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Historiographical Map of Iranian Engineering Scientific Publications during 1939-2011

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Abstract

Bibliometric, and scientometric approaches are used to provide appropriate tools for evaluating scientific products at local, national, and international levels. Iran, the same as other countries, has many universities and research centers in the field of engineering that Iran's most of the scientific products account for the field of engineering. This study is a descriptive approach using scientometric methods. is The present paper mainly focuses on visualizing the structure of the Iranian scientific publications in the field of engineering indexed in Thomson Reuters (ISI) accessible via WoS during 1939-2011. To draw the historiographical map of Iranian scientific outputs in the field of engineering, this study used HistCite™ software. Two indexes, Local Citation Score and Global Citation Score, were used for the purpose of ranking and visualizing data. The results showed that the published papers of Iranian researchers in the field of engineering showed fluctuation. The proportion of Iran in the engineering outputs constituted 0.65% of total publications and ranked 24 of the world. Five large clusters have been formed on the LCS index. The subject areas of the clusters were in “Thermodynamics and Chemical engineering”, “N-O Explosives, “liquid membranes”, “Liquid–liquid equilibrium”, and “decolorization”. However, three clusters have been formed on the GCS index. The subject areas of the clusters were in “liquid membranes”, “applied chemistry”, and “Liquid–liquid equilibrium”. Zafarani-Moattar and Sadeghi, and Ganji, played an important role in this map.

Keywords: Historiographical map, Scientific publication, Iran, Engineering, Visualization

Introduction

Identifying and measuring the impact and value of scientific output plays an important role in today's world of information overload. On one side, governments are trying to distribute research funds in ways that support research in strategically important fields, on the other side, researchers and scientists are seeking to access only relevant and quality information that mainly worth their attention.

Nowadays, countries are evaluated not only by their national products, military power, geographical area, etc, but also by such factors as the production and consumption of scientific information (Osareh and Zare, 2010). Therefore, it is necessary to conduct systematic evaluation of scientific products regularly.

Bibliometric and scientometric approaches are applied to provide appropriate tools for evaluating scientific products at local, national, and international levels. These tools have a number of advantages, including identifying core and significant journals, authors, institutions, universities, and papers; navigating thoughts and developing literatures and resources; anticipating scientific products trend; visualizing different subject fields and determining the most important subjects; identifying collaboration and co-authorship patterns; comparing courtiers based on scholarly publications etc.

Regarding the abovementioned cases, it seems that citation indexes and databases such as Web of Science (WoS) are suitable tools by which scientific products could be measured in all the fields. In addition, in ranking universities, the number of documents recorded in database is considered.

Iran, the same as other countries, has many universities and research centers in the field of engineering and Iran's most of the scientific products account for the field of engineering. Generally speaking, quality and quantitative evaluations of the scientific products can enlighten, to a great extent, Iran's scholarly products situation.

The basic emphasis of the current paper is to visualize the structure of the Iranian scientific publications in the field of engineering indexed in Thomson Reuters (ISI) accessible via WoS during the period from 1939 to 2011. The history of science was studied and the effective authors were identified according to this map and based on citations on both LCS and GCS, in the field of engineering in Iran. LCS (Local Citation Score) shows the count of citations to a paper within the retrieved collection, while GCS (Global Citation Score) shows the total number of citations to a paper in the whole Web of Science. In particular, this paper focuses on:

- Iranian research output, its growth trend, and global publication's share and impacts;
- the types and languages of the documents;
- the most important universities, institution and journals;
- countries whose academics have the most frequent collaboration with Iranian researchers;

- the most productive and highly cited Iranian authors in the field of engineering;
- the most effective Iranian engineering articles based on citation;
- the historiographical map of Iranian scientific publications of engineering;
- the most important scientific subject clusters formed in the field of engineering.

Related works

In the following, the paper first attempts to shed light on some of the literature which not only have drawn Iran's scientific products, but also have examined Iran's scientific products in one of the subject fields, particularly using HistCite™ software. Second, we will address those research studies that have studied Iranian scientific products in the fields of engineering regardless of the methodologies employed. We believe that this approach will help and clarify research gaps about Iranian scientific products, especially in the fields of engineering.

Osareh and Wilson (2002) analyzed international collaboration of Iranian scientific publications in SCI during 1995-1999. The results showed that Iran's publication output in science and technology increased dramatically in the SCI during this period. The results of Iran's increasing productivity over a 15-year period are presented in this paper. Iran doubled its output in the first two five-year periods and increased 2.8-fold from the second to the third five-year period. The rise in Iran's scientific publication output is mainly due to factors such as the ending of the war, enhanced economic conditions, recent changes in the Iranian government's policy, basic changes in the political environment brought about by the reformers, expansion of the Iranian presses for national publications, and the recent return of a large number of students trained overseas through government scholarships. External changes also account for the increased productivity e.g. the acceptance of three Iranian source journals by the SCI, increased access to international databases through the Internet and improved electronic communication facilities for international collaboration.

Osareh and McCain (2008**)** tried to draw the intellectual structure of Iranian chemistry research in Science Citation Index (SCI). The results of this research indicated that since 1990, Iranian chemistry research, as represented in the SCI, has grown at a rate of roughly 26% and 7 major clusters, Oxidation of Organic Compounds, Physical Organic Chemistry, Ionosphere, Analytical Chemistry, Solvent-Free Synthesis, CJ Pedersen and Crown Ethers, Synthesis of Carbonyl Compounds, were identified. The topic areas were primarily in organic chemistry, and after that in analytical chemistry; other major topic areas such as biochemistry, applied chemistry, and chemical engineering were not seen.

Osareh and Keshvari (2010) aimed to visualize a scientific map of Iran engineering research in Scientific Citation Index (SCI) via SciSearch in DIALOG database during 1990-2008. The results of this study indicated five main clusters in the structure of Iran engineering, the first cluster in chemistry and biochemistry, the second one in chemical engineering, the third cluster in mechanical engineering and computer applications, the forth one in artificial

intelligence and the fifth in biomedical engineering.

Osareh and Keshvari (2010) analyzed the Structure of Scientific Output of Iranian Scholars in Science Citation Index (SCI) during 2000-2006 and visualized using HistCite™ software. The results showed that, in the study period a total of 8 clusters were formed on the two levels (GCS and LCS). The subject area of whole clusters was chemistry, but included different areas of this discipline. The prominent subject area in our study was organic chemistry. The most effective document in this study was an article by Zolfigol with 123 global citations and 71 local citations. The subject category of cluster 1 was analytical chemistry and membrane electrodes. Cluster 2 consisted of 3 sub-clusters (sub cluster 1 hydrocarbons, sub-cluster 2 in the field of oxidation and nitrogen, and sub-cluster 3 catalysts). Cluster 4 was crystal structure, cluster 5 electrochemical analyses, cluster 6 macro cycles, cluster 7 aliphatic and aromatic complexes and the 8th cluster was polymers.

Due to the importance of Tehran University, Osareh and Zare (2010) conducted their academic scientific output in the Web of Science during 1989-2009 using a scientometric approach. Findings revealed that Ganjali, from the Department of Chemistry, was the most productive author followed by Mousavi Movahedi, Saboury, Norouzi and Zarrindast; 82.7% of documents were in article format. Approximately all documents (99.6%) were written in English. *FEBS Journal* published the most documents of UT, followed by *Biophysical Journal* and *Journal of Applied Polymer Science*. The growth rate of UT publications per year was, approximately, 37.8%. International collaboration among scholars is a traditional norm. Totally, UT authors collaborated with scholars of 81 countries. Among them, the authors from USA with 411 co-works were in first place, followed by authors from Canada, UK, Germany, and France. They used HistCite™ in order to draw scientific maps and depict the structure of science in UT. This study found that in the main clusters of both graphs, authors affiliated to the Chemistry Department and the Institute of Biochemistry and Biophysics was the cornerstone of science structure in UT. Ganjali, who had published the most articles, was present in both graphs more than others.

ZareBanadkoki and Oliya (2010**)** studied the status of products in the field of industrial engineering in Iran. In this study 87150 papers from 54 international journals were analyzed over 50 years. The results indicated that the number of scientific publishing in industrial engineering in Iran is ascending. American, English, China, Taiwan, and Canada were top countries in producing scientific publication in the field of industrial engineering respectively, and Iran located in 22 ranks.

