

# Mapping the Science of Soft Operations Research Based on ISI Subject Areas

Mohammad Reza Mehregan

Professor in Operations Research, Faculty of Management, University of  
Tehran, Iran

Mohammad Reza Akhavan Anvari<sup>1</sup>

PhD Candidate in Operations Research, Faculty of Management, University of  
Tehran, Iran

Kamyar Raissifar

PhD Student in Organizational Behavior, Faculty of Management,  
University of Tehran, Iran

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## Abstract

The present study aimed at visualizing the Soft Operations Research (SOR) domain. For this purpose, the six-phase mapping process was used. In this process, the first phase deals with extracting the data. Analysis unit is selected in the second phase. In the third and fourth phases, frequency of articles is studied and similarities among the extracted articles are determined, respectively. In the fifth phase, the related areas are identified by using a clustering algorithm. Finally, subject areas are mapped and analyzed by using the clustering steps in the sixth phase. Based on the results of the mapping process in this research, six clusters in the areas of management and social sciences, engineering sciences, behavioral sciences, geology and environmental studies, sociology and natural resources and mathematics were obtained.

**Keywords:** OR in societal problem analysis, Soft Operations Research (SOR), Science Map and ISI Database

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<sup>1</sup> Corresponding author's email: [mrahavan@ut.ac.ir](mailto:mrahavan@ut.ac.ir)

## Introduction

Great interest has recently been shown in visualizing the structures of scientific domains (Boyack, Klavans, and Börner, 2005). In fact, the accumulative nature of knowledge requires systematic ways to comprehend and make sense of what we know (Lucio-Arias & Scharnhorst, 2012). One of the most important methods in this field is generating science maps, which are visual representations of the interrelationships of various knowledge domains. Accurate science maps help understanding the structure and evolution of knowledge domains. In fact, mapping science is rather new area that seeks to depict, search, analyze, categorize and represent knowledge (Shiffrin and Börner, 2004).

Mapping of science, especially in the relatively new areas of science, can play a more effective role in informing about the internal structure and the external interactions of a domain by depicting the relationship of that domain with other science domains. In this regard, by mapping the Soft Operations Research (SOR) domain, which is considered a new one, the present study seeks to contribute to identifying the status of this domain and its relationship with other science domains.

Operations Research (OR) is a science aiming to analyze complex problems and help decision-makers to find the best means for achieving some goals. Since not all actual problems decision-makers are facing with can be modeled and analyzed within the context of OR traditional methods, and due to increasing complexity of the range of decision-making problems, a new OR branch namely SOR has been developed. Contrary to the traditional hard approach, i.e. Hard Operations Research (HOR), SOR uses qualitative and interpretative methods for interpreting, defining and considering the various aspects of the problem under study. SOR methodologies lead to debate, learning and understanding, and use this new understanding to further solve the problem (Heyer, 2004).

Since SOR is new domain comparing to HOR, studying the relationship of this domain and other domains, opening new horizons for the potential applications of the concepts of this domain seem to be significant. One of the major methods in this regard is visualizing the desired domain based on the data from scientific databases. The aim of the present study is to determine the knowledge areas and domains relevant to SOR by mapping this scientific domain.

## Literature Review

Categorization of knowledge is not a new subject. Its origins may be traced back to the nineteenth century and the efforts of August Comte for presenting a categorization of sciences into six branches (Klavans and Boyack, 2008). Nowadays, one of the tools for categorization of knowledge is generating science maps. Map of science is a special representation of the relationship between domains, fields, specialties and articles, in which distance and proximity, as well as the amount of relationship are represented. Science map can help better understand the conceptual relationships and advances in each field of science (Small, 1999). Science maps transform black box of knowledge into informative representations which help to find way, find collaborators, and identify

trends (Börner, 2010). Therefore, science maps capture the structure and dynamics of scientific endeavor and can provide insights into the inner workings of science (Börner et al; 2012). In fact, what distinguishes science map from other knowledge categorizations is firstly the visual representation of knowledge domains, and secondly depicting the relationships among the subjects (Klavans and Boyack, 2008). The aim of mapping of science is revealing the structures and dynamics of a science domain through representing the internal relationships of the citations within that domain (Van Den Besselaar and Heimeriks, 2006). The first attempt on mapping of science was made in 1965 in order to provide a description of the nature of the universal network of scientific papers (Price, 1965). Ever since, various methods of mapping of science have been introduced including journal index analysis, co-index analysis, bibliometric analysis and finally, co-word analysis (Van Den Besselaar and Heimeriks, 2006).

