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Collaboration Analysis Networks in the Technical and Engineering Research Institutes of Iran Ministry of Science, Research and Technology in Tehran (2011-2015)

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Abstract

This research intends to study the status of scientific outputs, core journals in the fields of technical and engineering, and the scientific collaboration between Technical and Engineering Research Institutes of Iran Ministry of Science, Research and Technology in Tehran. Data were obtained from Scopus and WOS databases during 2011 and 2015.

This scientometrics research has been carried out by Social Network Analysis. The community is scientific products of 7 different institutes related to MSRT in Tehran. These data needed in this research…..were collected databases in November 2015. The analysis result indicates that Iran's Institute of Polymer and Petrochemicals ranked first and the Genetic Engineering and Biotechnology Institute ranked second in the field of high-profile authors. There are also more scientific productions with more than 3 researchers. In the terms of cohesion, nearly %26 of researchers have collaborated with each other. Based on the (SNA) indicators, NIGB is the most active institute in the formation of scientific networks of research and technical areas. It was also shown that the largest scientific production was in collaboration with the United States.

Subject field can be one of the factors of high scientific production of two IIPPI & NIGEG. The result showed that in scientific interactions, the trend of group work in TETRI is not effective enough. One of the reasons might be the attention to the basic topics of each discipline and the lack of attention to the solution of interdisciplinary issues. The NIGEG has a privileged position among other research institutes and has more power and influence in the network. The United States has been the focus of the researchers' attention, and this could be due to less obstacles in the country.

Keywords- Scientometrics, Science Production, Collaboration, Social Network Analysis, Technical and engineering research Institutes in Tehran, Ministry of Science, Research and Technology

Paper Type- Research paper

Introduction:

Interaction between researchers is well-known to be the essence of research practice. Researchers interact not only to communicate research activities but also to collaborate with each other to co-produce research and co-author research results (Melin and Persson 1996), (Cheong and Corbitt 2009).

Since the first collaborative paper appeared in 1665 (Luukkonen, Persson et al. 1992), scientific collaboration has become prevalent in various disciplines (Glänzel 2002); (Larivière, Gingras et al. 2006); (Franceschet 2011); (Liu, Chang et al. 2012); (Chang and Huang 2013); (Han, Shi et al. 2014).

Collaboration is one of the ways of improving the quality of science (Ki-Wan, 2006; (Lundberg, Tomson et al. 2006); (Nikzad, Jamali et al. 2011). Collaboration among scientists has been on the rise over recent decades (Wagner and Leydesdorff 2003) and the wide availability of information technology and network information and facilities has improved national and international scientific collaborations (Wang, Wu et al. 2005). Collaboration increases the scientific and research potential of a country (Kim 1999). Although collaboration is not a quality indicator, it is a means to improve the quality of scientific works (Kim 2006); (Nikzad, Jamali et al. 2011).

The benefits and merits of research collaboration include: sharing and transferring knowledge and research equipment, connecting scholars to a large scientific network, expediting the research process, and increasing the visibility of article (Gazni and Didegah 2011); (Sooryamoorthy 2009); (Katz and Martin 1997); (Kim 1999); (Glänzel 2001); (Narin, Stevens et al. 1991); (Lawani 1986); (Gazni, Sugimoto et al. 2012).

A social network can be conceptualized as a set of individuals or references, each of which has connections of some kind to some or all of the others. In the language of social network analysis, people or groups are

called ‘‘actors’’ or ‘‘nodes’’ and connections are referred to as ‘‘ties’’ or ‘‘links’’. Both actors and ties can be defined in different ways depending on the questions of interest. An actor might be a single person, a team, or a company. A tie might be a friendship between two people, collaboration or common member between two teams, or a business relationship between companies (Newman 2001); (Newman 2001); (Newman 2001)[4] . In scientific collaborations' network actors (nodes) are authors and ties (links) are co-authorship relations among them. A tie exists between each two actors (scholars) if they have at least one co-authored paper.

About collaboration and network analysis a lot of studies have been done. However in the field of engineering and engineering institutes a few researches especially in Iran and other countries have been carried out. Due to the fact that engineering disciplines play an important role in the technology of the society, research in these fields leads to the effectiveness and efficiency of this field. Engineering subjects and related disciplines have a large volume of scientific publications in the whole world, which are based on a large number of bases to choose, provide, store, organize and disseminate information in this field. Science. A comprehensive map of knowledge and a detailed assessment of science in the technical and engineering departments of the Ministry of Science, Research and Technology of Tehran, can provide a visual representation of the current situation and take on a number of decisions. Strategic actions in this area are useful, effective and facilitating. The study will attempt to answer the following questions:

a. How is the trend of research outputs in technical and engineering fields separately sorted by different fields of study within institutions under supervision of Ministry of Science, Research and Technology in Tehran between 2011 and 2015?
b. What are the types of scientific outputs generated in technical and engineering fields in the Ministry of Science, Research and Technology in Iran?
c. What is the language of scientific outputs in technical and engineering fields?
d. Which journals published the documents generated in technical and engineering fields within institutes of Ministry of Science, Research and Technology in Tehran? What are core journals?
e. Who are the research producers with highest productions sorted by publications in technical and engineering fields within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran?
f. How are collaboration indices of authors in technical and engineering fields in institutions of Ministry of Science, Research and Technology in Tehran formed?
g. Who are core scientists in scientific interactions within collaboration network of researchers within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran, based on criteria of centrality, degree, betweenness and closeness?
h. Which one of research institutes in the scientific and technical network of the Ministry of Science, Research and Technology in Tehran are Active and influential?
i. What are the countries with most common collaborations with institutes under supervision of Ministry of Science, Research and Technology in Tehran (in technical and engineering fields) in generating scientific outputs?
j. Most important thematic clusters in technical and engineering institutes of Ministry of Science, Research and Technology in Tehran

Research Methodology

The methodology used is a kind of scientometrics research. The approach of this study is descriptive-analytical that is carried out in a sectional manner. The population consist of scientific outputs from seven technical and engineering institutes under supervision of Ministry of Science, Research and

4 . Newman 2001 a, b& c

Technology in Tehran (shown in Table 1). Data collection was done based on information databases of Web of Science and Scopus. The period of this research is between 2011 and 2015.

Table 1. Statistical society of research

Research Center Name	Abbreviation	No. of Faculty members	No. of Data in 2011-2015
International Institute of Earthquake Engineering and Seismology	IIEES	47	238
Iran Polymer and Petrochemical Institute	IPPI	91	1568
Chemistry & Chemical Engineering Research Center of Iran	CCERCI	38	556
National Institute of Genetic Engineering and Biotechnology	NIOAS	70	1108
National Institute of Oceanography and Atmospheric Science	NIOAS	37	36
Institute for Color Science & Technology	ICST	39	895
Aerospace Research Institute	ARI	-	92

To evaluate the data, scientometric software such as Bibexcel are used along with tools for drawing and analyzing data such as Ucinet and NetDraw. This software is of the most complete and the most practical software in analyzing social networks. In current research, the co-authorship network of scientific outputs from institutional societies are analyzed in both micro and macro levels.

Macro indicators for analyzing social networks evaluate indicators such as density, clustering, coefficient and mean distance of the network. The density indicator shows the way network nodes are connected to each other and determines the cohesion and compactness of the network. The value of density is always between zero and one. The zero value denotes that there is no connection between any nodes within the network, while 1 means otherwise. The clustering coefficient relates to the clustering and the inclination of an individual within the network to form different clusters through co-authorship. The mean distance factor indicates the mean of the shortest path (geodesic path) between two nodes. The mean distance facilitates faster transition of information within a network.