Fattahi, Danesh, and Soheili (2011) investigated the scientific productions by researchers at Ferdowsi University of Mashhad over a period of twenty years in order to assess the scientific collaboration among researchers at this university via measuring the frequency of received citations. The scientometric indicators such as Lutka law, Bradford Scattering law, and citation analysis were used to analyze the data gathered from the Web of Science

database. The findings showed that FUM researchers published 2318 documents in this database. The collaboration frequency in this university matches Lutka law, also the frequency of core subject documents published by these researchers was in accordance with Bradford law. Citation analyses showed that there is a positive relationship between frequency of journal publishers with received citations and collaboration of a researcher with frequency of published documents as well. Scientific structure of this university was mapped and analyzed with HistCite^{TM} Software according to the number of global citations and it showed that science map of this university covered 9 clusters (5 clusters in the area of chemistry, and the rest of clusters in the areas of physics, Mathematics, food industry, and statistics).

Behzadi and JowKar (2011) conducted their study with the aim of evaluating Iran's scientific populations in the field of library and information science during 1994-2009. The corpus for this study included all documents presented by Iranian researchers in the field of library and information science, which have indexed in Web of Science website during 1994-2009. Results showed that according to R^2 value related to annual growth of scientific publications, Iran's rate of scientific growth during the mentioned 16 years was significant. The results indicated that Iran gained a 33% growth rate during the years under study. Investigation of the document types showed that the Iran's 96 records were presented in four different formats and only in English, and the highest populated format was "paper". The highest impact factor belonged to the "Journal of Informatics", in which only two papers from Iran were published. In addition, the clusters in the historiography mapping based on LCS and GCS are depicted, as well as the top researchers in this field. The results showed that the geographical location, speaking with the same language, and working on the same topic are effective on the number of citations at global and local levels.

Consequently, there were published studies describing international collaboration of Iranian scientific publications. Also, the other works addressed the intellectual structure of Iranian research in the different subject fields and in some Iranian universities using scientometric softwares in the SCI. However; the literature review did not show a survey on Iranian engineering scientific outputs in a long period.

Methodology

This research was done with the scientometric approach. The data used in this research was found by the advanced search part of Thomson Reuters Web of Science (WoS) in March 12, 2012 based on the following query in advanced search: "SU= Engineering AND PY=1898-2011". 4591385 scientific records were retrieved. Then records were limited to author affiliation and attained 28010 records that were produced by Iranian authors in the field of engineering during 1939-2011 and indexed in SCI. Each document included name of authors, authors' addresses (affiliations), titles, year of publication, keywords, title of journals, and number of cited references. For data analysis, records were registered into an

Excel spreadsheet and made ready for analysis. To draw the historiographical map of Iranian scientific outputs in the field of engineering, the HistCite^{TM} software was used, that is a product of ISI. The input contains plain text files extracted from WoS and the output involved a graphical image of scientific outputs (Garfield, et al., 2006). Two indexes, Local Citation Score (LCS) and Global Citation Score (GCS), were used for ranking and visualizing maps through which the history of science and effective authors were found based on citations on both mentioned indexes. Additional coding was manually performed based on main research objectives.

Findings

Iranian research output, its growth trend, and global publication's share and impact

The results of the study showed that 28010 Iranian scientific outputs were published by engineering researchers indexed by Web of Science (WoS). Table1 shows that the number of Iranian scientific publications in field of engineering over the period from 1939 to 2011. According to the results of the present study, the first Iranian paper indexed by WoS in the area of engineering was published in 1939. Despite an overall increase, there were fluctuations in producing outputs. Therefore, there were a sharp rise in 2009 and a sharp drop in 2011. The most number of times cited based on LCS was in 2008 and GCS was in 2007. All in all, the average 0.48 times cited based on LCS and 2.51 times cited based on GCS were made up of degree of cited per outputs of Iranian engineering research in the study period 1939-2011.

Also, the geometric mean was used in order to calculate the average annual growth rate of works during 72 years. The results indicated that this rate was 47.58 percent and breaks in the growth of publications in some years it occurred.

Table 1

The number of Iranian scientific publications in field of engineering during 1939-2011

Publication Year	Recs	LCS	GCS	Publication Year	Recs	LCS	GCS
1939	1	0	1	1992	41	52	394
1972	2	1	17	1993	95	90	1132
1973	19	12	216	1994	132	89	632
1974	29	10	174	1995	169	163	1022
1975	41	8	202	1996	139	176	800
1976	27	5	287	1997	277	207	986
1977	47	16	147	1998	257	269	1529
1978	60	10	239	1999	215	213	1526
1979	35	26	223	2000	363	315	1950

Publication Year	Recs	LCS	GCS	Publication Year	Recs	LCS	GCS
1980	36	11	233	2001	405	411	2687
1981	26	8	365	2002	558	652	3383
1982	10	6	123	2003	824	789	4049
1983	11	1	51	2004	809	864	4214
1984	8	5	36	2005	1418	1203	5523
1985	9	2	79	2006	2076	1352	6869
1986	13	13	66	2007	3210	1731	9401
1987	11	10	56	2008	4494	1836	9124
1988	23	33	209	2009	4655	1701	7202
1989	23	21	396	2010	3826	997	3573
1990	26	7	91	2011	3547	307	864
1991	43	27	403	Total	28010	13649	70474

In order to determine world shares of Iranian scientific publications in engineering, the results provided that the first scientific publications in the field of engineering were published in year of 1911, which was number of 380 works indexed by the WoS database. Figure1 shows the top 10 countries in the field of engineering during period from 1911 to 2011 with the most products. As it could be seen in Figure1, USA, China, Japan, England, and Canada countries, published the highest number of publications in this period of time, respectively. Proportion of Iran in the engineering outputs constituted 0.65% of total publications during the sampled years beginning from 1911 to 2011 and devoted 24th rank of the world in the field of engineering.

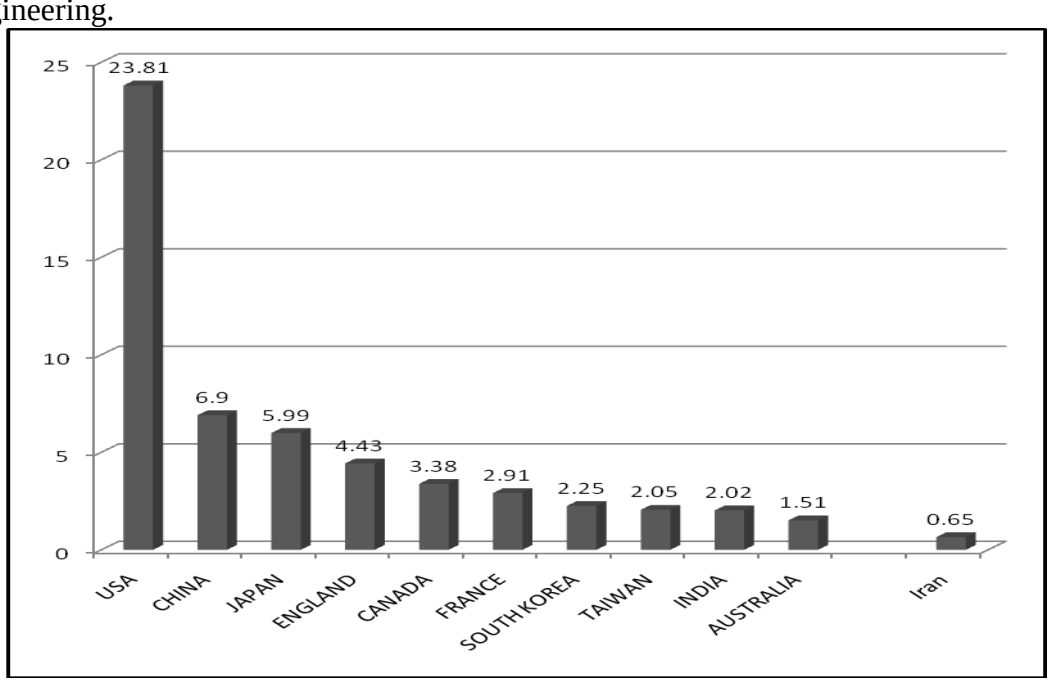


Figure 1. Top 10 countries in the field of engineering during 1911-2011

The types and languages of documents

The results of the analysis of the type of documents showed that the documents were in 12 different formats including article, proceeding paper, book review, correction, discussion, editorial material, letter, meeting abstract, news item, note, and reprint. As expected, the most frequent format was the articles (15853), distantly followed by Proceedings Paper (11695), and Book Review (74) (Table2). As it is obvious in Table2, scientific products of the field of engineering were published in seven languages. English documents ranked top (27987) followed by German (11) and French (8), respectively (Table 2).