### Research Methodology

The study of the structuring of scientific domains and of scientific activity is open to a variety of conceptualizations, methodologies and interpretations (e Silva & Teixeira, 2012). The research methodology used in present study is citation analysis, which is one of the newly-emerged methods in the area of scientometrics, bibliometrics and infometrics. In general, mapping of science process consists of the following six phases (Börner, Chen, and Boyack, 2005):

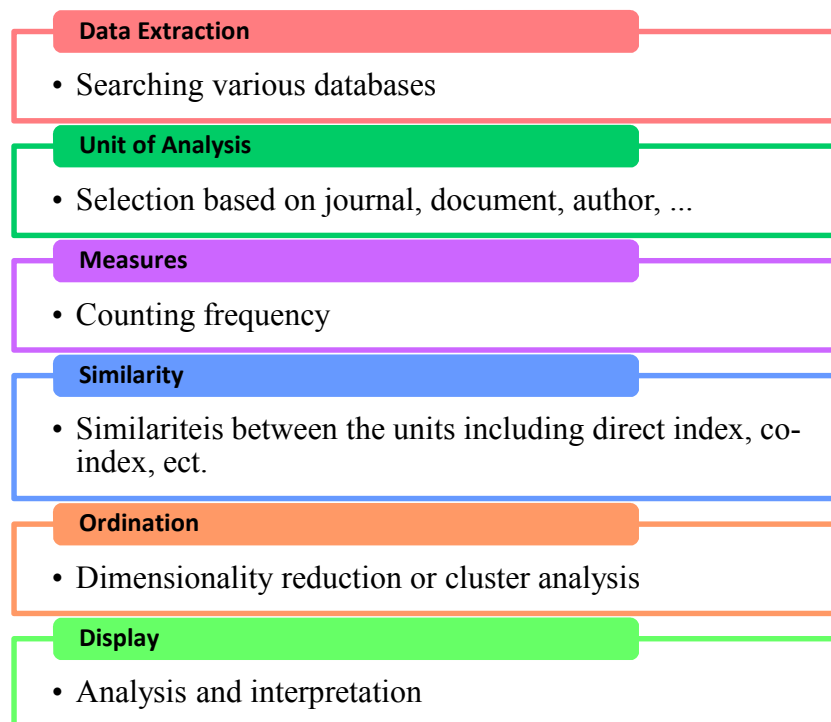


Figure 1 Process of mapping of science

As illustrated, the first phase in this process is data extraction. In the present study, the ISI web of science was used for this purpose. The second phase is determining the analysis unit. The analysis unit can be a journal, author, document or word. In this

study, word was selected as the analysis unit for searching the ISI database. According to the available sources, 17 SOR related keywords were selected and searched in the ISI database, and 819 articles were obtained. The aim of the third and fourth phases is to find similarities among the extracted articles. These phases were conducted by using the analyst software available at the website; hence, searched articles were categorized under 81 subject domains. However, some of these domains were excluded from the analysis because they consisted of a scarce number of articles. Then matrix of the relationship among the subject domains was prepared and normalized. In the fifth phase, using a clustering algorithm, interrelated domains were identified. Eventually, in the sixth phase, the map of the subject domains was depicted and analyzed based on the clustering phases.