Apart from macro indicators, micro indicators will be used to evaluate the performance of each node within the network. Centrality is one of the most important micro concepts in analyzing social networks and examines the importance and influence of individuals in social networks using three indicators of degree, betweenness and closeness. The centrality of a node shows its connection with other nodes of a network; in other words, it shows the number of co-authorships with other individuals within the network.

The obtained outputs from the pre-processing stage were entered as inputs to other software such as statistical software Vosviewer and NetDraw so as to be evaluated for answering research questions.

In this stage, the following processes are completed: conversion of text file to Word file, conversion of Word file to the text format of web of science, and in the third stage, since the co-occurrence matrix of names of countries and authors were drawn in this study, names of countries and authors were separately extracted from text files using Bibexcel. After that, co-occurrence of names of countries and authors were evaluated and entered Ucinet for drawing co-occurrence matrix of the achieved outputs. Using this software, drawn maps were evaluated next.

In order to examine the situation of authors' collaboration in producing papers in technical and engineering fields and in determining their collaboration coefficient, the formula proposed by (Ajiferuke, Burell et al. 1988) is used:

$$CC= 1 - [\sum_{j=1}^{k} \left(\frac{1}{j}\right) \times (\frac{fj}{n})$$

Where:
N= total number of published articles
K= the maximum number of authors in the article
J= articles with one author, two authors, three others and so on.
FJ= the number of articles with J authors.

In this formula, the collaboration coefficient (CC) is between one and zero; the coefficient values near one denote higher contributions (Ajiferuke, Burell et al. 1988).

Findings:

a. The trend of research outputs in technical and engineering fields separately sorted by different fields of study within institutions under supervision of Ministry of Science, Research and Technology in Tehran between 2011 and 2015

To answer this question, scientific outputs from technical and engineering institutes under supervision of Ministry of Science, Research and Technology are extracted from databases of Scopus, and ISI. These data are acquired based on the stages mentioned in the methodology section and presented sorted by institutes in Table 2.

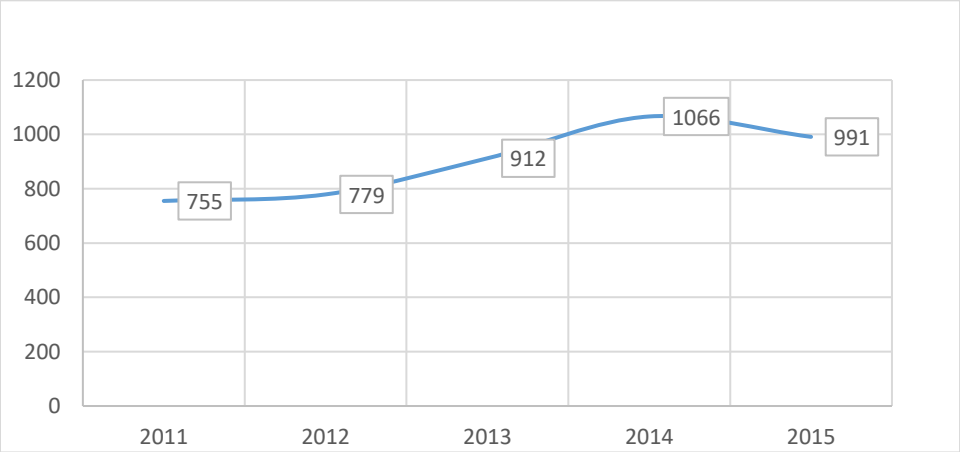
Table 2. Scientific achievements index

Instit.	ICST		CCERCI		(NIOAS)		(IIEES)		(IPPI)		(NIGEB)		(ARI)		total
Databases	Scopus	ISI	Scopus	ISI	Scopus	ISI	Scopus	ISI	Scopus	ISI	Scopus	ISI	Scopus	ISI	
2011	58	47	32	30	0	0	21	18	174	151	114	89	15	6	755
2012	68	58	56	46	0	0	20	25	157	131	120	68	17	13	779
2013	89	83	59	46	1	0	9	39	176	156	135	88	16	15	912
2014	133	114	75	68	16	0	19	39	163	150	161	120	4	4	1066
2015	129	116	73	71	19	0	14	34	164	146	127	86	3	9	991
Total	477	418	295	261	36	0	83	155	834	734	657	451	55	47	4523
	895		556		36		238		1568		1108		102		

Refer to table 2, Institute for Color Science & Technology has acquired 895 documents Chemistry & Chemical Engineering Research Center has acquired 556 documents, National Institute of Oceanography and Atmospheric Science has acquired 36 documents, Institute of Earthquake

Engineering and Seismology has acquired 238 documents, Iran Polymer and Petrochemical Institute has acquired 1568 documents, Institute of Genetics has acquired 1108 documents, and Aeorospace Research Institute has acquired 102 documents between 2011 and 2015. These quantities are the sum of gathered data that are acquired from WOS and Scopus databases through the strategies explained in the previous section.

Figure 1. The growth rate of scientific outputs in technical and engineering institutes in Tehran between 2011 and 2015



To calculate the overall average rate of research articles in the study period, the geometric mean has been used to calculate the overall growth rate and is calculated as following:

$$G = \sqrt[n]{G'1 \times G'2 \times G'3 \times G'4 \times \ldots \times G'n}$$

Where GN shows the number of research articles for each year.
Figure 1 shows the growth of scientific outputs of technical and engineering institutes related to the Ministry of Science, Research and Technology in Tehran from 2011 to 2015, in which the numbers are sorted by years and are calculated from Equation 1. As it can be witnessed. This trend shows an exponential relationship, such that most outputs were in 2014 with 1066 documents and fewest documents are related to 2011 with 755 documents. It can be shown in this figure that there is significant growth between 2011 and 2014, which denotes a growth with a high rate since the increase of documents from 755 to 1066 is not considered a notable growth. In fact, there were some kinds of gaps in the growth of publications between 2014 and 2015.
The results of this study indicate that the growth trend of scientific outputs of technical and engineering research institutes has risen in the period from 2011 to 2015 and has a significant annual growth rate of 199 papers per year, and has shown an increasing trend and an exponential relationship with the growth of publications. In the meantime Iran Polymer and Petrochemical Institute has produced the most scientific outputs among technical research institutes in the five-year period.

b. Types of scientific outputs generated in technical and engineering fields in the Ministry of Science, Research and Technology in Iran.

After the required data was extracted and evaluated from databases of Scopus and Web of Science, the related results are shown in Table 3. The numbers shown in this Table show that in total, the

extracted records are presented in 8 types of documents. In the table above, from the overall 2322 documents acquired from Scopus and Web of Science databases, 2112 of them (90.9%) were research articles. Furthermore, 105 seminar articles (4.5%) and 40 review articles (1.7%) were among these articles. Other generated documents are listed in Table 3.

Table 3. Types of scientific outputs

NO.	Type of documents	Plenty	Percent of total
1	Article	2112	90.9
2	seminar articles	105	4.5
3	Review articles	40	1.7
4	Ready to published articles	25	1.07
5	Section of book	15	0.64
6	Editor's Letter	15	0.64
7	Editorial	6	0.25
8	Notation	4	0.17

c. Language of scientific outputs in technical and engineering fields

A review of published articles in technical and engineering institutes of Ministry of Science, Research and Technology in Tehran is presented in Table 4. It can be witnessed that 2286 documents (98.36%) were written in English, while 24 documents (1.03%) were published in Persian.