Table 2

Iranian Scientific products in the field of engineering ranked by type and language of documents

Rank	Document Type	Rocs	Rank	Language	Rocs
1	Article	15853	1	English	27987
2	Proceedings Paper	11695	2	German	11
3	Editorial Material	125	3	French	8
4	Review	74	4	Croatian	1
5	Note	70	5	Polish	1
6	Letter	68	6	Romanian	1
7	Correction	64	7	Ukrainian	1
8	Meeting Abstract	46			
9	Discussion	12			
10	Biographical-Item	1			
11	Book Review	1			
12	News Item	1			

The most important universities and institutions and journals

There were 3936 institutions and universities involved in research activity in the field of engineering. Table 3 shows the status of the top 10 universities of Iran. As Table 3 presents, Tehran University ranked top in the list with 3680 publications (13.14%), followed by Sharif University of technology with 3656 publications (13.05%), Amir Kabir University of Technology with 2845 publications (10.16%), and Iran University Science and Technology with 2459 publications (8.78%). These four universities have produced the most scientific documents (45.13%) in the field of engineering. With respect to LCS and GCS Indexes Sharif University of Technology, Tehran University, and Amir Kabir University of Technology were made up of the most highly cited papers.

Table 3

The performance of top 10 Iranian universities in engineering

Rank	Universities	Recs	%	LCS	GCS
1	Univ Tehran	3680	13.14	1634	7646
2	Sharif Univ Technol	3656	13.05	1758	8356
3	Amir Kabir Univ Technol	2845	10.16	1511	6950
4	Iran Univ Sci & Technol	2459	8.78	1395	5429
5	Islamic Azad Univ	2180	7.78	632	3194
6	Tarbiat Modares Univ	1383	4.94	707	3846
7	Shiraz Univ	1145	4.09	1011	4184
8	Isfahan Univ Technol	1003	3.58	452	3127
9	KN Toosi Univ Technol	914	3.26	294	1243
10	Univ Tabriz	621	2.22	667	3190

Table 4 shows the status of the top 29 non-Iranian universities collaborated with Iran authors in this field, participated at least with 25 papers, in this research. As it can be inferred from table 4, University of Waterloo, University of Toronto and University of Calgary are the most important non-Iranian universities that collaborated with Iranian universities based on a the number of paper and ranked 1 to 3 respectively. However, based on LCS index, University of California Davis (76)**,** University of Southern California (76), and University of Calgary (75) ranked top. On the other hand, University of Waterloo (616), University of Saskatchewan (559), and University of Illinois (517) performed the highest based on GCS index.

Table 4

Top 29 non-Iranian universities collaborated with Iranian universities based on at least 25 papers

Rank	Institution	Recs	LCS	GCS	Rank	Institution	Recs	LCS	GCS
1	Univ Waterloo	111	72	616	16	Univ So Calif	38	76	268
2	Univ Toronto	90	40	497	17	Univ Stuttgart	36	49	228
3	Univ Calgary	81	75	381	18	Univ Surrey	35	36	275
4	McGill Univ	68	60	418	19	Univ Western Ontario	34	38	167
5	Univ Ottawa	60	40	281	20	McMaster Univ	33	24	264
6	Univ Calif Davis	56	76	318	21	Univ Birmingham	31	28	189
7	Univ Alberta	53	26	259	22	Univ Leeds	27	4	80
8	Texas A&M Univ	46	60	303	23	Univ Teknol Malaysia	27	13	38
9	Univ British Columbia	46	26	258	24	Carleton Univ	25	8	65
10	Univ Illinois	45	38	517	25	Mississippi State Univ	25	9	99

Rank	Institution	Recs	LCS	GCS	Rank	Institution	Recs	LCS	GCS
11	Concordia Univ	44	33	273	26	Ryerson Univ	25	5	57
12	Queens Univ	43	53	352	27	Univ London Imperial Coll Sci Technol & Med	25	11	94
13	Univ News Wales	42	29	304	28	Univ N Texas	25	40	84
14	Univ Saskatchewan	42	60	559	29	Univ Sains Malaysia	25	22	241
15	Indian Inst Technol	41	66	272					

Totally, 3352 Journals, Symposium, and Conference Proceedings have published Iranians' engineering output during the studied period. The number of journals that had published at least =<9 papers was 2723, that is, 81.23% of journals only have published 1-9 papers. The number of journals that have published ranging from 10 to 218 papers was 619 (18.46%) papers. Table 5 lists the 10 journals that have published the largest number of Iranians' engineering papers. As it can be seen in Table 5, only 0.29% of publications have published ranging from 218 to 478 papers. It can be assumed that the small part of journals have published the large part of papers. Also, Table 5 shows the most important journals based on LCS and GCS indexes. *Journal of Hazardous Materials, Journal of Chemical and Engineering Data, Fluid Phase Equilibria, and Desalination* are the top journals based on the number of papers, LCS index and GCS index.

Table 5

Top 10 journals in which Iranians' scientific outputs have been published in, based on the number of documents

Rank	Journal	Rocs		LCS		GCS
1	Iranian Journal of Chemistry & Chemical Engineering-International English edition	478	Journal of Hazardous Materials	656	Journal of Hazardous Materials	4312
2	Journal Of Hazardous Materials	327	Fluid Phase Equilibria	578	Journal Of Chemical And Engineering Data	2148
3	Journal Of Chemical And Engineering Data	296	Journal Of Chemical And Engineering Data	563	Journal Of Materials Processing Technology	1773
4	Journal of Materials Processing Technology	277	Industrial & Engineering Chemistry Research	286	Fluid Phase Equilibria	1749
5	Expert Systems With Applications	268	Journal Of Membrane Science	276	Progress In Electromagnetics Research-Pier	1350

Rank	Journal	Rocs		LCS		GCS
6	International Review Of Electrical Engineering-Iree	268	Desalination	210	Journal Of Membrane Science	1127
7	Fluid Phase Equilibria	266	Journal Of Sound And Vibration	188	Desalination	1025
8	International Journal Of Advanced Manufacturing Technology	262	Progress In Electromagnetics Research-Pier	180	Separation and Purification Technology	965
9	Iranian Journal Of Science And Technology Transaction B-Engineering	252	Computers & Structures	175	Journal Of Sound And Vibration	929
10	Desalination	218	International Journal for Numerical Methods In Engineering	168	Chemical Engineering Journal	923

Countries which their academics have the most frequent collaboration with Iranian researchers

The extent of International collaboration from co-authorship point of view is shown in Table 6. This table shows top 21 countries which their academics have the most collaboration with Iranian researchers in engineering field. Iran has collaborated more often with Canada (948), USA (946), UK (606), Australia (275), and France (219). Other countries collaborated with Iran in the level of less than 200 research papers (Table 6).

Table 6

Top 21 countries which their academics have the most frequent collaboration with Iranian researcher based on at least 30 papers

Rank	Country	Recs	LCS	GCS	Rank	Country	Recs	LCS	GCS
1	Canada	948	674	5412	12	Italy	57	32	259
2	USA	946	868	6036	13	Sweden	56	11	237
3	UK	606	457	3650	14	Switzerland	56	26	236
4	Australia	275	192	1514	15	Turkey	52	64	563
5	France	219	254	1298	16	Spain	37	16	128
6	Germany	160	145	842	17	Denmark	33	14	56
7	Japan	135	65	525	18	Finland	32	25	138
8	Malaysia	123	53	355	19	Singapore	31	5	182
9	India	90	85	380	20	South Korea	31	5	167
10	Netherlands	78	45	347	21	Norway	30	29	100
11	Peoples R China	62	34	282					

The most productive and highly cited Iranian authors in the field of engineering

Table 7 shows the most productive and effective Iranian authors in engineering. We can see that of the 28010 documents written by 26275 authors (average 1.06 authors per documents), 1142 documents (4.07%) were published by only 10 authors (0.03%). Kaveh, Faiz, Afzali, Kazemi, Hosseini, Shoaei, Lucas, Jamali, Madaeni, and Abdipour produced the largest number of papers. But, with respect to LCS index, Kaveh, Keshavarz, and Zafarani-Moattar were made up of the most highly cited papers and the more known people are in the local level and Based on GCS index, Daneshvar, Shamsipur, and Hashemi performed the most highly cited papers in the global level in the field of engineering in Iran, whereas Kaveh, Zafarani-Moattar, Faiz, Shamsipur, and Mohammadi performed well in the both levels.

