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Establishing and Analyzing the Pattern of Relationships in Co-authorship Networks: the Case Study of Scientific Productions of Researchers at Kerman University of Medical Sciences

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Establishing and Analyzing the Pattern of Relationships in Co-authorship Networks: the Case Study of Scientific Productions of Researchers at Kerman University of Medical Sciences

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Abstract:

Introduction: The purpose of this research is to evaluate the co-authorship network of researchers of Kerman University of Medical Sciences. This assessment includes a look at the co-authorship, patterns of co-writing, researchers' outputs, authors ranking, map drawing of the co-authorship network, comparing the network of co-writing of the medical field with other domains, main component and key researchers, review The fit of the network of the co-writing of medical researchers with the small world theory, as well as person-centered indicators such as degree centrality, between centrality, closeness centrality Eigenvector, vector centrality, beta centrality, and interstitial centrality.

Method: This research was carried out using scientific methods and network analysis techniques. The statistical population of this research is all articles of the faculty members and other researchers of Kerman University of Medical Sciences, indexed at the ISI database (the Science of Science Web site) during the period from 1978 to 2015, which consists of 1710 articles. The data were analyzed by Bibexcel, Histcite and Net drive softwares after pre-processing.

Findings: The review of the articles showed that the pattern of four and five writers had the highest percentage of the co-written articles. The co-authorship network of this university is lower un an index such as the number of papers for each author from many other areas, and in the index of authors for each article is higher than most of the areas.

The density index of this network is 0/003, its clustering coefficient is 0/64 and the percentage of the co-written articles in companion with the single-written articles is 97%. The researchers of this university have a high degree of collaboration in writing their articles, Iran University of Medical Sciences , Shahid Bahonar Kerman University and Shahid Beheshti University of Medical Sciences, and the United States, Australia and England have the most scientific cooperation with Kerman University of Medical Sciences. Studies show that most of the articles published at Kerman University of Medical Sciences have been produced by a small number of researchers of this university, and the ratio of national-to-international collaboration at this university has been. 2/9.

Conclusion: The co-authorship network of the researchers of this university is characterized by the average length trajectory and relatively high clustering coefficient, which is a small world network. The study of the distribution of the degree centrality of the central and key researchers of the network shows that the principle of "success breeds success", which was proposed by Age and Rousseau in 1996, is also valid in the surveyed network, and the researchers with high centrality play a very important role in the development and The evolution of co-writing networks

Key words: centrality measures, co-authorship, person-centered approach, aggregate approach, Lotka law, author fertility law

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Introduction

Today, researchers increasingly recognize the need for research collaboration and see it as a way of solving the existing problems of scientific progress and development. In spite of various indicators to explore formal and informal research collaboration, common writing or co-authorship is the most visible and accessible indicator used to measure the extent of research collaboration (Cheong & Corbett, 2009).

Co-authorship is the objective product of research collaboration [1] and is the most formal and visible effect of intellectual co-operation among authors in conducting scientific researches [2] [3], and is the contribution of two or more authors to the production of a work that results in the production of scientific output with higher quality and quantity than individual production and distribution [4] [5] [6]. Collections of co-authorship during the time form the network, which is referred to as a authorship network. This network consists of a number of nodes (entities such as individuals, universities, and countries) and links (communication in a co-authorship form) between them (Newman, 2004) In a co-authorship network, two nodes are connected to each other if they have at least one common writing When person-centered co-authorship networks are connected to each other by co-authors, they form a larger network, which includes a set of individualized co-authorship networks [7] [8] and illustrates the relationships between researchers who have shared their knowledge indirectly in published articles [9], which is referred to as social co-authorship network.

The process of reviewing and evaluating the structure of social networks is carried out using network analysis technology and in the analysis of co-authorship networks , macro level and micro level indexes are used to investigate the evolution of the development and structure[10]

The macro indexes examine the configuration and the general characteristics of the networks, including density, fragmentation, clustering coefficient, centralization, network components, connectedness, network diameter, and the average of the shortest path [11]; The network density represents the ratio of relationships existing between researchers to possible communications in the network and is always between zero and one. Zero density indicates that there is no relation between researchers in the network and the density of one represents the relationship between all of researchers on the network through co-authorship. The link index indicates the extent to which network researchers join each other through co-authorship or network of co-authors and the network's diameter represents the distance of the farthest network researchers with each other. Fragmentation shows the extent of the br eakdown of network researchers from each other. The clustering or social coefficient indicates the degree to which researchers in the network tend to form different clusters through co-authorship; the centralization index refers to the organization of a set of researchers around one or more central researcher on the network: if in a network, a large number of researchers are focused around one or some central researchers with high degree centrality, it is said that the network has a high concentration [12]. The number of network components and the average distance in the network, which is the average of the shortest paths available between the two researchers in the network, is the other major indicators of social network analysis. The less average distance in the network can provide data transfer faster [11].

In addition to analyzing the overall structure and how the network evolves co-authorship using macro indicators, the performance of each of the researchers in the network can be studied using micro indicators .Centrality, which is one of the most important individual concepts of social network analysis, addresses the importance and impact of individuals on the network. The centrality of network researchers can be studied using degree centrality ,closeness centrality,betweenness centrality, eigenvector centrality (specific value), flow betweenness, and Beta centrality indic ators. Degree centrality simply indicates the number of direct relationships that a researcher has with other researchers This type of centrality is also considered as the size of the feminine network [13]. The betweenness centrality places one researcher in the network according to its ability to link other pairs or groups on the network. Closeness centrality implies that how a researcher or agent can quickly access more researchers or agents on the network. The betweenness of the measurement flow is such that there is the possibility of reducing the flow between the pair of other factors in the network if a particular factor is eliminated and therefore the calculation of the contribution of a researcher to the maximum flow may be [14]. Eigenvector centrality has been suggested based on the idea that the centrality of a particular researcher cannot be distinguished from the centrality of other researchers associated with it [15].