Table 4. Language of scientific outputs

No.	Language	Plenty	Percent of total
1	English	2286	98.36
2	Persian	24	1.03
3	Arabic	3	0.12
4	Japanese	3	0.12
5	German	2	0.08
6	Russian	2	0.08
7	Bosnian	1	0.04
8	French	1	0.04
9	Portuguese	1	0.04
10	Serbian	1	0.04

d. Which journals published the documents generated in technical and engineering fields within institutes of Ministry of Science, Research and Technology in Tehran? What are core journals?

Table 5 shows the journals with highest number of published papers related to the population of this study. The information shown in this Table are acquired from Scopus and ISI databases, which are related to 10 best journals.

Table 5. Core journals in regards of scientific outputs of technical and engineering institutes in Tehran

Name of Journals	plenty	% of total
Journal of Applied Polymer Sciences	80	22.16
Iranian Polymer Journal	71	19.66
Bulletin of the International Institute of Seismology and Earthquake Engineering	43	11.91
Iranian journal of biotechnology	34	9.41
Journal of polymer research	31	8.58
RSC advances	27	7.47
Polymers for advanced technology	22	6.09
Polymer bulletin	19	5.26
International journal of civil engineering	17	4.70
Natural hazards	17	4.70

Overall in these 10 journals, around 361 articles are published between 2011 and 2015. Meanwhile, journal of applied polymer science related to Polymer and Petrochemical Institute with frequency of 80 (22.16% of all journals) was ranked the highest, and the journal of Natural Hazards related to the Institute of Earthquake Engineering and Seismology with 4.70 was ranked the lowest.

e. Research producers with highest productions sorted by publications in technical and engineering fields within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran

A list containing most productions in technical and engineering fields within technical and engineering institutes along with the names of their institutes are presented in Table 6.

Table 6. Research producers with highest productions

Authors	No. of ducuments	Name of Institutes
Khonakdar, Hossein Ali	78	Iran Polymer and Petrochemical Institute
Houshmand, S. Massoud	52	National Institute of Genetic Engineering and Biotechnology
Imani, Mohammad	46	Iran Polymer and Petrochemical Institute
Akbari, N, kambiz	46	National Institute of Genetic Engineering and Biotechnology
Naderi, Ghasem	45	Iran Polymer and Petrochemical Institute

Barikani, Mehdi	39	Iran Polymer and Petrochemical Institute
Ghasemi, Ismail	39	Iran Polymer and Petrochemical Institute
Mehdipour-Ataei, Shahram	39	Iran Polymer and Petrochemical Institute
Sadeghi, Mehdi	37	National Institute of Genetic Engineering and Biotechnology
Atai, Mohammad	35	Iran Polymer and Petrochemical Institute

After extracting information from related databases, it was revealed that ten authors that are included in the Table 6 are of most productive authors in seven technical and engineering institutes in Tehran. As you can see, Dr. Hossein Khonakdar is at the top of the table with 78 documents and, hence, is the most productive author among those in technical institutes. Moreover, Dr. Masoud Houshmand with 52 research articles from National Institute of Genetic Engineering and Biotechnology, and Dr. Mohammad Imani with 46 articles from Iran Polymer and Petrochemical Institute were second and third in most productive authors, respectively.

f. Collaboration indices of authors in technical and engineering fields in institutions of Ministry of Science, Research and Technology in Tehran

The collaboration coefficients of scientists within technical and engineering fields in institutions of Ministry of Science, Research and Technology in Tehran was also examined. In this regard, first, the articles were ranked based on their authors and after that, the collaboration coefficients for the authors was calculated using the following formula.

$$CC= 1 - [\sum_{j=1}^{k} \left(\frac{1}{j}\right) \times \left(\frac{fj}{n}\right)$$

Studying the collaboration network regarding the studied documents in this research showed that of 1960 studied documents, 33 documents were written by one author, 229 were written by two authors, 620 were written by three authors, 359 were written by four authors, and 719 articles were written by five or more authors. This denotes that only 33 documents were published by one author, and more than half of the documents were written by more than three authors(Ajiferuke, Burell et al. 1988).

Table 7. Ranking of articles in the field of engineering of research institutes based on their authors

No. of Authors	Plenty of documents	(1/J) × (fj/n)
One Author	33	(1.1) × (33 /1960) = 0.016
Two Authors	229	(1.2) × (229 /1960) = 0.005
Three Authors	620	(1.3) × (620 /1960) = 0.1023
Four Authors	359	(1.4) × (359 /1960) = 0.045
Five Authors	457	(1.5) × (457 /1960) = 0.046
Six Authors	33	(1.6) × (33 /1960) = 0.00256
Seven Authors	65	(1.7) × (65 /1960) = 0.00462
Eight Authors	164	(1.8) × (164 /1960) = 0.00996
Total	1960	1- 0.28144= 0.71856

The collaboration coefficient of researchers within technical and engineering institutes was calculated 0.72; this is a good collaboration coefficient for authors and shows that authors could bring about a fine and close collaboration in their scientific outputs. In other words, 72% of scientific outputs were

composed with scientific collaborations with other scientists. The collaboration coefficient takes a value between zero and one. The closer its value is to one, the highest the collaboration is; on the other hand, values close to zero shows lower levels of collaborations among scientists.

g. Important and core scientists in scientific interactions within collaboration network of researchers within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran, based on criteria of centrality, degree, betweenness and closeness.

To draw the scientific network of authors and researchers within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran, the co-occurrence of author's names in studied articles is used. In general, 3778 authors contributed to the production of scientific outputs in technical and engineering institutes. The collaboration network of these authors was previously presented in Figure 1; due to the extent of this area, only important authors are shown in the network.

Table 8. Cohesion Indicators of Co-operation between Researchers in Research institutes

Number of vertices	Avg. Degree	Density	Avg. Distance
990	6.77	0.007	4.430

Refer to Table 8, the network of researchers within technical and engineering institutes of technical and engineering institutes of Ministry of Science, Research and Technology in Tehran consist of 990 nodes. In fact, among 3778 authors related to scientific outputs in technical and engineering institutes, approximately 26% of them exist in the network and somehow collaborated to each other, which is also the basis of research collaboration in a research network. The collaboration network with the compaction of 0.007 denotes that the network is excessively insubstantial and the researchers could not establish many connections to each other and most connections are set up among a limited number of researchers; further, the value of 6.77 for the average network degree shows that on average, the authors collaborated with at least 6.7 other authors in generating their scientific outputs. The average distance between nodes of the network is 4.430, which shows that to create a scientific collaboration in the network, researchers should take at least four steps to reach the other side of the network. Hence, the distance between authors who attempt to collaborate is high.

Important and core authors in the collaboration network of researchers are determined using different criteria for evaluating collaboration network such as degree centrality, betweenness and closeness and are presented in Table 9.