Thus, the practical phases of conducting this research can be presented as below:

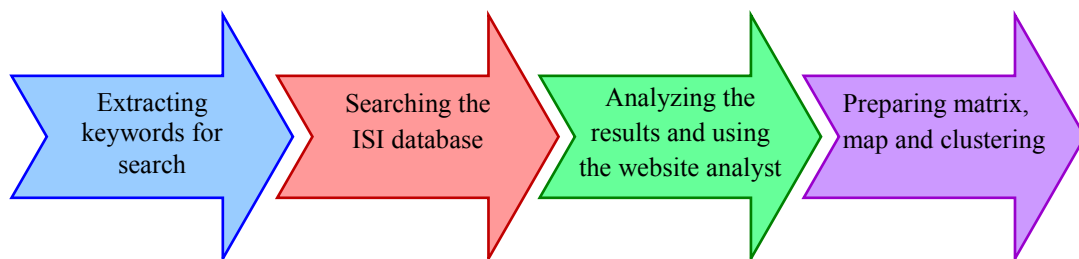


Figure 2 Research process

In summary, the research follows six-phase science mapping process, and uses Hierarchical Agglomerative Algorithm for clustering. Generally, there are two kinds of clustering algorithms, namely partitioning and hierarchical methods. A partitioning method, constructs K clusters, which each cluster must contain at least one object, end each object must belong to exactly one cluster (Kaufman & Rousseeuw, 2009). Hierarchical techniques produce a nested sequence of partitions, with a single, all-inclusive cluster at the top and singleton clusters of individual points at the bottom. Each intermediate level can be viewed as combining two clusters from the next lower level or splitting a cluster from the next higher level. There are two basic approaches to generating a hierarchical clustering: **a) Agglomerative:** Start with the points as individual clusters and, at each step, merge the most similar or closest pair of clusters. This requires a definition of cluster similarity or distance. **b) Divisive:** Start with one, all-inclusive cluster and, at each step, split a cluster until only singleton clusters of individual points remain (Steinbach, 2000). Researchers, use Hierarchical Agglomerative Algorithm, start with a similarity matrix, then merge the most similar two clusters, update the matrix, and repeat this process until only a single cluster remains.

## Findings

Based on the above-mentioned phases, the science map of SOR was depicted:

**1) Extracting keywords:** By referring to the sources available in the field of SOR, 17 related keywords were extracted and selected to be searched in the ISI database. These keywords are listed in Table 1.

Table 1 Keywords.

No	Keyword	No	Keyword	No	Keyword
1	Soft Operations Research	7	Journey Making	13	Root Definition
2	Soft System Thinking	8	Lumas Model	14	Cause Map
3	Strategic Choice Approach	9	Cognitive Mapping	15	Fuzzy Cognitive map
4	Strategic Options Development and Analysis	10	Causal Loop Diagrams	16	PQR Questions
5	Strategic Assumption Surfacing and Test	11	Soft Systems Methodology	17	CATWOE
6	Unbounded Systems Thinking	12	Causal Mapping		

**2) Searching the ISI database:** Within the ISI database, there is a search engine, which makes it possible to search based on subject, title, author, etc. Accordingly, using the 17 keywords extracted in the previous phase, 819 articles were found at this database.

**3) Analyzing the results using the website analyst:** After searching in the ISI database and analyzing the results, 81 subject categories were considered as the subject sub-domains of SOR.

Following the search operation, 819 articles were related to 81 subject domains; however, it is evident that domains with a small number of articles cannot be considered significant. Therefore, the researchers decided to eliminate the domains with less than 10% of the total number of articles from the analysis. Thus, 23 domains were left to be analyzed (Table 2).

Table 2 Research area.

No.	Research Area	Abbreviation	Frequency	Percent
1	Business Economics	BE	277	0.223
2	Computer Science	CS	192	0.154
3	Operations Research Management Science	OR and MS	123	0.099
4	Engineering	En	117	0.094
5	Psychology	Psy	96	0.077
6	Social Sciences Other Topics	SS	73	0.058
7	Environmental Studies	ES	62	0.049
8	Information Science Library Science	IS	35	0.028
9	Neurosciences Neurology	NS	30	0.024
10	Behavioral Sciences	BS	27	0.021
11	Public Environmental Occupational Health	PE	21	0.016
12	Geography	GEO	20	0.016