Table 7

The most productive and highly cited Iranian authors in engineering (top10) based on the number of documents

Rank	Author	Recs	Author	LCS	Author	GCS
1	Kaveh A	159	Kaveh A	370	Daneshvar N	973
2	Faiz J	147	Keshavarz MH	325	Shamsipur M	955
3	Afzali-Kusha A	127	Zafarani-Moattar MT	240	Hashemi H	849
4	Kazemi A	116	Faiz J	198	Zafarani-Moattar MT	763
5	Hosseini SH	103	Gharagheizi F	197	Kaveh A	748
6	Shoaei O	101	Shamsipur M	196	Madaeni SS	688
7	Lucas C	100	Mohammadi T	168	Ganji DD	670
8	Jamali S	99	Rahimpour MR	167	Faiz J	645
9	Madaeni SS	96	Madaeni SS	154	Yamini Y	626
10	Abdipour A	94	Sadeghi R	149	Mohammadi T	599

Historiographical maps

One of the key features of HistCite^{TM} is the ability to create historiographies. These graphs show the influential documents and history of science in a field or in an organization. Historiographical maps are drawn based on two indexes: local citation scale (LCS) and global citation scale (GCS). For LCS map, the sample data was 500 documents and for GCS map, the sample data was 600 documents. The reason for selecting these numbers of documents was to obtain a clear graph based on trial and error. In map, each circle is an indicator for a document: the larger the circle the more citations and lines are indicators for citation links. For analyzing maps, we will use two methods of analysis. First of all, we will consider documents that have been the most citation rates based on LCS and GCS indexes, and then we will analyze formed subject clusters in maps which were extracted from Iranian engineering scientific products based on above-mentioned indexes.

Analyzing the subject clusters of Iranian engineering scientific products based on LCS map

For drawing the map, based on LCS, 500 highly cited documents were extracted by HistCite™. These 500 top documents span from 1973 to 2011 with 554 links, with minimum LCS of 5 and maximum LCS of 28.

The results showed that the paper by Rassamdana et al. on Asphalt flocculation and deposition (node1005) with participating Department of Chemical Engineering, University of Southern California, Department of Chemical Engineering, Amir Kabir University of Technology, and Improved Oil Recovery Research Center, National Iranian Oil Company (LCS: 28) in comparison with the other 150 top documents, followed by the papers by Yamini et al. (node1589, LCS:27), in the area of "Thermodynamics and Chemical Engineering" and from Department of Chemistry, Tarbiat Modarres University; Gharagheizi et al. (node19083, LCS:24) in the area of "Chemical Engineering" and from Department of Chemical Engineering, University of Tehran and University of Shahid Beheshti; F. Gharagheizi et al. (node14852, LCS:24), in the area of "Energy & Fuels" and from Department of Chemical Engineering, University of Tehran and Malek Ashtar University of Technology; Kaveh & Sayarinejad (node3638, LCS:24) in the area of "Interdisciplinary Applications (Engineering & Mathematics)" from Department of Civil Engineering, Iran University of Science and Technology, received the most local citation (Table8).

Table 8

Top 5 highly cited Iranian papers in the engineering base on LCS

Records	Source	LCS
1005	Rassamdana H, Dabir B, Nematy M, Farhani M, Sahimi M (1996). **Asphalt flocculation and deposition .1. The onset of precipitation.** Aiche Journal. 42 (1): 10-22	**28**
1589	Yamini Y, Fat'hi MR, Alizadeh N, Shamsipur M (1998). **Solubility of dihydroxybenzene isomers in supercritical carbon dioxide.** Fluid Phase Equilibria. 152 (2): 299-305	**27**
19083	Gharagheizi F, Tirandazi B, Barzin R (2009). **Estimation of Aniline Point Temperature of Pure Hydrocarbons: A Quantitative Structure-Property Relationship Approach.** Industrial & Engineering Chemistry Research. 48 (3): 1678-1682	**24**
14852	Gharagheizi F, Alamdari RF, Angaji MT (2008). **A new neural network-group contribution method for estimation of flash point temperature of pure components .** Energy & Fuels. 22 (3): 1628-1635	**24**
3638	Kaveh A, Sayarinejad MA (2003). **Eigensolutions for matrices of special structures.** Communications in Numerical Methods in Engineering. 19 (2): 125-136	**24**

Because of the length of the map, the researchers decided to divide it by clusters and identify the clusters one by one. The results of analyzing map showed that on the LCS level there were five large clusters. In the following paragraphs, we will go through clusters (Figure2).

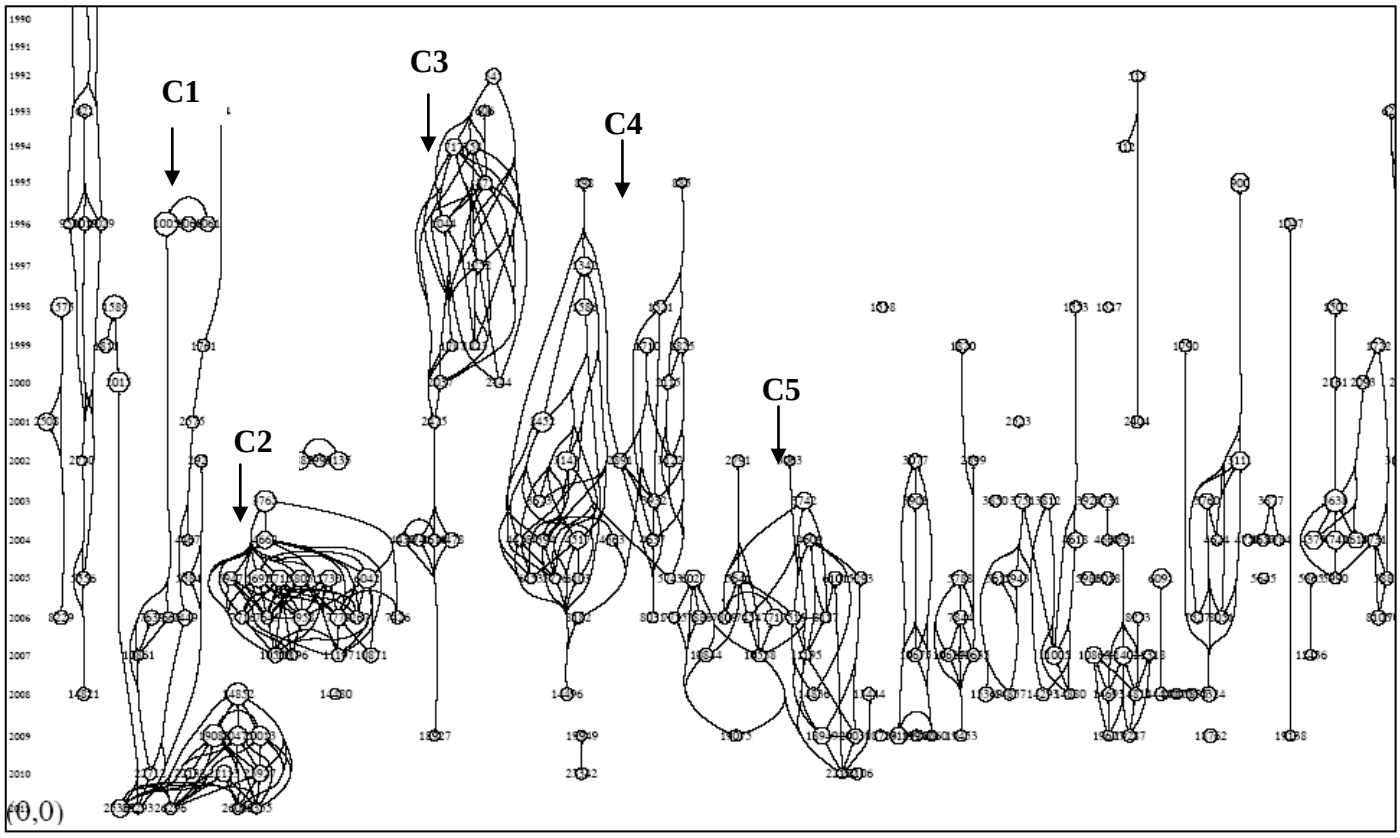
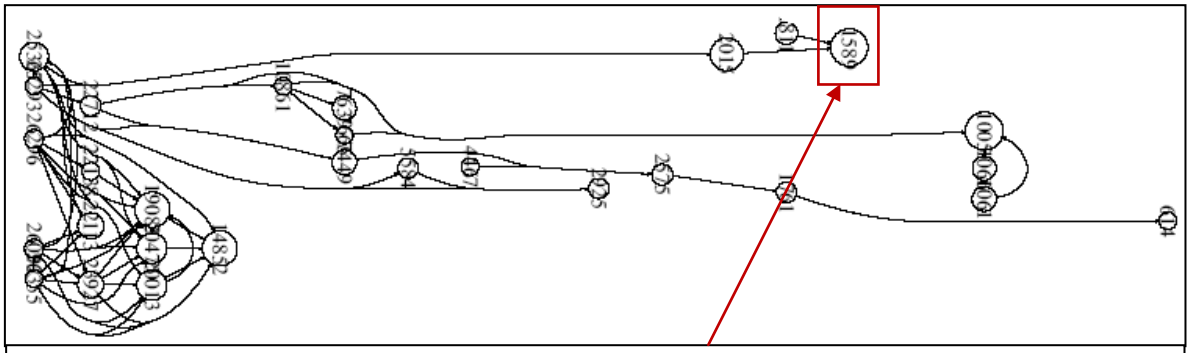