Recently several researchers such as Bozeman and Youtie [16], Kumar and, Ratnavelu [17], McConnell [18], Ludvigsson [19], Bender, Edwards [20], Mayrose and Freilich [21], Bader, Kofia 22 in the field of medicine have

used centrality measures for analyzing co-authorship networks. All of these researchers have argued that centrality measures are useful for evaluating the efficiency, productivity, and research performance of the authors and their scientific outputs. Therefore, in this research, we try to investigate the analysis of the structure of co-authorship network of the researchers at Kerman University of Medical Sciences using person-centered approach and population-based approach. The present study seeks to identify the connective structure (topology) of the social co-authorship network of the researchers of Kerman University of Medical Sciences is at a micro and macro level.

General Purpose of the Research:

The analysis of the structure of social co-authorship networks of Kerman University of Medical Sciences researchers using person-centered and population-based network approach.

Research Questions:

1. Is the Lotka law of the author correct about the scientific production of researchers of Kerman University of Medical sciences?
2. How is the structure of the co-authorship network of researchers at Kerman University of Medical Sciences in terms of measures of density, , number of components mean path length, fragmentation and clustering coefficient?

3-How is the structure of co-authorship network of researchers at Kerman University of Medical Sciences in terms of measures of degree centrality, closeness centrality, and betweenness centrality?

4.What is the rate of national cooperation compared to international cooperation in the co-authorship network of researchers at Kerman university of Medical Sciences?

5. How are the contributions of different universities in the co-authorship social network of researchers at Kerman university of Medical Sciences?

6. How are the contributions of different countries in the co-authorship social network of the researchers at Kerman University of Medical Sciences?

Research Hypotheses

1. There are multi interfaces between the various measures of centrality and the number of their research outputs in the structure of co-authorship network of researchers at Kerman University of Medical Sciences.

Research Methodology

Method

The type of research is bibliometrics and network analysis technology has been used to visualize the co-authorship networks. Lancaster describes bibliometrics as the study of communicative patterns of authors, publications, and texts by applying various statistical analysis methods [23]. In the network analysis method, attention is drawn to the quantity and quality of the shape and the content and their relationships and makeup. For example, if relationships between the government and the nation are considered, the researcher, in accordance with its own theoretical framework, looks at the shape of their relationship, the severity or weakness of the links, the symmetry or the asymmetry and the content of the relationship. Thus, in network analysis method, the emphasis is on interfaced data. In network analysis, mostly, the researchers consider the form and content of their relationships rather than the characteristics and attributes of the agents. A number of social network analysis studies focus on network morphology analysis, investigate the structural characteristics of researchers and their relationships and how they affect the network topology, structures, and behaviors of network members and the entire network [24].

Statistical Population

The statistical population of this study is all articles of the faculty members and other researchers at Kerman University of Medical Sciences, indexed at the ISI database (Science web site) during the period from 1978 to 2015, which consists of 1710 articles.

The data collection method

In this research, data collection was done in several steps. In the first step, for retrieving data, we went from the Science Web site to the advanced search section of the database, and this formula was used:

OG = Kerman University of Medical Sciences

Indexes = SCI-EXPANDED Timespan = 1978-2015

The data was then stored in plain text format in 500 records and stored as full records. Having completed the data storage task, the preprocessing process was performed on the names of the researchers and repetitive and incorrect cases as well as the same items were identified and corrected with different spelling. In the next step, a plan for creating relation matrices was developed in this study to be used as inputs for the UCINET [25]. Each relation matrix house represents the number of colloborations between each of two researchers (researcher / country / organization). Co-authorship of researchers, organizations and countries were extracted by using Bibexcel software. The type of matrix used in this study is a weighted matrix, because in this study, in addition to identifying the existence or absence of a relationship between researchers, organizations and different countries, the number of repetitions of the relationship between them is also needed. To determine the number of authors in each article, in addition to manual counting, the Histcite software was also used..

The findings

**** The scientific outputs of researches at Kerman University of Medical Science based on the year**

As shown in diagram 1,out of 1710 indexed articles in Web of science the 2013 edition, with 244 articles ranked first and 2014 and 2012 respectively, with 227 and 220 articles respectively in the second and third positions respectively. The frequency of articles published in other years in this study can be seen in the diagram below:

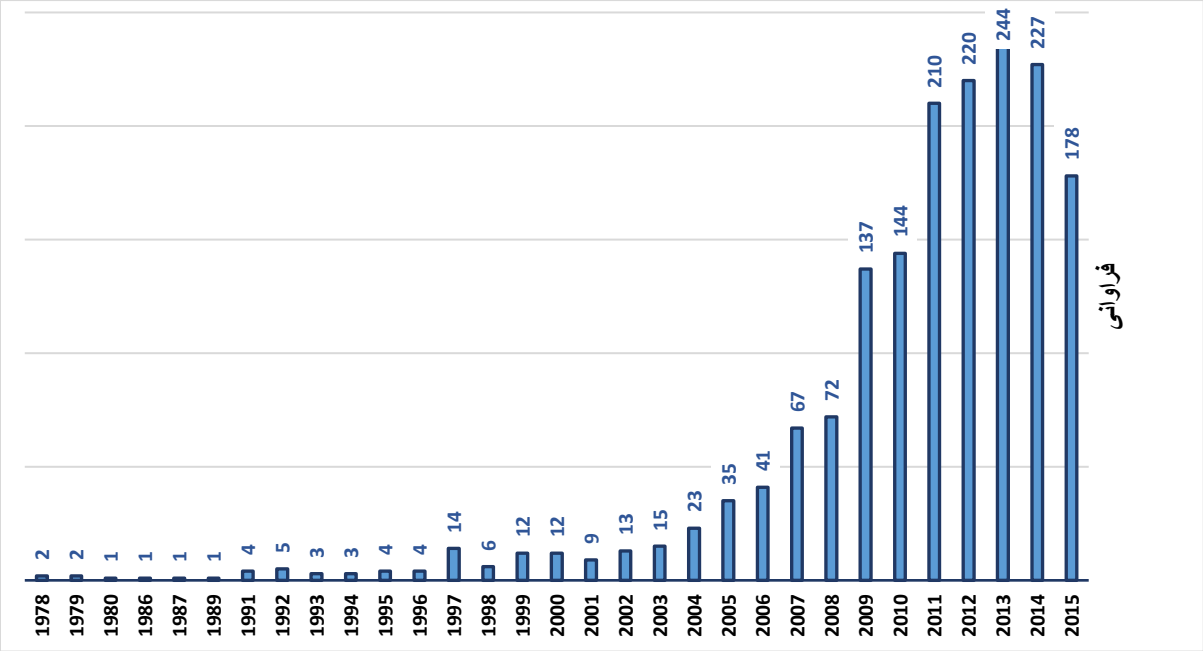

Diagram 1. Frequency of scientific productions of researchers at Kerman University of Medical Sciences at WOS database

**Distribution of frequency of researchers at Kerman University of Medical Sciences in the production of science based on Lotka law

According to the Lotka law, in a scientific field, a few authors produce a high percentage of scientific works, and a lot of authors have little participation in scientific production [28] .

The Lotka law is summarized in the following formula: Xn * y = C where: X: number of publications; Y = number of publishers with X emission; n = fixed number and C = constant number. About scientific subjects, n is approximately2, it means: X2*y=C

Using the above formula, Lotka law was tested on the data of this research, and the analysis of the papers published by various researchers showed that their distribution follows the Lutka's law that this distribution can be seen in diagram

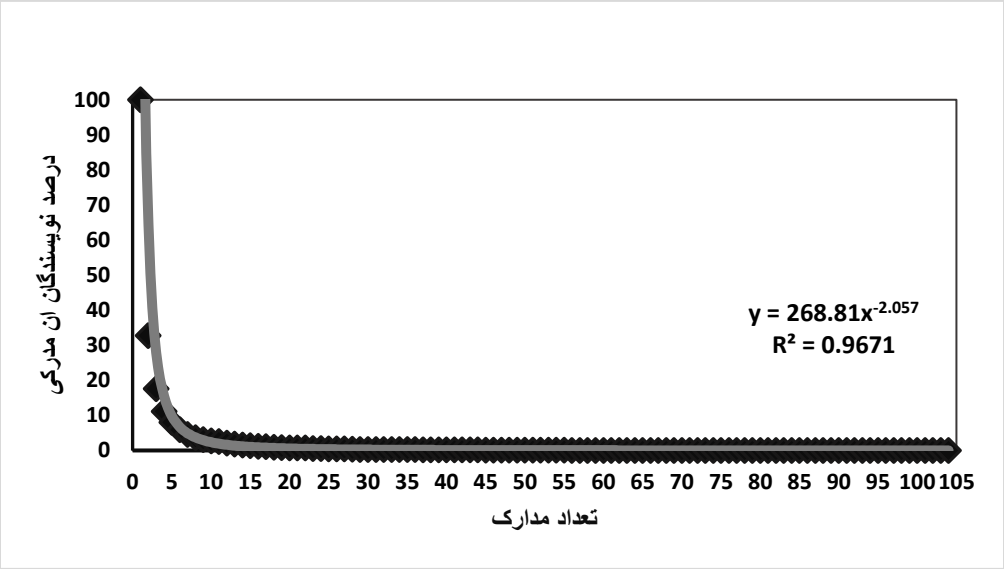

Diagram 2. Distribution of Lotka in relation to researchers at Kerman University of Medical Sciences

As shown in the diagram above, a small percentage of university researchers produce a high percentage of scientific works, and a large percentage of university researchers make a small percentage of the university's scientific productions. Frequency and percentage of all articles, single-authored articles and co-authorship articles are shown in table 1.

Table 1: Frequency distribution and percentage of articles in terms of how to participate in the writing

total number		single-authored articles		articles co-written		period
Percentage	Frequency	percentage	Frequency	percentage	Frequency	
%100	1710	3/04	52	96/96	1658	1978-2015

As it is seen in the table above, the total number of documents published during the whole period is 1710 records. In all these intervals, the percentage of the articles co-written (96/96 percent) is more than the single-authored articles. The total number of authors and documents in the co-authorship network at Kerman University of Medical Sciences has been shown in Table 2.

Table 2. The total number of authors and documents in the co-authorship network at Kerman university of Medical Sciences.

authors for each documents	documents per writer	Total document	Total authors
5/2	0/19	1710	8952

As shown in the table above, there are 0/19 documents per writer during this period. There are also 5/2 authors for each documents.

In order to better understand the issues associated with co-writing, the distribution of co-authorship articles is shown in diagram 1 on the basis of the number of authors.