13	Education Educational Research	ER	15	0.012
14	Mathematics	Math	15	0.012
15	Zoology	Zoo	14	0.011
16	Transportation	Trans	12	0.009
17	Mathematical Methods In Social Sciences	MSS	11	0.008
18	Water Resources	WR	11	0.008
19	Public Administration	PA	10	0.008
20	Nursing	NURS	10	0.008
21	Forestry	FOR	10	0.008
22	Agriculture	AG	9	0.007
23	Sociology	SOC	9	0.007

**4) Preparing the matrix, generating the map, and clustering:** In this phase, hierarchical agglomerative clustering algorithm was used. This clustering method consists of three steps. In the first step, adjacency matrix is calculated, a matrix that contains the numbers related to the distance of pairs of data from each other. In this step, each domain is regarded as a cluster. In the second step, the most similar pairs of the matrix are determined and their respective clusters are integrated. Then the adjacency matrix is updated based on this integration. The third step states that if all domains are located within the same cluster, the process is over; otherwise the previous step is repeated (Jain, Murty, and Flynn, 1999). Accordingly, at this phase, a normal matrix of the relationship of various subject areas was obtained based on the information related to the amount of articles shared in the subject sub-domains and normalization based on the percentage of shared articles. To this end, using the software at the ISI web of knowledge, and by entering each research domain, the amount of shared articles (comprise the elements of the matrix of the relationship among the domains) was calculated. But since the number of articles shared between two subject domains is a function of the number of articles in each domain, thus comparing them with one another would not be a proper comparison. In order to assimilate the basis of comparison, the relationship matrix must be normalized in a way that the effect of the number of articles in each domain is neutralized. For this purpose, using the following equation, the normalized relationship matrix was calculated:

$$\frac{X_{ij}}{(N_i + N_j) - X_{ij}} * 100$$

Where,  $X_{ij}$  represented the elements of relationship matrix, or the number of articles shared between the two subject domains of  $i$  and  $j$ ; and  $N_j$  is the amount of articles in the subject domain  $j$ .

Finally, hierarchical agglomerative clustering algorithm was employed in order to categorize 23 subject sub-domains and obtain the areas of the map. To generate the map, the information about the number of articles in each subject domain and the number of articles shared among the subject domains (normalized relationship matrix) were used. Drawing of the map was performed using Pajek software, which is a software for drawing networks (De Nooy, Mrvar, and Batagelj, 2011). It is noteworthy that the size of nodes was calculated based on the amount of articles in each subject sub-

domain, and the weight of the edges (lines connecting nodes) indicated the percentage of the articles shared in the related subject sub-domains.

Taking into consideration all of the articles shared among the 23 domains under study, a figure was drawn, which not only includes the nodes but also the relationship between them (Figure 3).

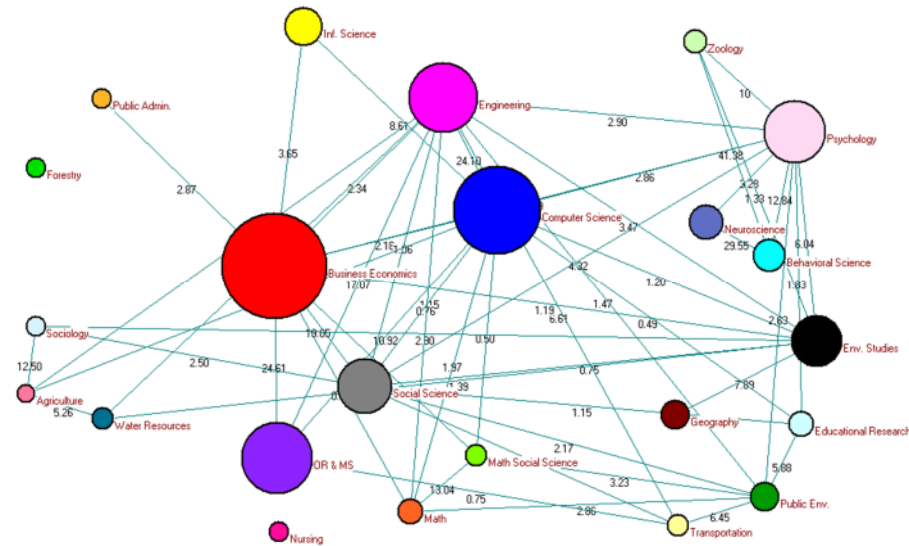


Figure 3 Subject areas and relation between them

Then unclustered subject domains were drawn so that the path of clustering based on the normalized relationship matrix may be followed step by step:

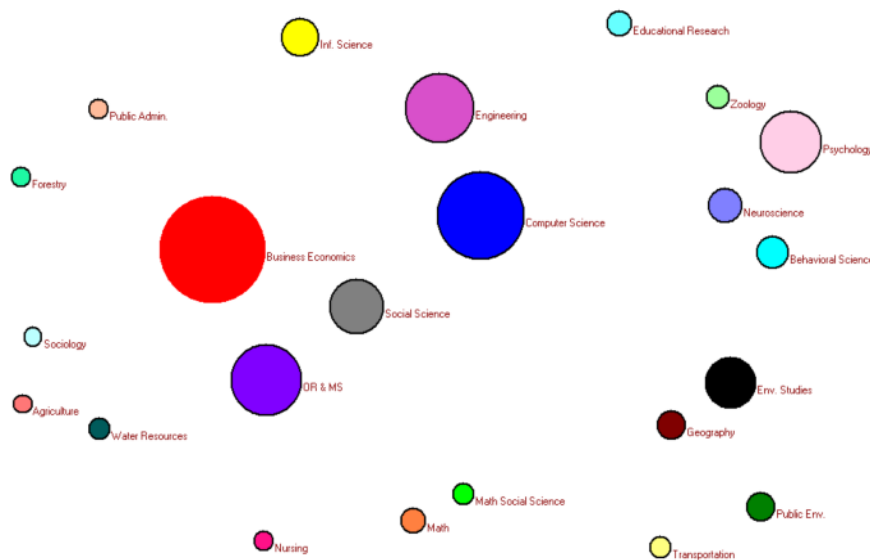


Figure 4 Unclustered subject areas

Clustering path means that in the normalized matrix, the biggest number, which indicates the maximum number of articles shared between two domains, is found; this relationship has been represented in Figure 4. Then the matrix is updated according to this relationship; and again the main relationship is found and drawn in the figure. This continues until all domains are connected to one another and a comprehensive cluster (containing all domains) is formed. However, whenever, as a result of a new connection, a domain from a cluster is related to a domain from another cluster, the clustering path continues but these two domains are considered as independent of one another.

In Figure 5, the ultimate status of clustering of domains can be observed. It is worth nothing that this process was achieved through the aforementioned steps, and here for the sake of brevity, not all of the figures have not been presented here.

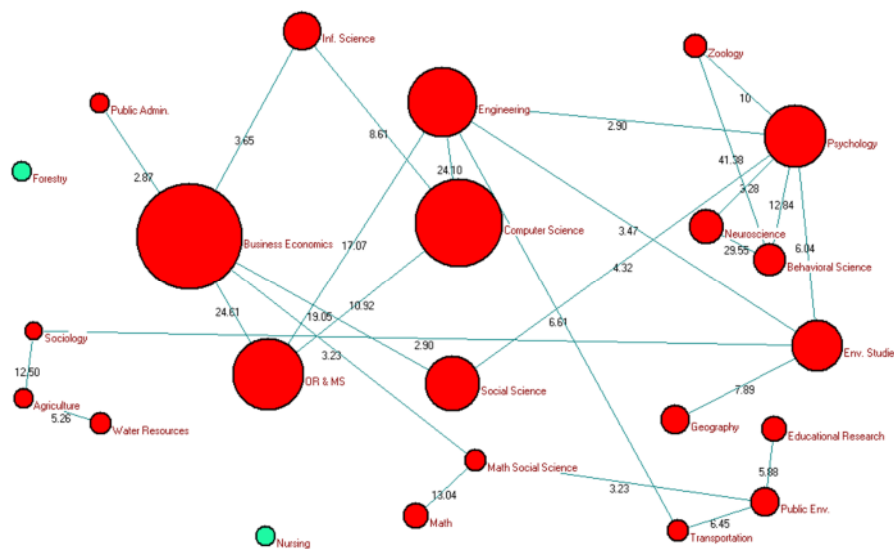


Figure 5 The final situation of clustering.