Figure 2. Historiographical Map of Iranian Engineering Scientific Publications during1939-2011 based on LCS

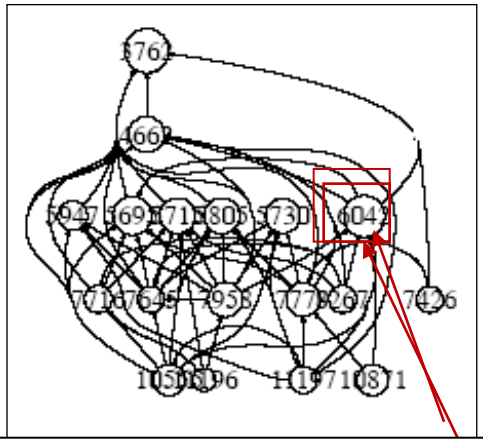
Cluster1. This cluster consisted of 36 document and 25 authors over the period time 1998-2011, in the subject area of "Thermodynamics and Chemical Engineering". The most effective document (considering the number of citations received and links to it) is Yamini and his/her colleagues (1589) with 27 LCS, as they are from Department of Chemistry, Tarbiat Modarres University and Department of Chemistry, Razi University, Kermansha. According to this graph, Gharagheizi played an important role with the most number of articles (Figure3).



1589 Yamini Y, Fat'hi MR, Alizadeh N, Shamsipur M. **Solubility of dihydroxybenzene isomers in supercritical carbon dioxide.** FLUID PHASE EQUILIBRIA. 1998 OCT 30; 152 (2): 299-305.

Figure 3. Cluster1 in LCS level

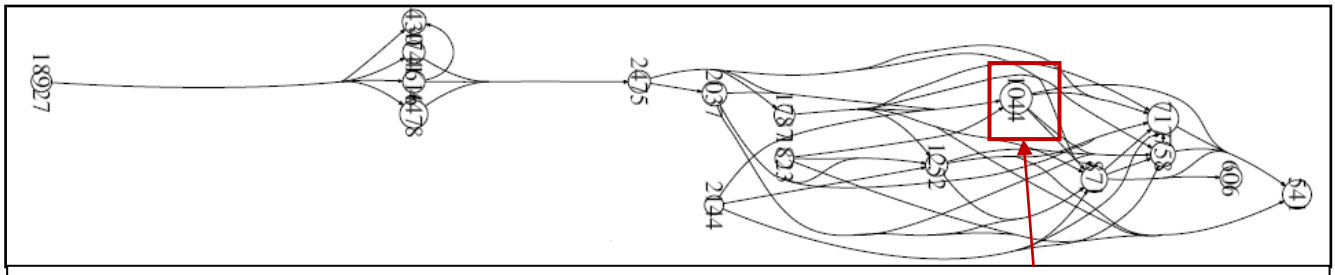
Cluster2. This cluster consisted of 18 document and 8 authors over the period time 2003-2007, in the subject of "N-O Explosives". The most effective document is Keshavarz (6042) with 20 LCS, as he is from Department of Chemistry, College of Sciences, Malek-Ashtar University of Technology. According to this graph Keshavarz, again, played a very important role and the most number of articles (Figure4).



6042 Keshavarz MH, Pouretedal HR. **Simple empirical method for prediction of impact sensitivity of selected class of explosives.** JOURNAL OF HAZARDOUS MATERIALS. 2005 SEP 30; 124 (1-3): 27-33.

Figure 4. Cluster2 in LCS level

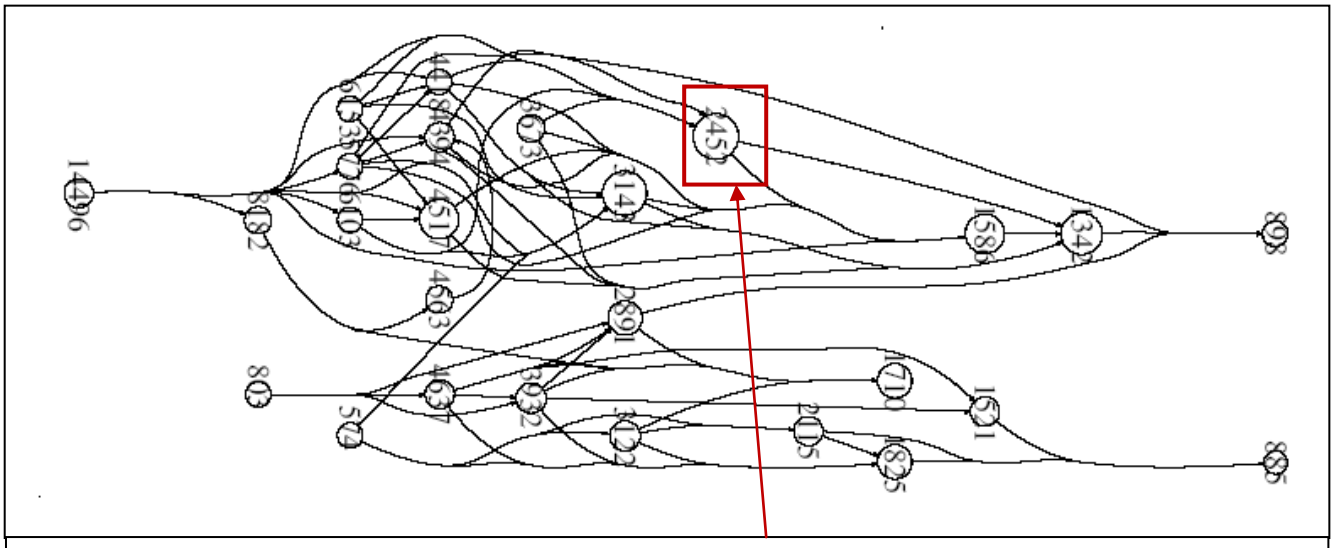
Cluster3. There are 17 document and 22 authors over the period time 1992-2009, in the area of "liquid membranes". The most effective document (considering the number of citations received and links to it) is Akhond and Shamsipur (1044) with 15 LCS, as they are from Department of Chemistry, Shiraz University and Department of Chemistry, Razi University, Kermanshah. According to this graph Shamsiour played a very important role and the most number of articles (Figure 5).



1044 Akhond M, Shamsipur M. **Specific uphill transport of Cd2+ ion by a cooperative carrier composed of aza-18-crown-6 and palmitic acid.** JOURNAL OF MEMBRANE SCIENCE. 1996 AUG 21; 117 (1-2): 221-226

Figure 5. Cluster3 in LCS level

Cluster4. This cluster consisted of 27 document and 20 authors over the period time 1995-2008, in the subject of "Liquid–liquid equilibrium". The most effective document is Zafarani-Moattar and Sadeghi (2452) with 20 LCS, as they are from Physical Chemistry Department, University of Tabriz. According to this graph Zafarani-Moattar and Sadeghi together played a prominent role with the most number of articles (Figure6).