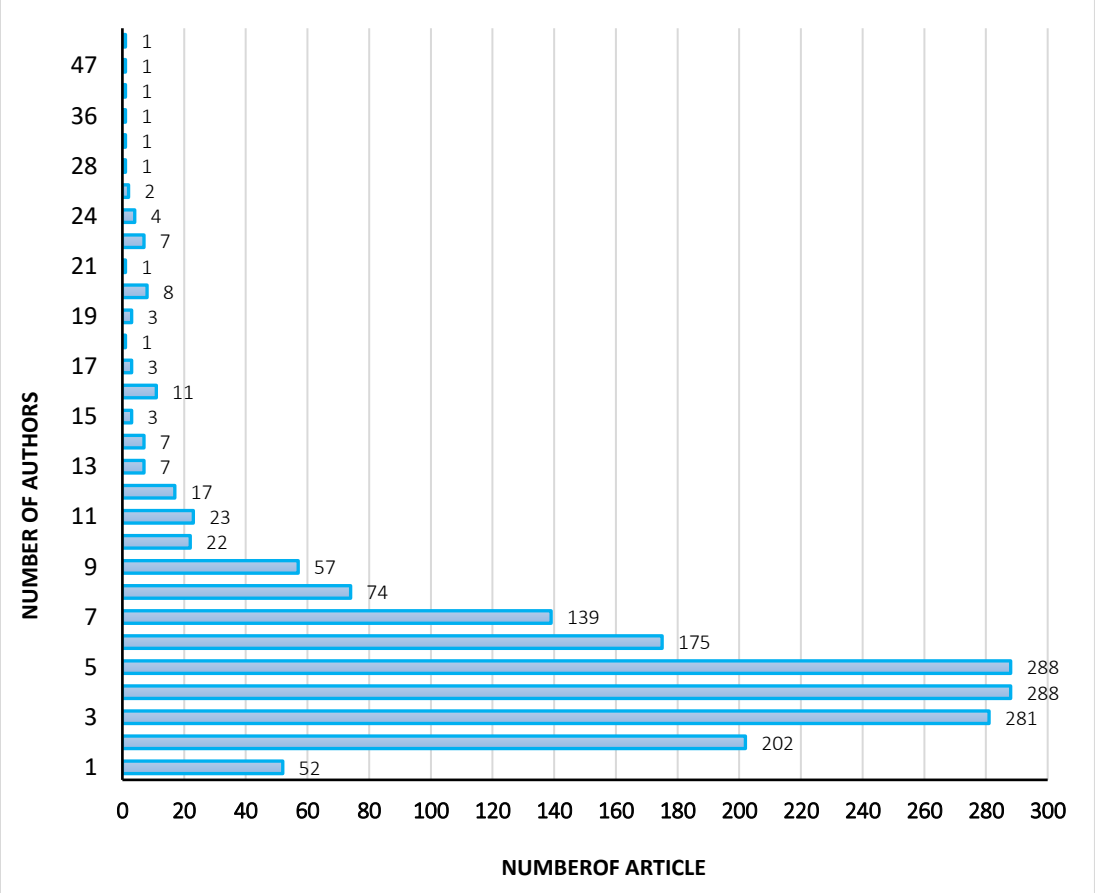

Diagram 2. Frequency distribution of the number of authors in the co-authorship network at Kerman University of Medical Sciences.

As shown in diagram 2, out of a total of 1658 co-written articles, the co-written articles with 4 and 5 co-authors , both together with 288 papers (17/4) make up the largest number of co-written articles. Co-written articles with 3 co-authors with 281 articles (16/9) rank second, and co-written articles with 2 co-authors with 202 articles (12/2) are in third place. The topological structure of the co-authorship social network at Kerman University of Medical Sciences has been shown in Table 3:

Table 3. The topological structure of the co-authorship social network at Kerman University of Medical Sciences

account	Index
3727	Number of researcher
38388	Number of link
0/003	network density
72	Components
3350	the ratio of its largest component
0/89	the ratio of its largest component to whole
4/371	the mean path length
0/192	Regarding the fragmentation
0/641	Network clustering coefficient
13	Network diameter
0/087	network concentration
0/808	connectedness index
0/202	Network compression
10/296	average of degree centrality

As shown in table 4, the co-authorship social network of researchers at this university includes 3727 researchers and 38388 links. The network density is 0/003 and the connectedness index is 0/808.This network consists of 72 components that the ratio of its largest component is 8/73 overall and the mean path length is 4/371. Regarding the fragmentation, the amount of this measure is 0/192. The clustering coefficient is 1/458 and the network concentration is equal to 0/087. Network diameter index or the distance of the farthest researchers of the main component is 13, and the average of degree centrality in this network is 10/296.

In order to understand more, the mapping of the co-authorship network of the researchers at Kerman University of Medical Sciences is depicted in Figure 1:

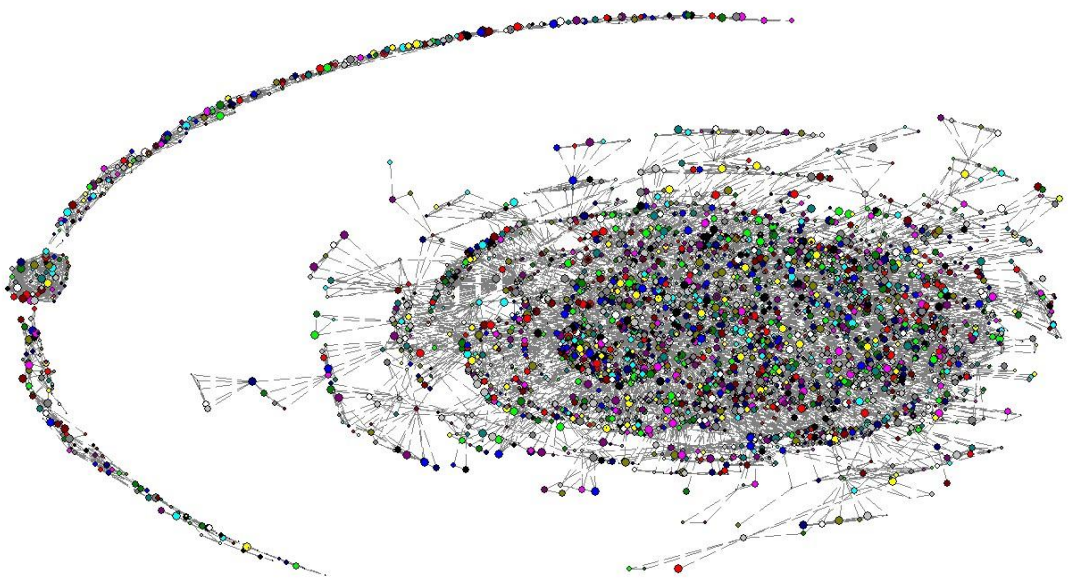

Figure 1. Mapping of the co-authorship network of researchers at Kerman University of Medical Sciences

Centrality measures of researchers at Kerman University of Medical Sciences have been shown in table 4:

Table 4.The rate of centrality measures for ten higher researchers of each measure

oseness ntrality	Distance	author	Row	Normalized Betweennes	Betweennes s centrality	author	Row	Normalized rank	degree centrality	Author
0/263	1414171	Haghdoost, Aliakbar	1	20/699	1436446	Haghdoost, Aliakbar	1	0/414	524	Haghdoost, Aliakbar
0/263	1414553	Nakhaei, Nozar	2	8/955	621451	Nakhaei, Nozar	2	0/231	293	Sharifi, Eraj
0/263	1414894	Najafipoor, Hamid	3	5/032	349236	Baneshi, Mohammadreza	3	0/225	285	Ftuomadi, Alireza
0/263	1415003	Sipehri, Gholamreza	4	4/744	329214	Sharifi, Eraj	4	0/208	263	Shibani, Vahid
0/263	1415019	Sharifi, Eraj	5	4/192	290909	Dabiri, shahriar	5	0/189	239	Fasihi Harandi, Majid
0/263	1415106	Dabiri, shahriar	6	3/930	272761	Ftuomadi, Alireza	6	0/189	239	Shafiei, Abbas
0/263	1415108	Zahedi, MohammadJavad	7	3/876	268954	Shibani, Vahid	7	0/154	195	Nakhaei, Nozar
0/263	1415139	Khameshipoor, Ali	8	3/336	231509	Fasihi Harandi, Majid	8	0/130	165	Emami, saeid
0/263	1415185	Nematollahi Mahani, nooreddin	9	3/272	227088	Sipehri, Gholamreza	9	0/116	147	Shabani, mohammad
0/263	1415256	Soror Azimzadeh,Behzad	10	3/171	220048	Najafipoor, Hamid	10	0/114	144	Esmaeili mahani, saeid
0/027	1414171	Mean		0/073	5075/297	Mean		0/010	12/743	Mean
0/071	3747777/750	Standard deviation		0/471	32704/744	Standard deviation		0/017	21/013	Standard deviat
w-connectivity networks, it is not computed		connectedness index		%20/63		connectedness index		%0/404		connectedness i

betweenness	Normalized flow betweenness	Author	Row	Normalized Beta centrality	Beta centrality	Author	Row	Normalized IbEigenvecto r centrality	IbEigenvector centrality	Author
7/136	678/329	Haghdoost, Aliakbar	1	31/435	59750/19	Ftuomadi, Alireza	1	72/961	0/516	Ftuomadi, Alireza
6/404	608/792	Nakhaei, Nozar	2	29/636	56330/75	Shafiei, Abbas	2	68/816	0/487	Shafiei, Abbas
3/888	369/613	Mehrbani, Mitra	3	23/833	45300/44	Emami, saeid	3	55/395	0/392	Emami, saeid
3/846	365/563	Parirokh, Masoud	4	10/721	20378/80	Moshafi, Saeid	4	24/829	0/176	Moshafi, Saeid
3/324	363/508	GhaffarineJad, Alireza	5	7/886	14990/13	Rajabalian, Saeid	5	18/312	0/129	Rajabalian, Saeid
3/113	295/891	Mondegari, Ali	6	6/861	13040/42	Sakhteman, AmirHossein	6	15/939	0/113	Sakhteman, AmirHossein
3/054	290/339	Ayatollah, Amin	7	6/503	12360/51	Alipoor, Ali	7	15/101	0/107	Asadipoor, Ali
3/038	288/806	Esfandyarpoor, Eraj	8	5/297	10069/23	Kokabi, Mahdi	8	12/295	0/087	Kokabi, Mahdi
3/016	286/661	Dabiri, shahriar	9	5/254	9986/49	Sorkhi, Maedeh	9	12/221	0/086	Sorkhi, Maedeh
2/640	250/988	Shibani, Vahid	10	5/208	9898/52	Mansoori,Shahla	10	12/021	0/085	Mansoori,Shahla
1/289	122/571	Mean						0/263	0/002	Mean
1/182	112/344	Standard deviation						2/302	0/016	Standard deviat
%5/906		Network focus						%73/93		Network focu

The results of calculating centrality measures indicate that in degree centrality , Ali Akbar Haghdost, Iraj Sharifi Alireza Foromadi; in Betweenness centrality. Ali Akbar Haghdost.Noza Nakhaee and Mohammadreza Baneshee ; in closeness centrality, Ali Akbar Haghdost, Nozar Nakhee and Hamid Najafipor; ibEigenvector centrality and Beta centrality ; Ali Reza foromadi, Abbas Shafee and Saeed Emami ; in flow betweenness, Ali Akbar Haghdost, Nozar

Nakhaee and Mitra Mehrabani are placed first to third ranks respectively .Other information can be seen in the above table.