## Conclusion and Explanation of the Model

As a result of this research, after extracting the SOR related keywords, searching the ISI web of science, analyzing the results, generating the map based on the normalized relationship matrix of subject domains and finally, clustering the domains, six clusters and seven independent subject domains were determined. On the whole, the six clusters comprising of 16 subject domains along with the seven independent domains made up the total of 23 domains under study.

The six obtained clusters are as follows:

**First cluster:** Management and Social Sciences Cluster, including the subject domains of business economics, OR and MS and social sciences with 437 articles and 57.7% of the total articles;



**Second cluster:** Engineering Sciences Cluster, including the subject domains of engineering and computer science with 309 articles and 37.7% of the total articles.

**Third cluster:** Behavioral Studies Cluster, including the subject domains of zoology, behavioral sciences, neurosciences and psychology with 167 articles and 20.3% of the total articles;

**Fourth cluster:** Environmental and Geographical Sciences Cluster including the subject domains of geography and environmental studies with 82 articles and 10.0% of the total articles;

**Fifth cluster:** Sociology and Natural Resources Cluster, including the subject domains of agriculture, sociology, and water resources with 29 articles and 3.5% of the total articles;

**Sixth cluster:** Mathematics Cluster, including the subject domains of mathematics, and mathematics in social sciences with 26 articles and 3.1% of the total articles.

Also the seven independent subject domains were:

1. The subject domain of Information Science Library Science with 35 articles and 4.2% of the total articles;

2. The subject domain of Public Environment and Occupational Health with 21 articles and 2.5% of the total articles;

3. The subject domain of education Educational Research with 15 articles and 0.01% of the total articles;

4. The subject domain of Transportation with 12 articles and 0.01% of the total articles;

5. The subject domain of Nursing with 10 articles and 0.01% of the total articles;

6. The subject domain of Forestry with 10 articles and 0.01% of the total articles;

7. The subject domain of Public Administration with 10 articles and 0.01% of the total articles.

Evidently, due to what domains share, their cumulative rate will be higher than 100%.

## **Discussion**

### *First cluster: Management and Social Sciences*

This cluster consists of the three subject domains of Business Economics, Operations Research/Management Science (OR/MS), which, on the whole, include 473 (57%) articles out of the total of 819 articles.

First, in the third phase, the two subject domains of Business Economics and OR and MS (OR/MS) were connected. Then in the fifth phase, Social Sciences was also linked to them and the cluster was completed. But very soon and in the sixth phase, this cluster was integrated with another cluster. The early integration of this cluster suggests its lack of strong internal coherence.

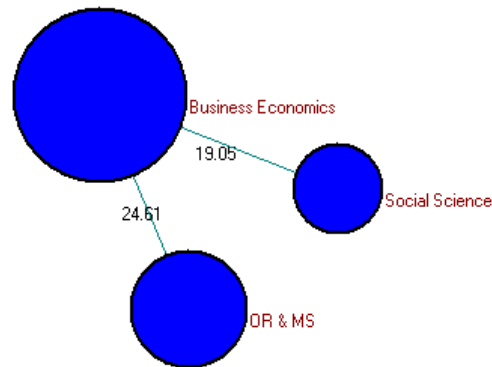


Figure 6 First cluster: Management and Social Sciences.

#### *Second cluster: Engineering Sciences*

This cluster consists of the two subject domains of Engineering and Computer Sciences which include the total of 309 articles and approximately 37.7% of the articles.