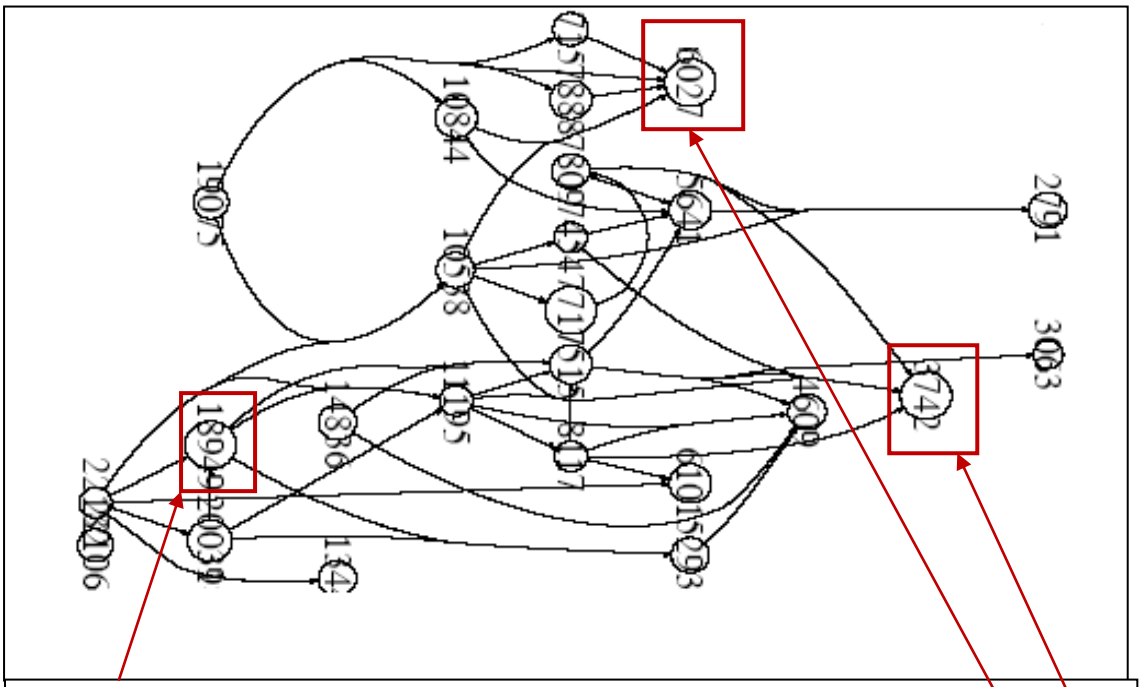


2452 Zafarani-Moattar MT, Sadeghi R. **Liquid-liquid equilibria of aqueous two-phase systems containing polyethylene glycol and sodium dihydrogen phosphate or disodium hydrogen phosphate - Experiment and correlation.** FLUID PHASE EQUILIBRIA. 2001 MAY; 181 (1-2): 95-112

Figure 6. Cluster4 in LCS level

Cluster5. This cluster consisted of 25 document and 20 authors over the period time 2002-2010, in the subject of "decolorization". The most effective documents are Khataee et al (18949), Daneshvar et al. (3742), and Mahmoodi et al. (6027) with 15 LCS, as they are from Water and Wastewater Treatment Research Laboratory, Department of Applied Chemistry, Faculty of Chemistry, University of Tabriz and Environmental Science and Engineering

Department, Iran Color Research Center. According to this graph, Daneshvar, again, played a significant role with the most number of articles (Figure7).



18949 Khataee AR, Vatanpour V, Ghadim ARA. **Decolorization of CI Acid Blue 9 solution by UV/Nano-TiO(2), Fenton, Fenton-like, electro-Fenton and electrocoagulation processes: A comparative study.** JOURNAL OF HAZARDOUS MATERIALS. 2009 JAN 30; 161 (2-3): 1225-1233.
3742 Daneshvar N, Ashassi-Sorkhabi H, Tizpar A. **Decolorization of orange II by electrocoagulation method.** SEPARATION AND PURIFICATION TECHNOLOGY. 2003 MAY 1; 31 (2): 153-162.
6027 Mahmoodi NM, Arami M, Limaee NY, Tabrizi NS. **Decolorization and aromatic ring degradation kinetics of Direct Red 80 by UV oxidation in the presence of hydrogen peroxide utilizing TiO2 as a photocatalyst.** CHEMICAL ENGINEERING JOURNAL. 2005 SEP 1; 112 (1-3): 191-196

Figure 7. Cluster5 in LCS level

Analyzing the subject clusters of Iranian engineering scientific products based on GCS map

This study extracted 600 top documents that received the most global citations. These 600 top documents span from 1973 to 2009 with 290 links, with minimum GCS of 21 and maximum GCS of 530.

The results of analysis showed that the paper by Hashemi on the indoor radio propagation channel (node 619) from department of electrical engineering, Sharif University of Technology received the most global citations (GCS: 530) in comparison to the other 400 top documents, followed by the papers by Ghodsypour and O'Brien (node1575, GCS:240), in the area of "operations research management science" and from Department of Industrial

Engineering, Amirkabir University of Technology and Department of Manufacturing Engineering and Operations Management, University of Nottingham; Ahmadi (node105, GCS:217) in the area of "mechanics" and from Department of Physics, University of Saskatchewan, Canada and School of Engineering, Pahlavi University, Shiraz; Jamieson et al. (node11325,GCS:191), in the area of "automation control systems" and from Biomaterials & Tissue Engineering Centre (BTEC), University College London and Iran Polymer and Petrochemical Institute; Massoumnia et al (node417, GCS:190), in the area of "Hardware & Architecture" from Sharif University of Technology received the most global citation (Table9).

Table 9

Top 5 highly cited Iranian papers in the engineering base on GCS map

Records	Source	GCS
619	Hashemi,H. (1993).**The indoor radio propagation channel.** Proceeding of the IEEE. 81 (7): 943-968.	530
1575	Ghodsypour SH, O'Brien C. (1998). **A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming**. International Journal of Production Economics. 1998 SEP 20; 56-7: 199-212.	240
105	Ahmadi, G. (1976). **Self-similar solution of imcompressible micropolar boundary-layer flow over a semi-infinite plate**. International Journal of Engineering Science. 14 (7): 639-646.	217
11325	Jamieson T, Bakhshi R, Petrova D, Pocock R, Imani M, et al. (2007).**Biological applications of quantum dots. Biomaterials**. 28 (31): 4717-4732.	191
417	Massoumnia, MA. et al. (1989). **Failure-detection and identification**. IEEE Transactions on Automatic Control. 34 (3): 316-32.	190

The results of analyzing map showed that on the GCS level, there were three large clusters. In the following paragraphs, we will explain clusters (Figure 8).