**The frequency distribution of countries that has had the highest degree of cooperation with the researchers of Kerman University of Medical Sciences

The names of the ten countries that are at the forefront of the cooperation of the researchers of Kerman University of Medical Sciences are shown in the table below.

Table 5. Ten higher countries in the field of scientific cooperation with researchers of Kerman

University of Medical Science

scientific cooperation		**Countary**	Row
percentage	**Frequency**		
4/6	78	United of States of	1
3/4	58	Australia	2
3/3	57	England	3
2/1	36	Canada	4
1/2	20	Sweden/ Holand	5
0/9	16	Malezia	6
0/6	11	Germany	7
0/6	10	Switzerland	8
0/5	9	Hungary	9
0/5	8	Scotland	10

As it is shown in Table 5, the researchers of Kerman University of Medical Sciences have had the most scientific cooperation with researchers from the United of States of America ,Australia and England. Figure 2 shows the co-authorship network of the researchers of Kerman University of Medical Sciences with other countries:

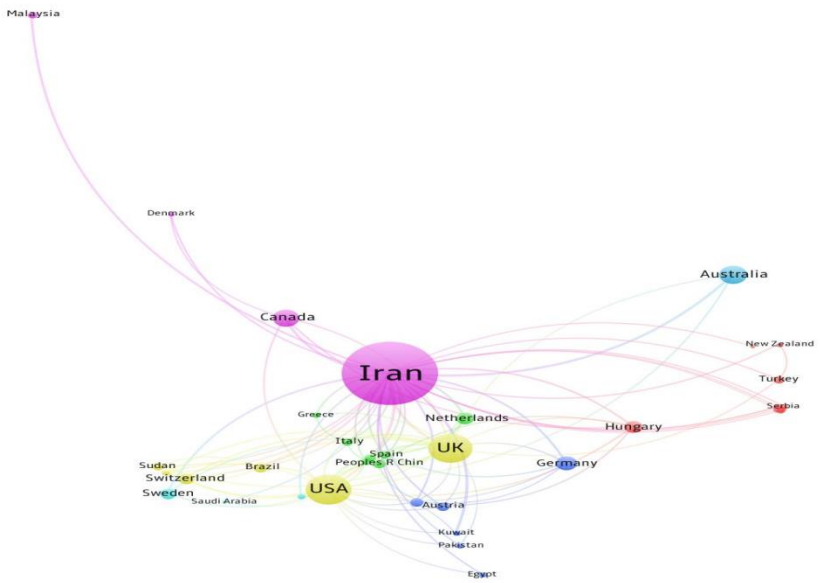

Figure 2.Mapping co-authorship network of Kerman University of Medical Sciences with other countries

As it is seen in the figure above , the researchers of Kerman University of Medical Sciences have had the common scientific cooperation with the researchers from 54 countries.

**Frequency distribution of universities/organizations have had the highest degree of cooperation with researchers of Kerman University of Medical Sciences.

The names of ten universities/organizations that are at the forefront of scientific cooperation with the researchers of Kerman University of Medical Sciences are listed in the table below:

Table 6.Higher ten universities/organizations in the field of scientific cooperation with the researchers of Kerman University of Medical Sciences

scientific cooperation		University/Organization	Row
percentage	Percentage		
26/1	447	Tehran University of Medical Sciences	1
10/6	181	Shahid Bahonar	2
8/9	152	Shahid Beheshti	3
5/8	99	Islamic Azad University	4
4/3	74	Shiraz University of Medical	5
3/9	66	Rafsanjan University of Medical Sciences	6
3/8	65	Mashhad University of Medical	7
3/1	53	University of Tehran	8
3/1	53	Mazandaran University of	9
2/8	48	Esfahan University of Medical	10

As it is seen in table 6, the researchers of Kerman University of Medical Sciences have had the most scientific cooperation with the researchers from Tehran University of Medical Sciences, Shahid Bahonar Kerman University and Shahid Beheshti University of Medical Sciences.

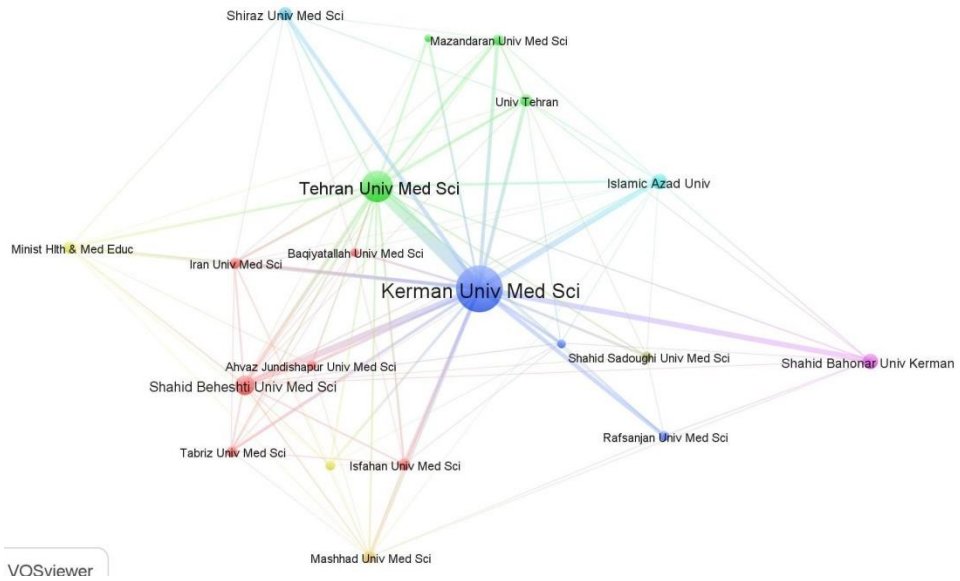

Figure 3.Mapping co-authorship network of Kerman University of M. S. with other universities