This cluster was formed in the fourth phase as a result of integration of the two abovementioned domains; however, in the sixth phase, it was integrated with the first cluster (Management and Social Sciences); this early integration suggests this cluster's lack of internal coherence and, on the other hand, its relationship with the first cluster.

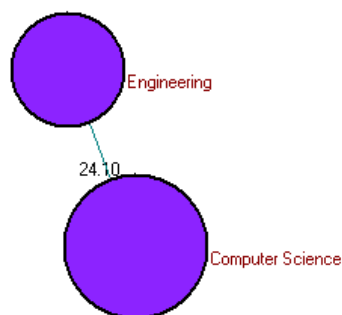


Figure 7 Second cluster: Engineering Sciences.

### *Third cluster: Behavioral Studies*

This cluster consists of four subject domains: Zoology, Behavioral Sciences, Neurosciences and Psychology. The number of articles in this cluster is 167, which comparing of 20.3% of the total articles.

In the first phase, the two domains of Zoology and Behavioral Sciences were connected. In the second phase, Neurosciences was linked to them, and in the eighth phase, psychology was also added to this cluster. This cluster remained independent up to the fourteenth phase. However, in this phase, it was integrated with another cluster. The late integration of this cluster suggests its high internal coherence.

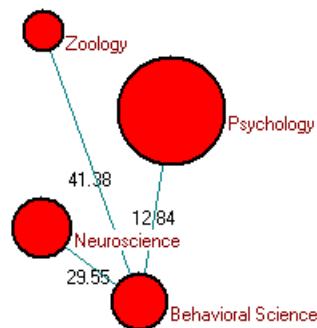


Figure 8 Third cluster: Behavioral Studies.

### *Fourth cluster: Environmental and Geographical Sciences*

This cluster consists of the two subject domains of Geography and Environmental Studies with 82 articles and 10.0% of the total articles. It was formed in the eleventh phase and remained independent up to the fourteenth phase. But in the fourteenth phase, it was integrated with the third cluster (Behavioral Sciences). It is to be mentioned that 7.89 relationships among the components of this cluster and its formation in the eleventh phase is representative of its rather weak internal coherence.

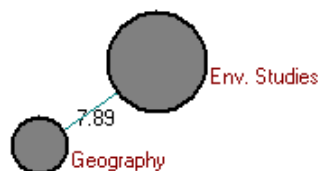


Figure 9 Fourth cluster: Environmental and Geographical Sciences.

### *Fifth cluster: Sociology and Natural Resources*

This cluster consists of the three subject domains of Agriculture, Sociology and Water Resources with 29 articles and 3.5% of the total articles.

This cluster was formed in the ninth phase by relating sociology to agriculture, and in the sixteenth phase, it was completed after being integrated with water resources. It remained independent up to the nineteenth phase when it was integrated with the fourth cluster. Although the relationship among the components of this cluster is weak; however its internal coherence, i.e. its late integration with other clusters, is rather strong.

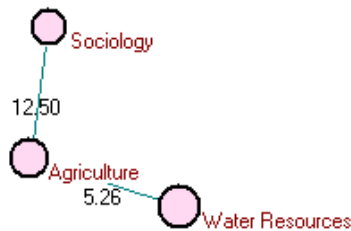


Figure 10 Fifth cluster: Sociology and Natural Resources.

#### *Sixth cluster: Mathematics*

This cluster consists of the two subject domains of Mathematics, and Mathematical Methods in Social Sciences with 26 articles and 3.1% of the total articles under study. It was formed in the seventh phase with 13.04 relationships among its components, and it lost its independence in the eighteenth phase. This cluster enjoys a high internal coherence, which taking into considerations its subjects, is not far from the expectations.

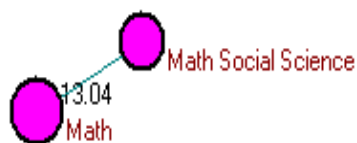


Figure 11 Sixth cluster: Mathematics.

Finally, a comprehensive map, in which the individual clusters have been specified, was drawn.