Table 9. Ranking of betweenness indicators in collaboration network among researchers

Degree	score	Betweenness	score	Closeness	Score
Akbari Noghabi, K.	148	Najafi, F.	15.21	Sadeghizadeh, M.	2.331
Houshmand, M.	142	Sadeghi, M.	9.37	.Noghabi, K.A	2.330
Sadeghi, M.	142	Houshmand, M.	8.5	Najafi, F.	2.328
Ramezanzadeh, B.	123	Sadeghizadeh, M.	8.4	Sadeghi, M.	2.324
Saeb, M.R.	119	.Noghabi, K.A	6.9	Ahmadian, G.	2.323
osavi-Movahedi, A.A.	118	Zare, M.	6	Yakhchali, B.	2.321
Najafi, F.	110	Mousavi, A.	5.6	Behmanesh, M.	2.320

Yakhchali, B.	98	Yakhchali, B.	4.9	Aminzadeh, S.	2.320
Mousavi, A.	96	Ahmadian, G.	4.3	Salmanian, A.H.	2.320
Sharafi, H.	96	Ebrahimi, M.	4.6	Houshmand, M.	2.318

Based on degree centrality, Mr. Abari Neghabi received the highest degree centrality with 148 points, which means that this author has had highest collaborations in scientific collaboration networks among researches within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran. Thus, due to shaping the collaboration network and increasing the interactions among researchers in technical and engineering fields related to Ministry of Science, Research and Technology in Tehran, this author has a central and polar role and most of our collaborations within the network are attracted to this author.

When examining betweenness, Mr. Najafi received the highest betweenness level among researchers with the level of 15.21, which shows that this author contributes actively in cohesion and connections among different nodes and the body of the network. In other words, this author acts as a bridge that has connected different authors in the network. As it can be witnessed in the collaborative network of researchers in Figure 1, this author has established connections among different components of the network; therefore, he has enabled the information to be shared among components. As a result, the connections among researchers will be eliminated if this node does not exist within the network system.

In regard to closeness, Mr. Sadeghizadeh has gained the highest closeness level among authors within the collaborative network of technical institutes with the grade of 2.331. This denotes that this author could enjoy a close and comfortable relation with different people in the network; in other words, his connections and interactions with other members of the network happened with minimum constraints and he can have a close relationship with different researchers.

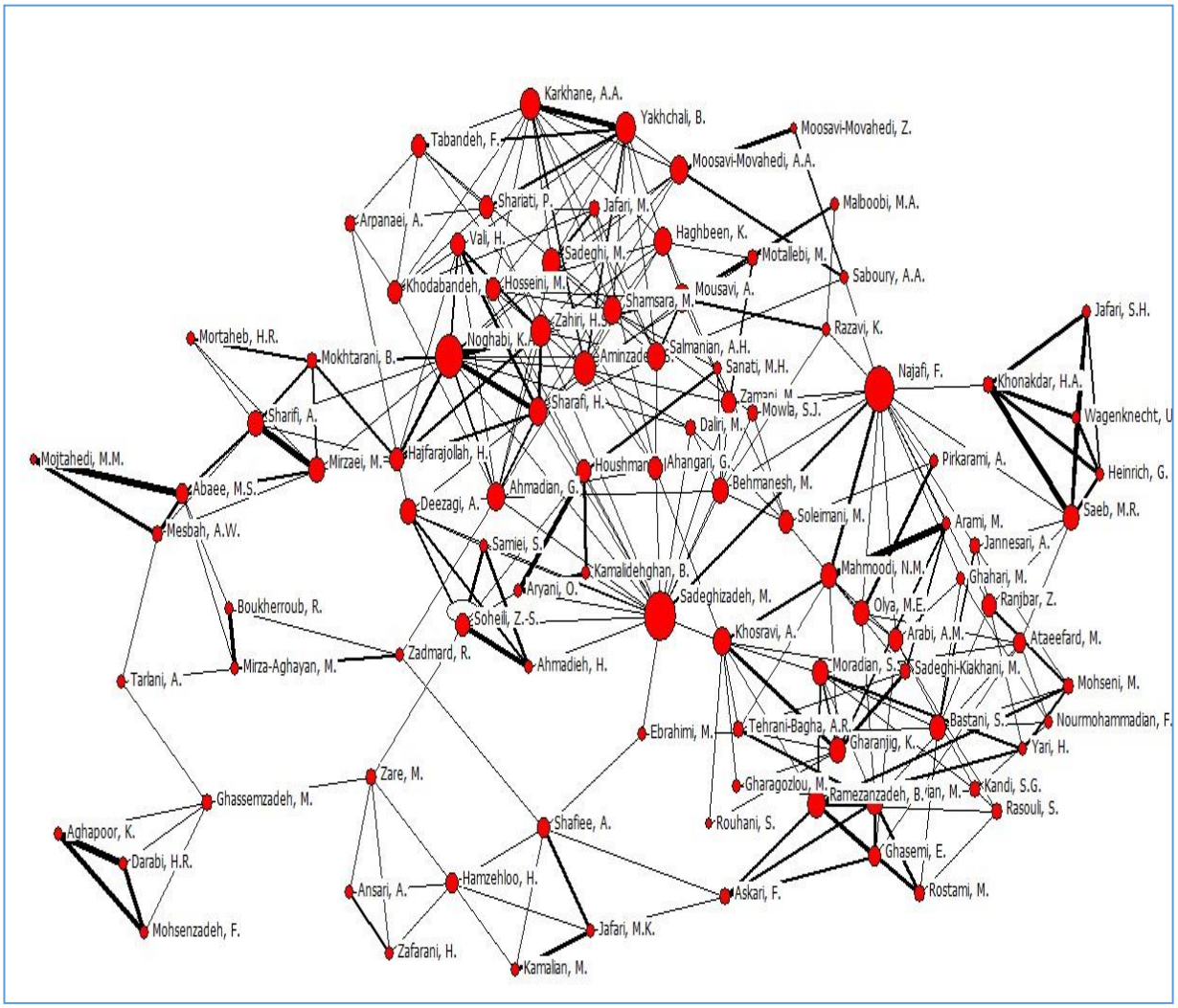


Fig 1. The collaborative network of researchers

h. Active and influential research institutes in the scientific and technical network of the Ministry of Science, Research and Technology in Tehran

To draw the collaboration network of active institutes and universities in producing scientific outputs related to technical and engineering institutes, the co-occurrence of names of institutes and universities was used in the specifications of article. In this regard, since the names of institutes and universities were written in different formats in articles, first these names were converted to one format. After that, the co-authorship network and classification of subjects were conducted using co-occurrence section of Bibexcel. The outputs of Bibexcel which are in the NET format were then used as inputs to NetDraw software.

Table 10. Cohesion Indicators of Collaborative between Researches institute in Tehran with other institutes & universities

Number of vertices	Avg. Degree	Density	Avg. Distance
256	6.311	0.143	2.148

The collaboration network of institutions and universities that has the compaction of 0.143 (table 10) shows a weak and discontinuous network. This denotes that despite the fact that there are

connections among different institutes in the network, not many connections have been made between institutes, organizations and universities.

Compactness in a network is defined as direct connections between factors within a group and has the highest share in potential relations within the network (de Nooy, Mrvar et al. 2005). The value of compactness takes values between zero and one. If this value is close to one, it shows that the network has a proper compactness; on the other hand, the values close to zero denotes that the connections between factors are weak and due to low number of connections, the network is insubstantial.

The average value for network degree is 6.311, which shows that technical and engineering institutes collaborated with approximately 6 other institutes and universities in generating scientific outputs. In other words, each institute collaborated to average of 6 institutes or universities in generating scientific outputs. The mean value of geodesic distance is 2.148, which shows the diameter of the network. This indicator, in fact, shows that to reach to one side of the network from the other side, at least two and a half steps should be taken. Particularly, institutions should pass other 2.148 mediator nodes to establish a collaboration within the scientific network.

As it can be seen in the network, technical and engineering institutes of Ministry of Science, Research and Technology in Tehran are shown with blue color (figure 2).