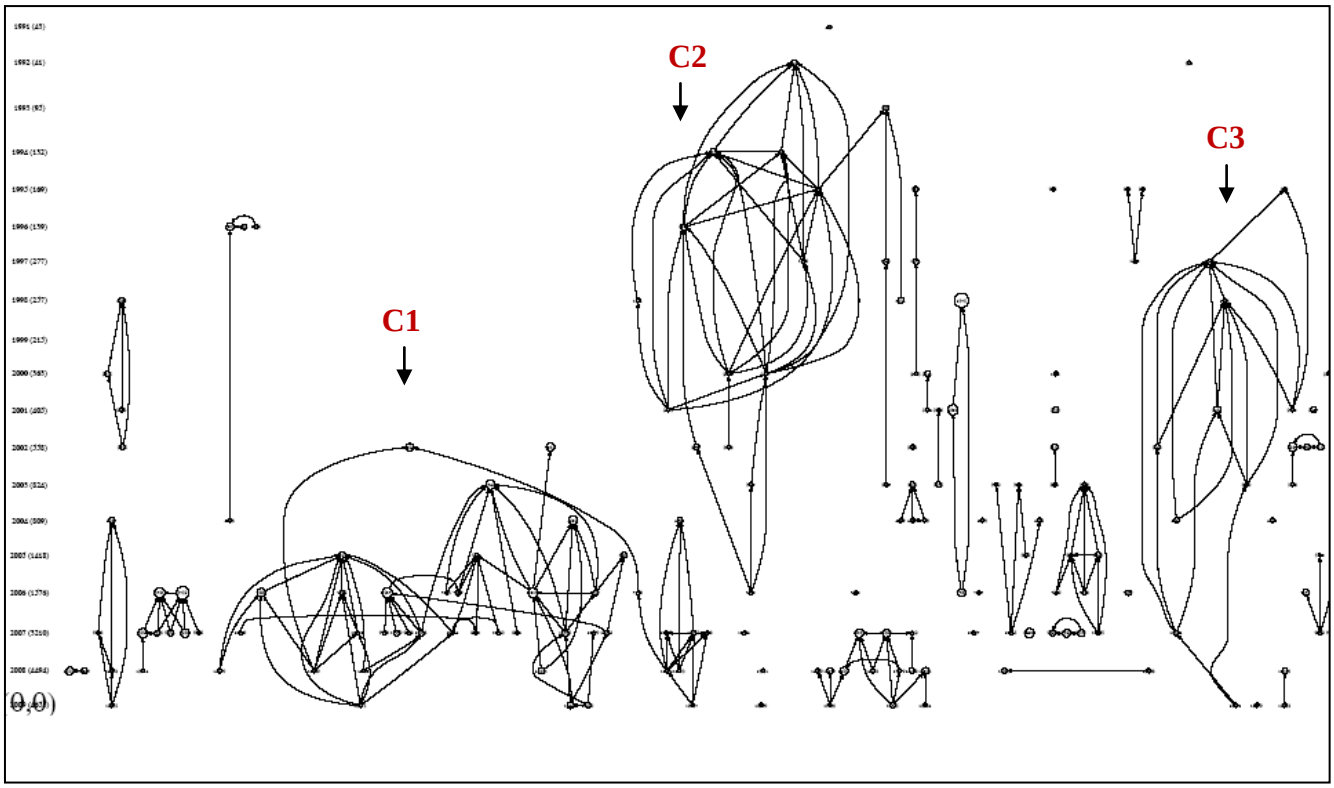
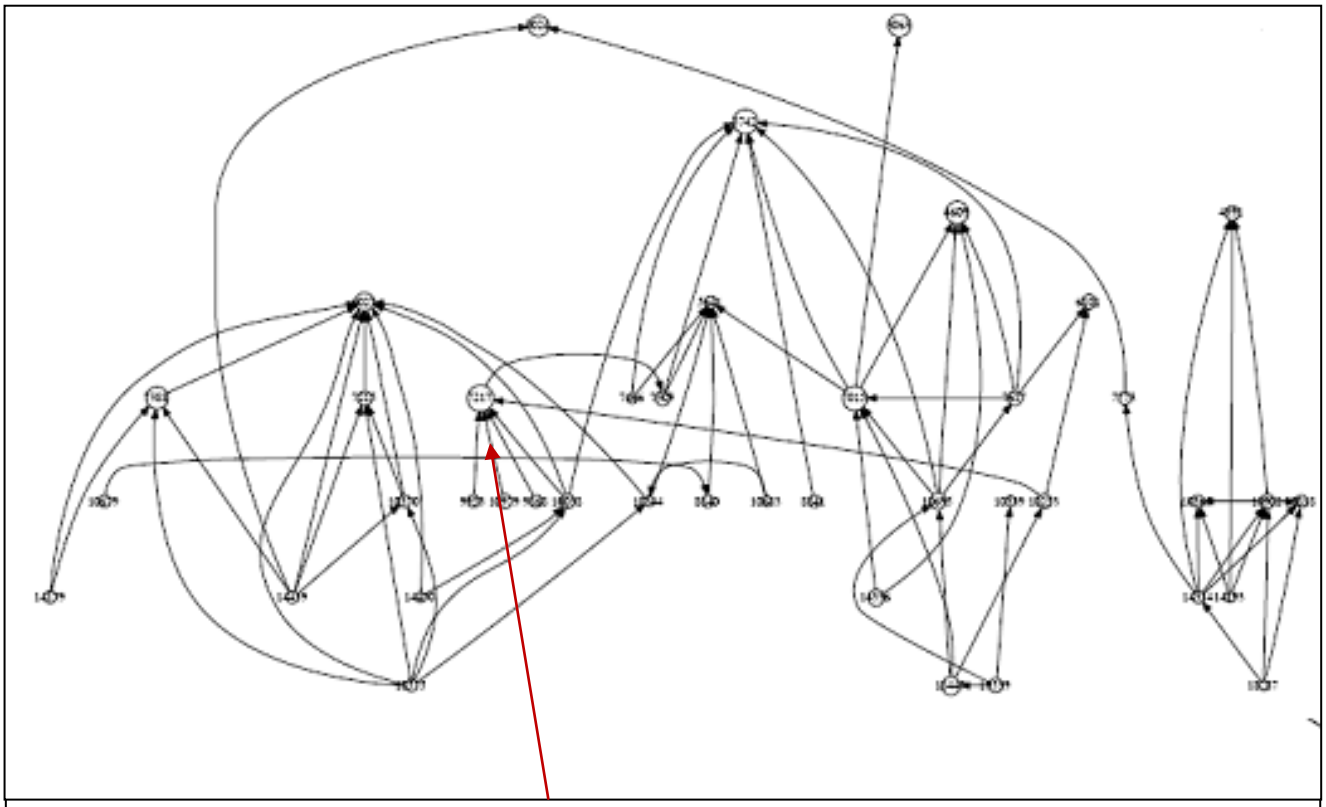


Figure 8. Historiographical Map of Iranian Engineering Scientific Publications during1939-2011 based on GCS

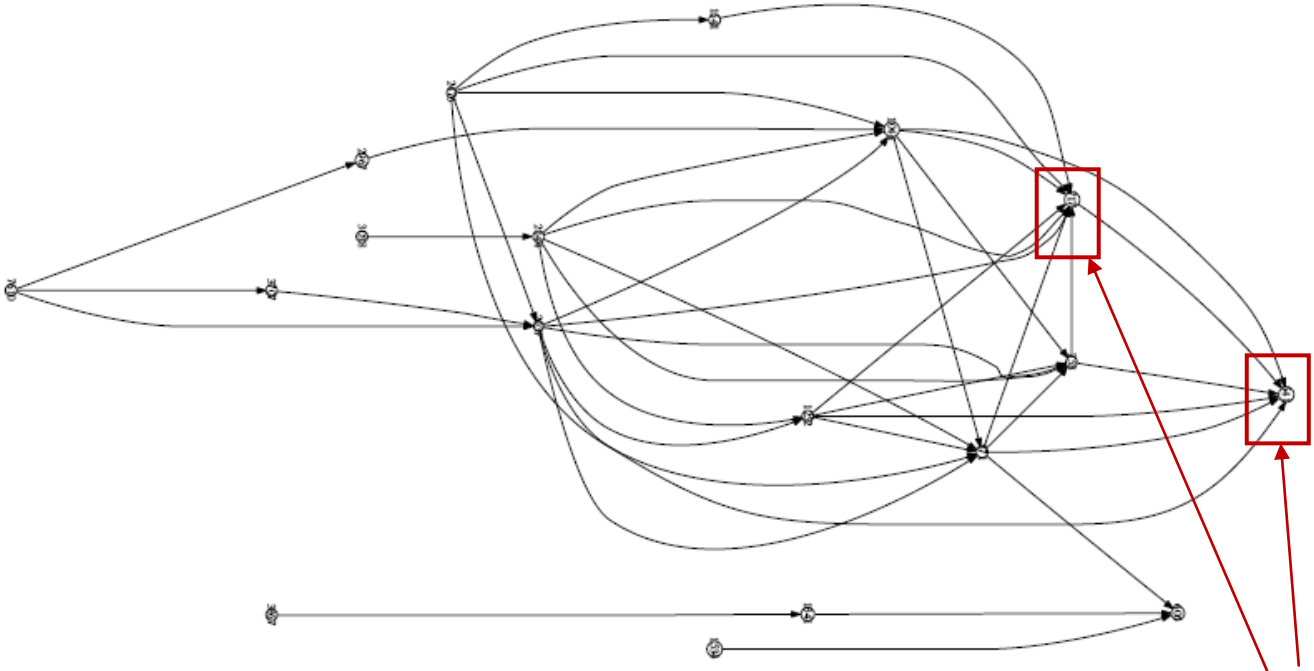
Cluster1. This cluster consisted of 42 document and 52 authors over the period time 2002-2009, in the area of "applied chemistry". The most effective document is Behnajady and his/her colleagues (7217) with 125 GCS, as they are from Department of Applied Chemistry, Islamic Azad University, Tabriz Branch (Figure9).



7217 Behnajady MA, Modirshahla N, Hamzavi R. **Kinetic study on photocatalytic degradation of CI Acid Yellow 23 by ZnO photocatalyst .**Journal of Hazardous Materials. 2006 MAY 20; 133 (1-3): 226-232.

