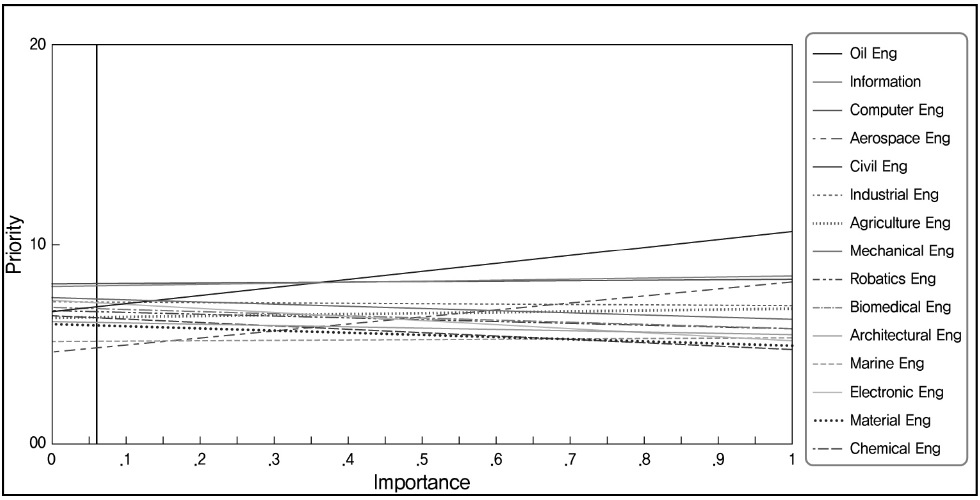

Figure 6. Priority of fields (Political group)

Figure 7 shows that in the services group, computer, information technology, and civil and biomedical engineering have top priorities. Figure 8 shows that if societal demands in the health sector, biomedical, robotics, information technology and chemical engineering have greater priority in responding to the needs of this group.

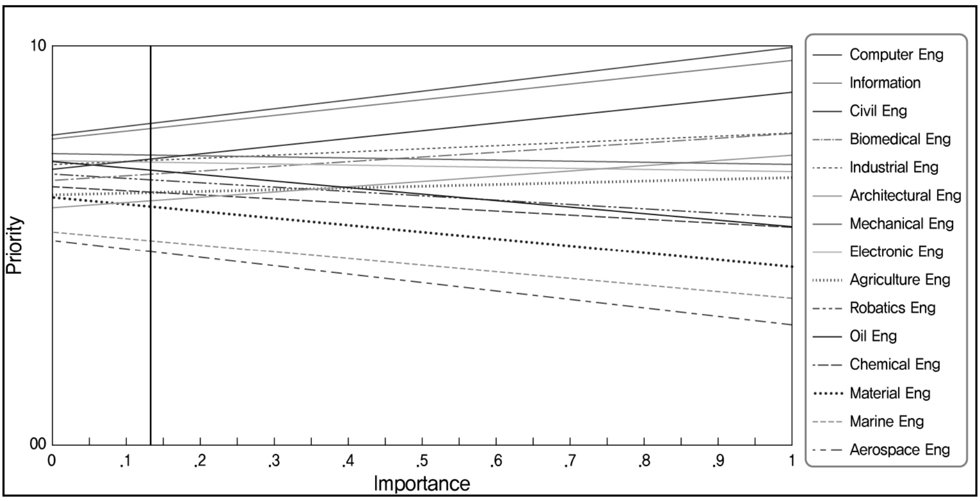

Figure 7. Priority of fields (Service group)