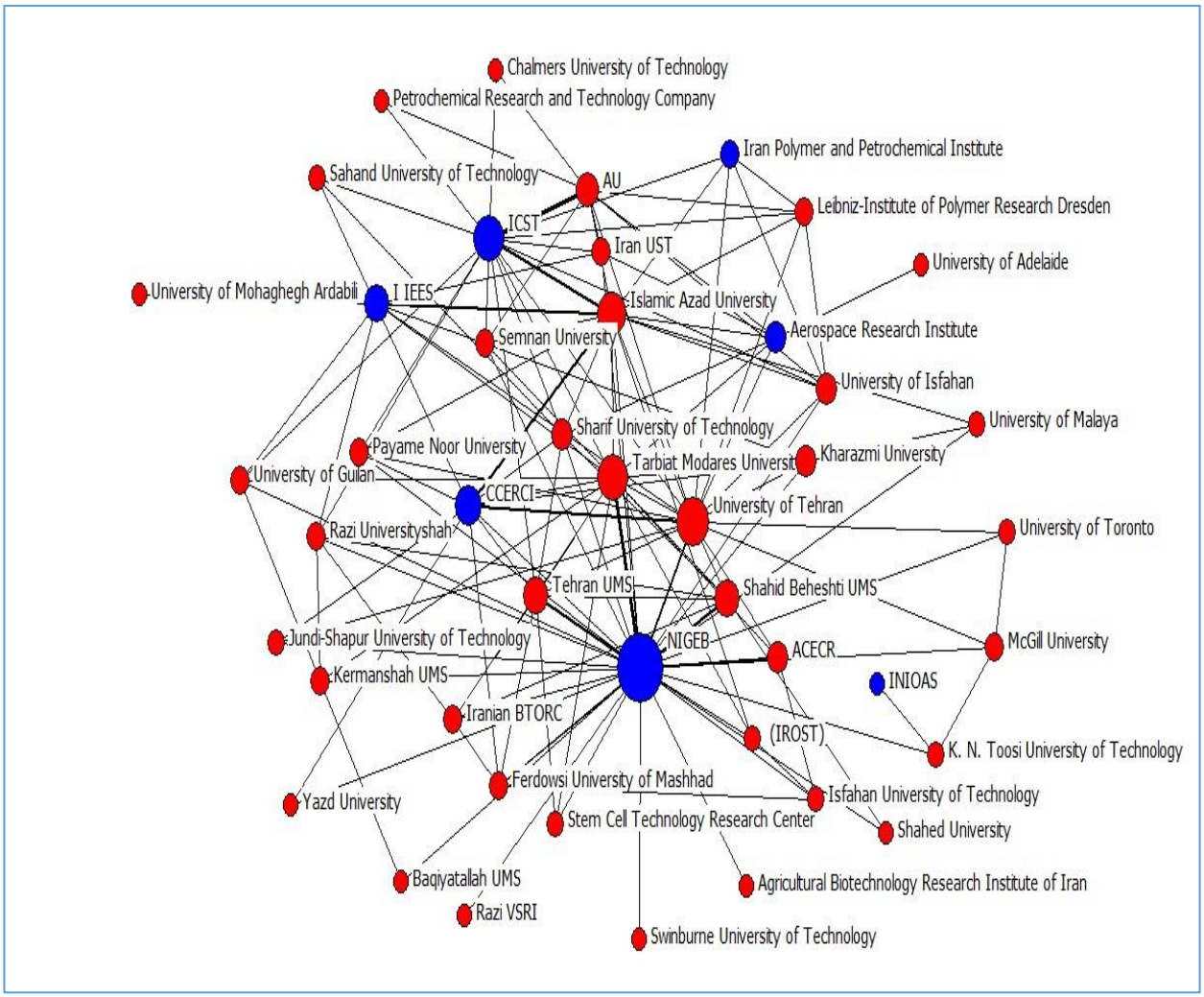


Fig 2. Collaborative network of research institutes, universities

Using different criteria for evaluating the network, the significance and importance of institutes in network structure were examined, the results of which are presented in Table 11.

Table 11. Ranking of technical and engineering institutes based on network analysis indicators

Degree	score	Betweenness	score	Closeness	Score
NIGEB	159	NIGEB	47/4	NIGEB	73/3
ICST	137	ICST	10/6	CCERCI	54/3
CCERCI	29	IIEES	5/1	ICST	53
IIEES	21	CCERCI	3/4	IIEES	50
ARI	10	IPPI	2	IPPI	40/2
IPPI	5	ARI	1/5	ARI	37
INIOAS	1	INIOAS	0/8	INIOAS	30

Based on the criteria for evaluating the scientific network in this study, National Institute of Genetic Engineering and Biotechnology (NIGEB) was known as the most active, the most central and the most important institute in forming the scientific network of technical and engineering fields within different institutes. Indeed, this institute has gained the score of 159 for degree centrality, which shows that most collaborations and connections that exist in the scientific network are attracted to this institute and this institute plays the central role in forming collaboration networks.

Based on the betweenness criterion, National Institute of Genetic Engineering and Biotechnology with the grade of 47.4 exists in the confluence of different institutes and universities within the network. Particularly, this institute has been placed in the center of the network and, thus, it facilitates the transfer of information and science among universities and institutes. Also, the value of closeness of this institute is 73.3, showing that this institute can use its closeness to other institutes so as to build collaborations within the network. Hence, the National Institute of Genetic Engineering and Biotechnology plays an important role in the producing, orienting and guiding the network of scientific collaborations.

i. The countries with most common collaborations with institutes under supervision of Ministry of Science, Research and Technology in Tehran (in technical and engineering fields) in generating scientific outputs.

Cohesion criteria related to the collaboration network of technical and engineering institutes and other countries are shown in Table 12.

Table 12. . Cohesion Indicators of Collaborative between Researches institute in Tehran with other countries

Number of vertices	Avg. Degree	Density	Avg. Distance
34	4.44	0.127	1.61

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The mean value of 4.44 for network degree shows that, on average, each institute have collaborated with 5 other countries. The mean value of geodesic distance is 1.61, which shows the diameter of the

network; it also denotes that for reaching the other side of the network, at least to steps should be taken from one side. In other words, to get from one side to the other side of the network, one should take approximately one and a half steps; based on this, nodes within the system pass through a short path to establish collaborations. The compactness of the network is equal to 0.127, which denotes that there were few collaborations among technical and engineering institutes in Iran and other countries and some countries contributed well in forming scientific outputs of institutes.
With the numbers in the table 12, Figure 3 is derived from the software, which indicates the linkages between the entities or the collaborative countries and Engineering and Technology Institutes in Tehran. The size of nodes indicates their greater association with the studied population.