Figure 9. Cluster1 in GCS level

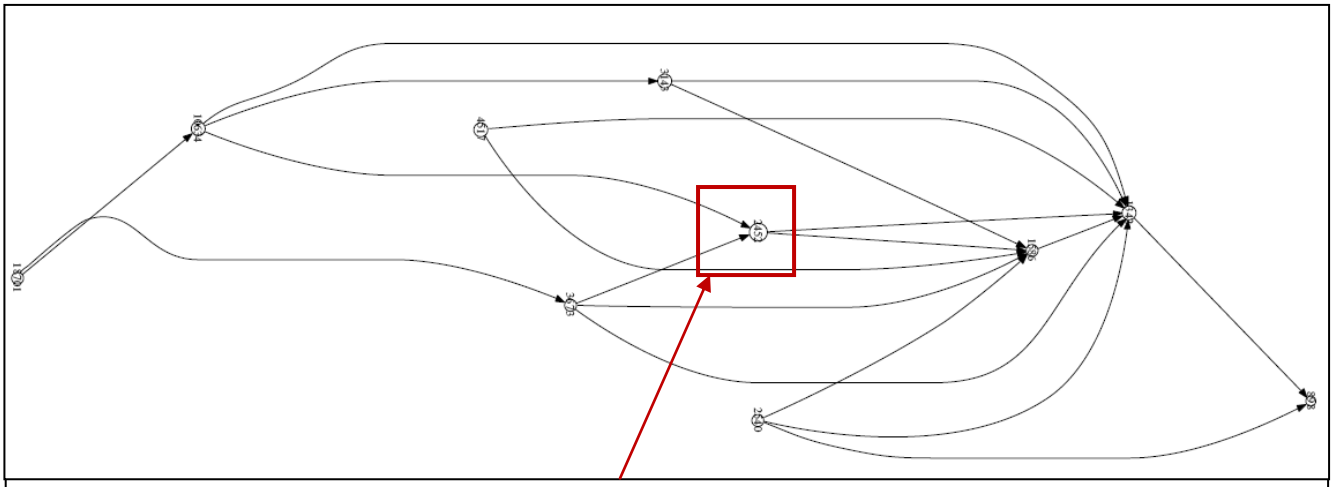
Cluster2. There are 18 document and 28 authors over the period time 1992-2006, in the area of "liquid membranes". The most effective document (considering the number of citations received and links to it) is Dadfarnia and Shamsipur (541) and Parham and Shamsipur (717) with 52 GCS, as they are from Department of Chemistry, Shiraz University. According to this graph, Shamsipur played a very important role with the most number of articles (Figure10).



541 Dadfarnia S, Shamsipur, M. **Specific membPECIFIC MEMBRANE-TRANSPORT OF COPPER(II) ION BY A COOPERATIVE CARRIER COMPOSED OF 1,7-DIAZA-15-CROWN-5 AND PALMITIC ACID**. JOURNAL OF MEMBRANE SCIENCE. 1992 DEC 16; 75 (1-2): 61-68
717 Parham H, Shamsipur M. **HIGHLY SELECTIVE AND EFFICIENT TRANSPORT OF MERCURY AS HG(NO2)(4)(2-) ION USING BA2+-18-CROWN-6 AS CARRIER**. JOURNAL OF MEMBRANE SCIENCE. 1994 JAN 27; 86 (1-2): 29-35

Figure 10. Cluster2 in GCS level

Cluster 3. This cluster consisted of 10 document and 11 authors over the period time 1996-2009, in the area of "Liquid–liquid equilibrium". The most effective document is Zafarani-Moattar and Sadeghi, R. (2452) with 56 GCS, as they are from Physical Chemistry Department, University of Tabriz. According to this graph Zafarani-Moattar and Sadeghi together played an important role with the most number of articles (Figure11).



2452 Zafarani-Moattar MT, Sadeghi R. **Liquid-liquid equilibria of aqueous two-phase systems containing polyethylene glycol and sodium dihydrogen phosphate or disodium hydrogen phosphate - Experiment and correlation.** FLUID PHASE EQUILIBRIA. 2001 MAY; 181 (1-2): 95-112

Figure 11. Cluster3 in GCS level

Discussion

In this study, we have identified the key researchers, journals, institutions and visualized scientific products of Iranian engineering researchers using HistCite™ software. Totally, 28010 scientific outputs were published by engineering researchers covered by Web of Science (WOS) during 1939-2011. The results of this study showed that the published papers of Iranian researchers in the field of engineering had fluctuation. In other words, during the period under study (1939-2009) the trend of outputs productions were upward but during 2010-2011, a dramatic fall was observed. The results of the study revealed a growth rate of 47.58 percent. The results of present study are in line with the results obtained by Osareh and Keshvari (2010) indicating that the trend of Iranian engineering outputs during 1990-2008 had an ascending rate. In another work, Osareh and Wilson (2002) showed that Iran's publication output in science and technology increased dramatically in the SCI during 1995-1999.

It was also observed that the share of Iran in the engineering outputs is only 0.65% of total publications and Iran ranked in the 24 place in the world. This finding supports the ideas of Osareh and McCain (2008**)** and ZareBanadkoki and Oliya (2010**)**, who suggested that chemistry research and field of industrial engineering in Iran is situated in a rather good position. Our findings suggested that 15853 documents out of 28010 were in article format and approximately all documents were written in English language. These findings are consistent with those of Behzadi and JowKar (2011), Osareh and Zare (2010), Osareh and Keshvari (2010), Osareh and Keshvari (2010) who found that the most frequent document type was paper format and almost all documents were written in English language.

Tehran University, Sharif University of Technology, Amir Kabir University of Technology, Iran University Science and Technology have produced the most scientific

documents in the field of engineering and ranked 1-4 respectively. However, with respect to LCS and GCS Indexes, Sharif University of Technology, Tehran University, and Amir Kabir University of Technology were made up of the most highly cited papers, so that this result confirmed Osareh and Keshvari (2010) finding. Also, University of Waterloo, University of Toronto and University of Calgary were the most important non-Iranian universities that collaborated with Iranian Universities.

Our findings suggested that the small part of journals have published the large part of papers. *Journal of Hazardous Materials, Journal of Chemical and Engineering Data, Fluid Phase Equilibria, and Desalination* were the top journals in a number of paper, LCS index and GCS index.

Iranian engineering authors collaborated with scholars of 21 countries. Among them, the authors from Canada were in first place, followed by authors from USA, UK, Australia and France. The advantages of scientific international collaboration have been always discussed by scientists and policy makers and have been important research topics in the field of scientometric and quantitative researches of science and technology. Therefore, the policy makers should pay more attention to collaboration and should provide further areas of cooperation.

Kaveh, Faiz, and Afzali had the largest number of papers. But, with respect to LCS index, the most highly cited papers and Based on GCS index were related to Kaveh, Keshavarz, and Zafarani and Daneshvar, Shamsipur, and Hashemi had the highest numbers of cited papers in the field of engineering in Iran.

This study constructed the historiographs for Iranian engineering outputs based on both local citation scores (LCS) and global citation scores (GCS), and identified key papers. This study found that the engineering research knowledge flow among different Institutions in Iran. A total of five large clusters were formed on the LCS index. The Most clusters were related to subject area "Thermodynamics and Chemical engineering", "N-O Explosives, "liquid membranes", and "Liquid–liquid equilibrium", and "decolorization". Gharagheizi, Keshavarz, Shamsipur, and Zafarani-Moattar and Sadeghi, and Daneshvar played a very important role with the most number of articles.

The results indicated that a total of three clusters have been formed on the GCS index. The Most clusters was related to subject area belong to "liquid membranes", "applied chemistry", and "Liquid–liquid equilibrium". Shamsipur, Zafarani-Moattar and Sadeghi, and Ganji, played a very important role and the most number of articles.

Conclusions

The purpose of this paper was to visualize the structure of the Iranian scientific publications in the field of engineering indexed in Thomson Reuters (ISI) accessible via WoS during 1939-2011. The results revealed that five subject area "Thermodynamics and Chemical

engineering", "N-O Explosives, "liquid membranes", and "Liquid–liquid equilibrium", and "decolorization" are the most important subjects and Gharagheizi, Keshavarz, Shamsipur, and Zafarani-Moattar and Sadeghi, and Daneshvar play a vital role in the field of engineering on the LCS index. However, the subjects area belong to "liquid membranes", "applied chemistry", and "Liquid–liquid equilibrium" are the most subjects based on GCS and Shamsipur, Zafarani-Moattar and Sadeghi, and Ganji, play a very important role in the field of engineering.

Hopefully, this paper provides some additional attitudes into the current state of Iranian engineering research such as the characteristics of research activities, research hot spot tendencies or irregularities, the most important universities and institution and journals, researchers etc. Also, we contend that the results of this research can provide unique and detectable indicators to describe future research.

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