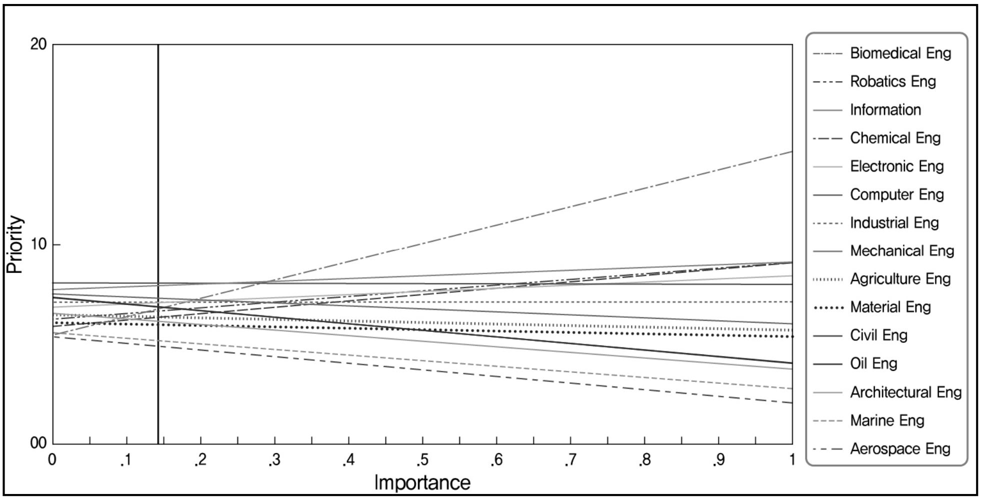

Figure 8. Priority of fields (Therapy/Health group)

Figure 9 shows that if there is a shortage of agriculture experts, agricultural, mechanical and chemical engineering have a higher priority. Figure 10 shows that if the department of the environment and natural resources need professionals, the agriculture, oil, civil and mining engineering increase in priority.

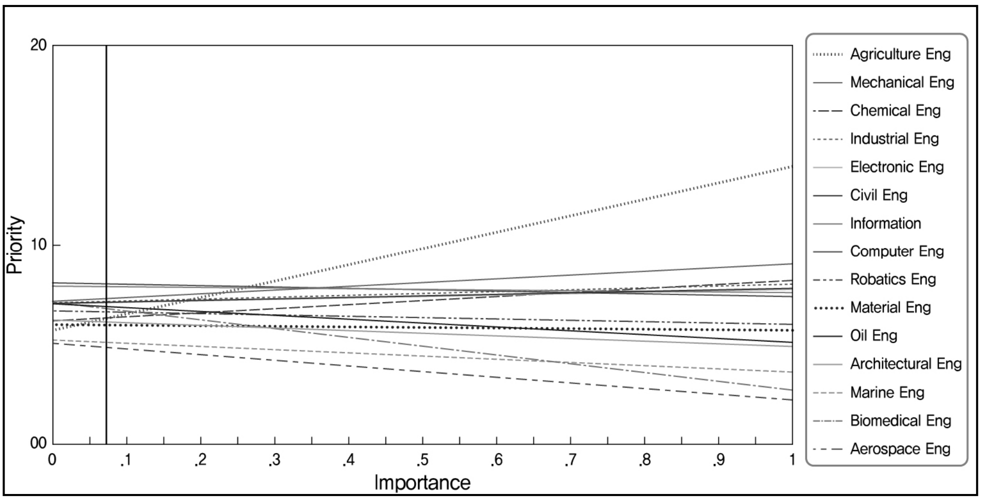

Figure 9. Priority of fields (Agricultural group)

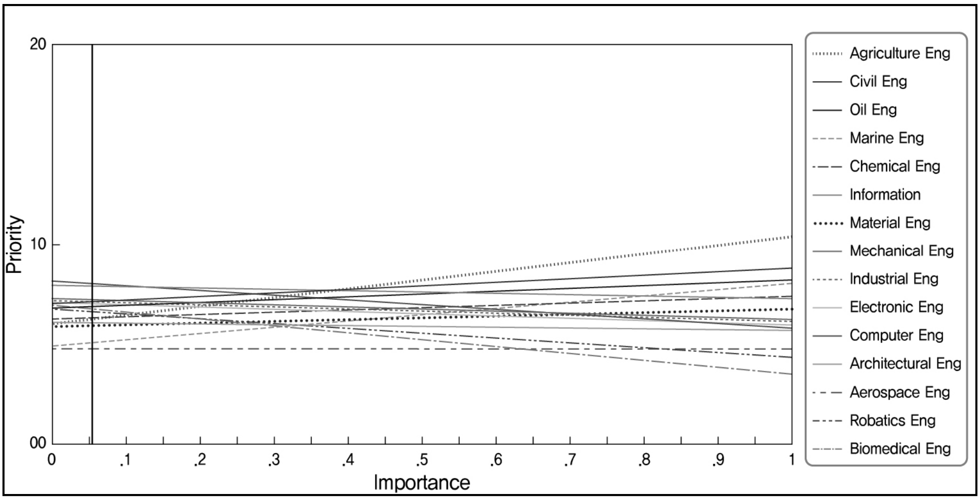

Figure 10. Priority of fields (Environmental/Natural resources group)