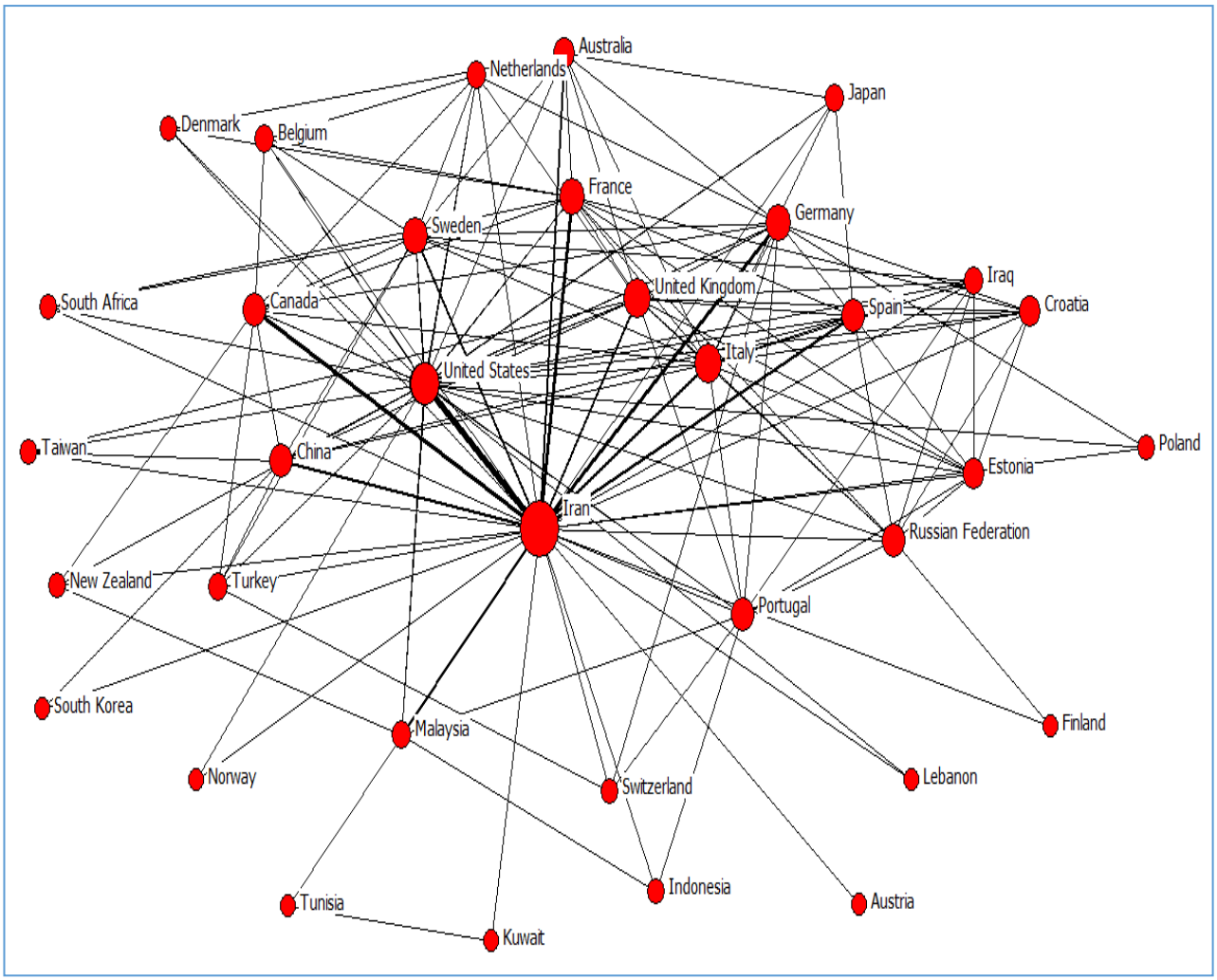

Fig 3. Collaborative network of different countries in the field of scientific output of technical and engineering research institutes

With regard to centrality criterion, the United States has had most interactions with technical and engineering institutes in Iran and other countries. In other words, this country with 88 points in degree centrality shows that it was the focal point of collaboration from other researchers. England, France, Germany, and Italy are ranked next based on degree centrality.

As it shows in (table 13), USA and Germany were important collaborators with technical and engineering institutes in Tehran with 104 and 102 documents respectively. Japan, Canada, Pakistan and France were other countries with high levels of collaborations with technical and engineering institutes. As it can be witness in the collaboration network, the connections among technical and engineering institutes (which are determined by the tag of Iran) and these countries are bolder than others.

Table 13. Collaborative countries with technical& engineering institutes in Tehran Based on cohesion indicators

Record	score	degree	score	Betweenness	score	Normalized Closeness	Score
United State	104	United State	88	Portugal	10/3	United State	23
Germany	102	United Kingdom	68	Italy	10	United Kingdom	12
Japan	96	France	55	France	8/7	Turkey	8
Canada	95	Germany	41	Sweden	7/9	Spain	6/4
Pakistan	63	Italy	35	Germany	6	Sweden	5/7

Furthermore, the United States with the closeness centrality of 23 has shown that it can establish comfortable and close relationships with other countries. Particularly, the connections and interactions of this country with other countries within the collaboration network is faced with fewer constraints and it can have collaborations with different countries within this network. Based on the aforementioned criterion, England, Turkey, Spain and Sweden are of most important and influential countries with respect to scientific collaborations.

When examining betweenness centrality, Portugal with the grade of 3.1 has had the highest betweenness centrality between collaborator countries with technical and engineering institutes of Ministry of Science, Research and Technology in Tehran. In particular, the high value of betweenness centrality in networks of scientific collaborations of technical and engineering institutes shows that this country is in the confluence of connections between different countries. Moreover, this institute has been placed in the center of the network and, thus, it facilitates the transfer of information and science among universities and institutes. Besides Portugal, countries of Italy, France, Sweden and Germany are other countries with high level of betweenness centrality in the scientific network of technical and engineering institutes in Tehran, each of which have a considerable share in transforming information among different countries.

j. Most important thematic clusters in technical and engineering institutes of Ministry of Science, Research and Technology in Tehran

To determine thematic clusters, scientific production of technical and engineering fields, their titles and their abstracts were examined and the keywords extracted from them were evaluated. After that, frequently used keywords for thematic clustering are used and, then, thematic clusters related to technical and engineering fields were drawn using Vosviewer software. (Li, Ding et al. 2009).