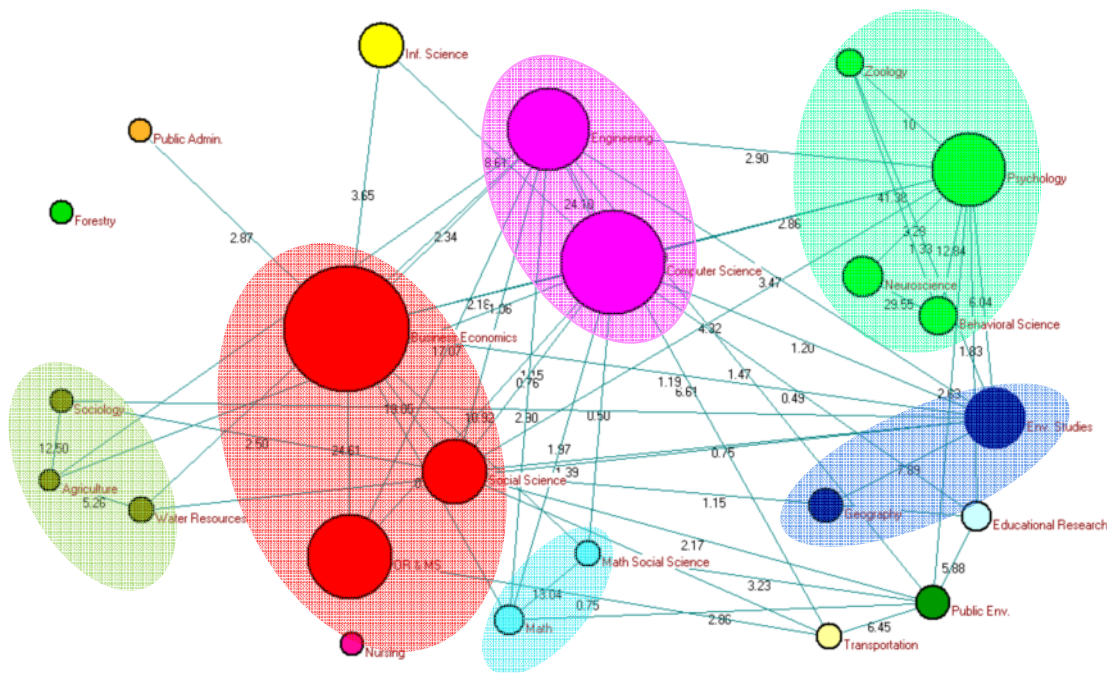


Figure 12 All clusters

## Recommendations

Mapping of SOR domain not only shows its relationships of SOR with other areas, but also opens horizons for future research for the researchers in this field. In this regard, few points are mentioned:

First, in preparing and drawing the science map of SOR, the need for preparing a comprehensive encyclopedia of this field which containing all specialized relevant keywords is felt. Due to the increasingly vast domain of this field of knowledge, preparing and compiling such an encyclopedia seems to be necessary and helpful.

Besides, the relationships shown on the map indicate the application of SOR in various scientific fields and areas. Therefore, on the one hand, OR researchers can become more familiar with the applications of their field in other domains, and the researchers in other domains who use OR may become aware of the existence of this science and its applications in their own fields on the other. They can further devise and implement new applications of this science in their own fields. In other words, mapping of SOR domain makes it possible to extend the applications of this science in other scientific domains.

The other recommendation is related to research methodology. This research can be conducted making use of other clustering methods, at other databases or with different analysis units.

The last recommendation deals with the educational content of SOR. By depicting new trends in this field and their relationships with other knowledge domains, drawing

the science map of SOR really helps develop educational content for this field in order to be taught at universities. The use of this map can further enrich and update the educational areas of SOR at academic and university centers.

As final point, it can be argued that mapping science domain, can be beneficial for science policy makers, for two reasons: Firstly, science policy makers need to dynamic monitoring and forecasting of scientific developments and technological breakthroughs. And secondly, they need to better understanding the institutional and organizational conditions for a healthy and high-performing research system, and gaining knowledge about the relations between science domains can help them achieving this.

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