Conclusion

The findings of this study will help the government to identify priorities in the engineering fields. This method will help the government to determine the rank and priority of each field whenever one group becomes more important or more demanded by society. In other words, whenever and wherever more expertise is required, this method could be used to discern the priorities of any field. Some of these skills are more important at any particular time and in any particular location. Thus, the government will be better informed to meet society's needs, invest in the desired sectors, use its resources properly, and avoid wasting resources training people in unnecessary fields and to reduce unemployment rate among graduates.

It would be helpful to conduct future studies on other groups or fields with new and in-demand specialties, which are not available in the academic disciplines list, and specify their position, status, and importance. In addition, effective factors and regional characteristics in attracting students in these fields can be studied. This helps to avoid immigration to large cities and facilitates regional development because local specialists fill positions where expertise is in demand. For example, jobs required in the desert regions are different from those needed in mountainous regions. Likewise, a variety of jobs emerge in coastal cities. By leading the youth of these regions toward the fields that are related to their climatic conditions, many related problems will be solved.

This study's findings suggest the need to investigate regional findings in this vein so that the required fields in each region can be understood. The human resources in the region would then be encouraged to focus education on the related fields. In addition, we suggest a fuzzy hierarchical algorithm to be used to achieve more accurate results. We also recommend continuing this study in the training groups and in the new required fields, which are distinct from academic fields, to clarify their significance.

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Appendix: Academic degree ranking surveys in Iran

Respondent Name:
Level of education:

Dear Sir/Madam

In this study we are trying to determine the importance to society currently of various academic fields. This knowledge will provide governments with better evidence upon which to create policies that facilitate development of those fields. This questionnaire's aim is to specify the importance of any field relative to the other fields. We would appreciate your help in answering this survey, and have provided you with a list of criteria and instructions are given.

Instructions for completion of the questionnaire:

With the help of spectrum, try to determine the relative importance of the right index in comparison with the left index (or vice versa) in each of the following questions, and select a number to represent the importance.

Help spectrum

Absolute importance	Much more important	More important	Slightly more important	Equal importance
9	7	5	3	1

For example:

1. If the relative importance of criteria1 is equal to criteria 2, choose number 1 on the spectrum.

Measure 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Measure 1

2. If the relative importance of criteria1 is much more than criteria 2, choose number 7 from the left half on the spectrum.

Criteria 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 1

3. If the relative importance of criteria 2 is much more than criteria1, choose number 7 from the right half on the spectrum.

Criteria 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria 1

Now please choose appropriate number for each following spectrum:

Social/Religious	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic
Industrial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic
Political	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic
Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic
Agricultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic
Therapy/Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic
Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Financial/economic

Industrial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social/religious
Political	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social/religious
Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social/religious
Agricultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social/religious
Therapy/Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social/religious
Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social/religious

Political	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	industrial
Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	industrial
Agricultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	industrial
Therapy/Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	industrial
Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	industrial

Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	political
Agricultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	political
Therapy/Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	political
Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	political

Agricultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	service
Therapy/Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	service
Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	service

Therapy/Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	agricultural
Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	agricultural

Environmental/Natural resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Therapy/health

Dear Respondent,
In the following table, insert a number between 1-9 for each field to indicate the importance of the relevant criteria.

Therapy/health	Agricultural	Service	Political	Industrial	Social/religious	Financial/economic	Field name
							Electrical eng
							Industrial eng
							Chemical eng
							Computer eng
							IT eng
							Mechanical eng
							Material eng
							Biomedical eng
							Electronic eng
							Mining eng
							Robotics eng
							Civil eng
							Oil eng
							Architectural eng
							Aerospace eng
							Agriculture eng