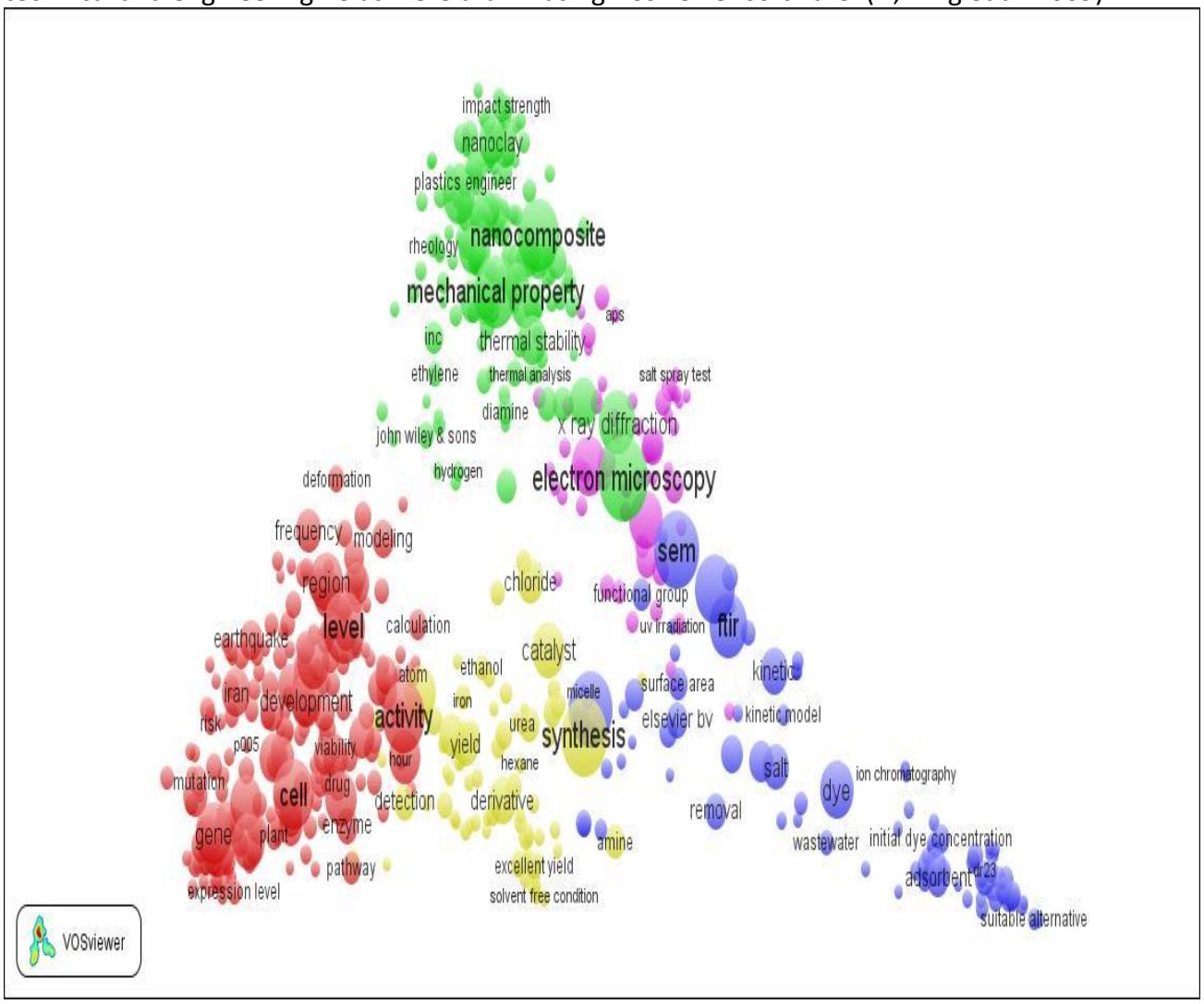

Fig 4. Most important thematic clusters in technical and engineering institutes

Also in this study, co-occurrence of keywords has been used as the basis of drawing thematic clusters. The nodes in the network show the concepts and the distances between concepts shows their relationships. The size of nodes determines the number of occurrence of keywords in the articles. The distribution of in the map of keywords co-occurrence and the close relationship between concepts and clusters shows that most of the articles focused on special subject such as genes, cells, Nano technology and so on.

The co-occurrence network shows the concepts within technical and engineering fields, in which each of clusters is shown in a distinct color. To better introduce the clusters, the keywords with highest number of events are assigned to their corresponding cluster.

The largest cluster in Figure 1 is shown in red color and covers 204 phrases. The concepts with highest frequency in this cluster are: Gene, Cell, Iran, Level, and Activity. The examination of concepts under cover of this cluster include concepts such as stem cells, tissue engineering, gene, cell proliferation, central nervous system. The information related to this issue is shown in Table 14:

The red cluster is mainly related to concepts of stem cells, so stem cells are the main subject of this cluster.

Also, the second cluster shows that this cluster is mostly related to Nano technology. The important concepts under this field include: Nano composite, mechanical properties, crystal structures, and thermal stability.

Table 14: Clusters and important subjects in research institutes in Tehran

Cluster's color	Important covered subjects	Total terms
Red	Gene, Cell, Iran, Level, Activity	204
Green	Nano composite, Mechanical Property, Blend, Nano clay, Electron Microscopy, X ray Diffraction	152
Blue	SEM, FTIR, Fourier, Kinetic	89
Yellow	Synthesis, Derivative, Chloride, Catalyst	78
Purple	Coating, X-ray, Electrochemical Impedance Spectroscopy	57

The third cluster, that has the blue color and can be seen at the right of the map, covers 89 phrases and subjects that are conceptually related to each other. Some of the concepts under this cluster include: Fourier-transform infrared spectroscopy (FTIR), X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM). This cluster is also in the concept of Nano composites; however, because that cluster is related to a special part of this concept, the open source software for text-mining has considered a separate cluster for this concept.

The fourth cluster which is shown on the left side of the map and has a yellow color, has covered 78 interdependent phrases, examples of which include Synthesis, Catalyst, derivative, and excellent yield procedure.

The fifth cluster which is in purple at the bottom of the map, has covered 57 interrelated phrases, some of which are carbon nanotube, corrosion inhibition, electrochemical impedance spectroscopy, and epoxy coating.

Results and Discussion

This research examined the collaboration network of researchers within technical and engineering institutes of Ministry of Science, Research and Technology in Tehran between 2011 and 2015. The results obtained from this study showed an increasing trend in research outputs related to engineering fields. In seven institutes examined in this study, the tendency to work is extremely week, and scientists could not establish suitable networks among each other. This can be due to the fact that these institutes are expert facilities with different fields of study; however, because engineering fields are inter-disciplinary fields of study, this collaboration must be higher. Regarding the studied institutes, no prior research has addressed these institutes and, hence, no comparison among these institutes could be made. This shows the novelty of this study related to the aforementioned institutes.

Although different scientific institutes are connected to each other in their network, few connections have been made among institutes, organizations and universities. When examining betweenness and centrality, National Institute of Genetic Engineering and Biotechnology holds the highest ranking. This demonstrates that this institute is in the confluence of connections between different countries and in the center of the network, which, in fact, facilitates knowledge and information transfer among universities and institutes. Furthermore, directing and leading the collaboration network of technical and engineering institutes done by this institute play an important role in productions. This institute holds an excellent position among others and has more power and authority in the network.

When examining degree and closeness criteria, the collaboration between technical and engineering institutes in Iran with those in USA was ranked the highest. This shows that USA was the center of attention of Iranian institutes for establishing collaboration. This also means that collaborating institutes within USA with technical and engineering institutes of Ministry of Science, Research and Technology in Tehran is faced with fewer restraints and this country (USA) is able to co-operate with different players within the network. All of these factors show the effectiveness, centrality and the key role of this country in the distribution of information among other countries. This research has also shown that the scientists with higher amount of scientific products held more share in co-authorships and group collaborations.

These research encountered some limitations, of which we can mention the high numbers of common documents that existed in both databases, which brought some problems in homogenization, preparation and also merging the obtained data. On the other hand, since the names of institutes and universities were written in different formats in articles, homogenizing these names created some problems for data evaluations. Also, because of the fact that naturally the research community will not stop their activities regarding the examined subjects and this project was a completely dynamic sort of project, a large amount of time was needed to result in best results and static projective representations as knowledge maps, which is in fact one of other limitations come across this study.

Researches and scientists must be aware of the advantages of group working so as to be successful in enacting research policies in a way for reaching the goals of country's sixth development plan. By looking at the highest-ranked scientific documents which are ranked based on global citations, and successful and prominent universities, it can be witnessed that high spirit for collaboration has resulted in publishing more successful scientific outputs. Generally, it can be concluded that the faculty within these seven institutes had not have any collaborations in common and few of them have been successful. It is essential that the authority should pay deep attention to bolster and plan for these institutes so as to improve them in the best way. Authors should know the value of publications that are based on valuable projects and scientific works and are published in prestigious journals in the world. This results in the scientific level of Iranian scientists to be known to the world, and the real value of Iranian scientific outputs will be presented to scientists from other countries.