**Ratio of national cooperation compared to international cooperation

To answer this question, two indexes (international co-authorship and national co-authorship) were calculated and the ratio of these indexes was measured to each other (NI/INI).To calculate international co-authorship index, this formula is used :

$$\text{INI} = \frac{\text{the number of international co} - \text{authorized articles}}{\text{The number of total article}} \times 100$$

International co-authorship index = $(435/1710) \times 100 = 25/4$

National co-authorship index= $(1275/1710) \times 100 = 74/6$

Out of the1710 articles Kerman University of Medical Sciences, 435 articles have been international co-authorship and the rest, 1275 articles, have been national co-authorship. Therefore, the rate of national collaboration among researchers at Kerman University of Medical Sciences has been 2/9 in comparison with international cooperation.

Discussion and Conclusion

Comparison of the characteristics of the co-authorship network (medicine) at Kerman University of Medical Sciences with some other areas is shown in Table 8:

Table 8. Comparison of the co-authorship network of the researchers at Kerman University of Medical Sciences with some other scientific areas

)Computer Science(2001)	**Turism(Yee & et al, 2013)**	Biomedical(Numan, 2001)	Management and organization(Aed & et al, 2006)	Science and Technology Nuclear(Sadat mousavi,201	strategic Management(Coseoglu,2016)	researchers of Iran University of Medical Sciences

				6)			
2/60	**1/10**	**6/40**	**2/04**	**0/43**	**0/88**	**0/19**	number of articles per writer
2/22	**1/87**	**3/75**	**1/88**	**2/35**	**1/13**	**5/2**	authors' index for each article
0/50	**0/75**	**0/07**	**0/68**	**0/39**	**0/13**	**0/64**	clustering coefficient
6396	**1376**	**1395**	**4625**	**5835**	**296**	**3350**	Main component size
57/2	**59/3**	**92/6**	**45/4**	**96/6**	**69/0**	**89/9**	Main component size(percentage)
9/70	**7/20**	**4/60**	**---**	**4/18**	**5/05**	**4/37**	average distance

The co-authorship network of the researchers of this university is lower in terms of the number of articles per writer and in the authors' index for each article is higher than other mentioned areas in table. Perhaps one of the reasons for this could be attributed to the theoretical or practical aspects of the various scientific fields, because some of the areas that have a more practical aspect need more to use the experiences and opinions of other researchers and group collaboration and some areas which involve a combination of theoretical and practical discussions have less group collaboration .The clustering coefficient illustrates the closeness of members of the scientific community to each other, indicating the tendency of the network to form small groups and clusters. The amount of the clustering coefficient in researchers of this area (medicine) is 0.64, which indicates that if two researchers A and B each have had a co-authoring with the researcher C respectively, then there is a possibility of 64% that two researchers A and B also, in the future, would have to collaborate. This indicates that the researchers of Iran University of Medical Sciences are very close to each other. In the index of clustering coefficient, the field of medicine is lower than management and organization and tourism, and higher than other areas. The results obtained in this study are greater than the amount of clustering coefficient offered in the field of physics (43%) and the field of biology (7%) [31]. The study of the average distance in this network shows that despite increasing the size of the network and the relationships of co-authorship among researchers, the average of the shortest paths available between the two researchers is 4/4. The diameter index of the network, or the farthest distance of the researchers of the main component, is also 13. It can be argued that the co-authorship network of the researchers of this university, with the characteristics of the average low path length and relatively high clustering coefficient , is considered as a kind of "small world" network. The small world network is a social network in which, although most researchers are not directly connected to each other, they can be accessed through a chain of co-authorship relationships and within a short path [33] [37] [30] [28] [30] [31] [31] [31] [30] [29].

In other words, in small networks, despite the expansion of the network and the arrival of new researchers, the connection between researchers remains strong and the distance between them remains low. The average distance indicator in this area is lower than the areas of strategic management, biomedical, tourism and computer and, in terms of proportion, the percentage of researchers' presence in the main component is lower than the areas of science and nuclear technology and biological Medicine. In the co-authorship network of researchers at Kerman University of Medical Sciences, the percentage of co-written articles is about 97% in comparison with the single-written articles.

This percentage is higher compared to the percentage of co- written articles in the field of mathematics (34%) and biomedical (79%). It is also higher than the percentage of the co-written articles of the field of education, in which the percentage of the co-written articles in comparison with single-written articles is 60.6 [35]. Part of this controversy is due to differences in the nature of science. Research in the field of mathematics is a developer of theories and is generally done separately, while research in the field of medicine and biomedicine is conducted further in the laboratory and by a large group of scientists, and that is why the ratio of the co-written articles with

the single-authorized articles in research of the field of medicine, biomedicine and chemistry is more than mathematics.