Furthermore, one can draw knowledge maps in short-term, mid-term and long-term strategic planning schemes. The author's suggestion is to: 1) draw the growing trend of technical and engineering institutes within the country; 2) draw knowledge maps of technical and engineering fields within middle-east countries and compare them with those obtained from Iran; 3) compare and evaluate the position of technical and engineering fields in scientific outputs of the world; and 4) draw scientific maps of industrial outputs and compare them with productions.

With the ongoing development of inter-disciplinary fields and the need for different experts in future research, a codified is suggested for increasing collaboration indices and inter-disciplinary projects defined in this matter. Scientific collaboration is one of the most important components in scientific evaluation of various levels of authors, universities and countries. Hence, and since the scientific results have shown

that countries are more interested in establishing collaboration with multiple countries, it is suggested for institutions to devise approaches for increasing the collaborations of their employees with other countries to increase the quality of scientific outputs.

One suitable approach can be to set a committee in the Ministry of Science, Research and Technology for preparing and drawing knowledge maps of technical and technical and engineering; in this way, the scattering works in this regard will be minimized.

The scientific-technical-engineering maps can be available for experts, students and decision makers through Internet, just as these maps in other countries are available to me retrieved as scientific atlases.

Furthermore, encouraging and supporting policies can be implemented on scientific outputs by Ministry of Research, Science and Technology; this can be very helpful in increasing Iran's ranking in regional and global scales.

Surname, Initials (year), "Title of article", *Journal Name*, volume issue, pages.

References

Ajiferuke, I., et al. 1988. Collaborative coefficient: A single measure of the degree of collaboration in research. Scientometrics, Vol. 14, no. 5-6: 421-433.

https://link.springer.com/article/10.1007/BF02017100

Chang, H.-W. and M.-H. Huang 2013. Prominent institutions in international collaboration network in astronomy and astrophysics. Scientometrics, Vol. 97, no. 2: 443-460.

https://link.springer.com/article/10.1007/s11192-013-0976-x

Cheong, F. and B. J. Corbitt. 2009. A social network analysis of the co-authorship network of the Pacific Asia Conference on Information Systems from 1993 to 2008. PACIS 2009 Proceedings: 23.

https://aisel.aisnet.org/pacis2009/23

de Nooy, W., et al. 2005. Exploratory social network analysis with Pajek (Structural analysis in the social sciences), illustrated edition ed." Google Scholar.

DOI: 10.1007/s11336-005-1410-y

Franceschet, M. 2011. Collaboration in computer science: A network science approach. Journal of the American Society for Information Science and Technology , Vol. 62, no. 10: 1992-2012.

https://doi.org/10.1002/asi.21614

Gazni, A. and F. Didegah. 2011. Investigating different types of research collaboration and citation impact: a case study of Harvard University's publications. Scientometrics, Vol. 87, no. 2: 251-265.

https://link.springer.com/article/10.1007/s11192-011-0343-8

Gazni, A., et al. 2012. Mapping world scientific collaboration: Authors, institutions, and countries. Journal of the American Society for Information Science and Technology, Vol. 63. no. 2: 323-335.

https://doi.org/10.1002/asi.21688

Glänzel, W. 2001. National characteristics in international scientific co-authorship relations. Scientometrics, Vol. 51, no. 1: 69-115.

https://link.springer.com/article/10.1023/A:1010512628145

Glänzel, W. 2002. Coauthorship patterns and trends in the sciences (1980-1998): A bibliometric study with implications for database indexing and search strategies.

http://hdl.handle.net/2142/8409

Han, P., et al. 2014. International collaboration in LIS: global trends and networks at the country and institution level. Scientometrics, Vol. 98, no. 1: 53-72.

https://link.springer.com/article/10.1007/s11192-013-1146-x

Katz, J. S. and B. R. Martin. 1997. What is research collaboration? Research policy, Vol. 26, no. 1: 1-18.

https://doi.org/10.1016/S0048-7333(96)00917-1

Kim, K.-W. 2006. Measuring international research collaboration of peripheral countries: Taking the context into consideration. Scientometrics, Vol. 66, no. 2: 231-240.

https://link.springer.com/article/10.1007/s11192-006-0017-0

Kim, M.-J. 1999. Korean international co-authorship in science 1994-1996. Journal of Information Science, Vol. 25, no. 5: 403-412.

https://doi.org/10.1177/016555159902500506

Larivière, V., et al. 2006. Canadian collaboration networks: A comparative analysis of the natural sciences, social sciences and the humanities. Scientometrics, Vol. 68, no. 3: 519-533.

https://link.springer.com/article/10.1007/s11192-006-0127-8

Lawani, S. M. 1986. Some bibliometric correlates of quality in scientific research. Scientometrics, Vol. 9, no.1-2: 13-25. https://link.springer.com/article/10.1007/BF02016604

Li, L.-L., et al. 2009. Global stem cell research trend: Bibliometric analysis as a tool for mapping of trends from 1991 to 2006. Scientometrics, Vol. 80, no. 1: 39-58.

https://link.springer.com/article/10.1007/s11192-008-1939-5

Liu, H.-I., et al. 2012. Collaboration patterns of Taiwanese scientific publications in various research areas. Scientometrics, Vol. 92, no. 1: 145-155.

https://link.springer.com/article/10.1007/s11192-012-0719-4

Lundberg, J., et al. 2006. Collaboration uncovered: Exploring the adequacy of measuring university-industry collaboration through co-authorship and funding. Scientometrics, Vol. 69, no. 3: 575-589.

https://link.springer.com/article/10.1007/s11192-006-0170-5

Luukkonen, T., et al. 1992. Understanding patterns of international scientific collaboration. Science, Technology, & Human Values, Vol 17, no. 1: 101-126.

https://doi.org/10.1177%2F016224399201700106

Melin, G. and O. Persson. 1996. Studying research collaboration using co-authorships. Scientometrics, Vol. 36, no. 3: 363-377.

https://link.springer.com/article/10.1007/BF02129600

Narin, F., et al. 1991. Scientific co-operation in Europe and the citation of multinationally authored papers. Scientometrics, Vol. 21, no. 3: 313-323.

https://link.springer.com/article/10.1007/BF02093973

Newman, M. E. 2001. Scientific collaboration networks. I. Network construction and fundamental results. Physical review E, Vol 64, no. 1: 016131.

DOI: 10.1103/PhysRevE.64.016131

Newman, M. E. 2001. Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality. Physical review E, Vol. 64, no. 1: 016132.

DOI: 10.1103/PhysRevE.64.016132

Newman, M. E. 2001. The structure of scientific collaboration networks. Proceedings of the national academy of sciences, Vol. 98, no. 2: 404-409.

https://doi.org/10.1073/pnas.98.2.404

Nikzad, M., et al. 2011. Patterns of Iranian co-authorship networks in social sciences: A comparative study. Library & Information Science Research, Vol. 33, no. 4: 313-319.

DOI: 10.1016/j.lisr.2011.01.005

Sooryamoorthy, R. 2009. Do types of collaboration change citation? Collaboration and citation patterns of South African science publications. Scientometrics, Vol. 81, no. 1: 177.

https://link.springer.com/article/10.1007/s11192-009-2126-z

Wagner, C. S. and L. Leydesdorff . 2003. Mapping global science using international co-authorships: a comparison of 1990 and 2000. Proceedings of ninth international conference on scientometrics and informetrics, Beijing.

DOI: 10.1504/IJTG.2005.007050

Wang, Y., et al. 2005. Scientific collaboration in China as reflected in co-authorship. Scientometrics, Vol. 62, no. 2: 183-198. https://link.springer.com/article/10.1007/s11192-005-0013-9