In this network, the percentage of researchers of the main component is 89/9. The findings of this study are aligned with other areas such as biology, physics and mathematics, [34] in which the largest component comprised 82 to 92 percent of the researchers, and with some areas of science such as education, in which the amount of 3 percent for the size of the largest component mentioned has a dramatic difference[36] [40] [33] [31] [33] [34] [34] [34] [33] [32]. Researchers of part of the main component, which is assumed including a large percentage of network researchers, usually play the main and core role in the productivity (number of scientific productions) in the co-authorship network. The largest number of researchers who have relatively large links with others usually tend to be in the center of gravity of the main component of the network of co-authorship. The study of the components of the network of this university shows that this network like many other social networks is composed of a major component and a large number of small components. The presence of small components in the network is usually due to the distance between researchers with a low degree centrality and researchers with high degree centrality and the entry of young and novice researchers into the field of research. On the other hand, since some researchers do not find the possibility of co-writing to prominent and prolific researchers, they turn to intragroup partnership or collaborations with researchers of their level, and that is why they are not connected to the main component in the network. The index standard of the density of the network of co-authorship in the field of medical researchers is 0.003. Nikzad, Jamali, and Hariri, in their research, reported that the density of the network of co-authorship of articles in economics, librarianship and information science , management, and psychology during the years 2000-2009 was 0.018,0.019, 0.020 and 0.014 [29].

Investigating the number of co-authorship of the researches of this university shows that their degree centrality follows the power-law distribution [37]. On the other hand, there are a limited number of researchers with high degree centrality and other researchers with low or very low degree centrality. As a result, the network of co-authorship of the researchers of this university can be called" scale-free network." As noted, sale-free network networks have a power-degree distribution. The study of the distribution of the degree centrality of the central and key researchers of the network shows that the principle of "success breeds success", proposed by Age and Rousseau in 1996, has been correct in the surveyed network. According to this principle, the centrality of full-participated people is increasingly being increased in the network, and they will be able to get a better and more central place by attracting new people in the network. As social networks are constantly being augmented by the addition of researchers and new links, and according to the principle of the preferential attachment, based on which new researchers are usually connected to the old researchers with high centrality [39], it can be stated that researchers with high centrality play a very important role in the development of co-authorship networks Hence, the greater cooperation of key researchers with each other, as well as the attraction of young researchers to the network, can be effective in its development and dynamism.

Power or influence on the network is as an indicator for controlling one factor over other factors, and is a concept that increases or decreases based on the position, place and communication of each researcher within the network and because of the limitations or opportunities created for that researcher The less researcher's limit, the more his opportunities are, and as a result, it leads to a more desirable position in the network, in other words, it becomes more powerful, indicating its capability [40]. In this study, in order to identify the strength and influence of each of the researchers in the network, the importance of the existence of researchers in the network, and whether they are vital or not, central measurements have been used. In a social network, a person who has a direct relationship with many people (ie, High-level centrality) is probably at the core of the information flow within the network (Freeman, 1979).

The results of the analysis of the social network of co-authorship of the researchers, based on their communication, showed that there is a high dispersion among the researchers' centrality scores. This means that researchers with higher degree centrality have more opportunities and alternatives than other researchers, since they have more options to choose. This opportunity makes them independent and they do not depend on specific researcher. In the context of a co-authorship network, a researcher with a high degree centrality means that he has a lot of communications with his colleagues; therefore, this researcher can take advantage of structural capital and receive more information, knowledge, and resources. In other words, these researchers have a prominent position in the network, and because they have many colleagues, there are more ways to achieve their needs, and if they break the

relationship with a researcher, they maintain their relationship with other researchers. In this way, researchers with high centrality have the maximum access to all resources and information published on the network and have the ability to call the maximum information from the network.

The closeness centrality means that an actor is linked to all other people through multiple paths (Otte and Rousseau, 2002), and represents the mean distance of the node of an actor from the nodes of others (Lu and Feng, 2009). The approach of closeness centrality measurement focuses on the distance of a researcher with other researchers in the social network of medical co-authorship and focuses on the shortest path from each researcher to other researchers.

Because the formed network among researchers with a high closeness centrality in this network is more coherent ,as a result , there is more communication between them , and the high closeness centrality has made it possible for the researchers of these countries to make the maximum use of the knowledge available on the network. A central actor controls both sources and information and has a position that gives him the power to influence the behaviors of other members of the group (Liu et al., 2005). In the context of a co-authorship network, a researcher with a high closeness centrality means that he has access to all researchers in the network faster than anyone else. Using the benefits of high closeness centrality, he can receive the necessary resources more appropriately and increase the quality of his publications.

The betweenness centrality of an actor indicates his ability to control the flow of resources or information in the network and enables him to act as a mediator of information and resources for other actors (Freeman, 1979).Thus, the high betweenness centrality for a writer means that he plays the role of mediator or bridge (Lu and Feng, 2009; Otte and Rousseau, 2002), and can gain different sources or information from different groups in the co-authorship network.The betweenness centrality is the reflection of the relative position of an actor in covering structural cavities in a network. A structural cavity between two clusters in a network does not mean actors that present in these two clusters are not aware of being, but merely means that they are so focused on their personal activities that they pay little attention to do other cluster activities. A structural cavity indicates that clusters located on both sides of a cavity act with different flows of knowledge The people who bridge these cavities have a good position to gain information and enjoy the benefits of control (Abbasi et al, 2011; Burt, 1992). Therefore, an actor with a greater betweenness centrality likely acquire a wealth of knowledge that is not only not repetitive but also more increasing (Chi et al, 2007). As a result, we anticipate that researchers with high betweenness centrality can promote their research through the benefits of non-recurring resources and knowledge.This improves the quality of their publications, and in turn leads to more citations.

The approach of the betweenness centrality is to examine the shortest path that a researcher runs between two pairs of researchers; therefore, according to the results of this research, it can be stated that the aforementioned researchers have the greatest opportunity to stay in the shortest path to the flow of information and knowledge and they have less intermediate access to the available knowledge in scientific resources, and in addition, they monitor and control the flow of information and knowledge .. Perhaps the reason for the role of control for such researchers is that the quality of scientific resources published by these researchers is higher than other researchers, and, moreover, they also have more up-to-date information.

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