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Bibliometric Analysis for Site Selection Problems Using Geographic Information Systems, Multi-Criteria Decision Analysis and Fuzzy Method

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Abstract. The integration of Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (GIS-MCDA) are widely used in many fields. Nowadays, GIS-MCDA is combined with a fuzzy method, especially fuzzy logic, as the solutions for many problems, including site selection problem. Site selection is a process to find the most appropriate site with desired conditions by considering a number of criteria. This paper attempts to review various studies undertaken by researchers in order to implement GIS-MCDA and fuzzy method for the site selection problems. The aims of this paper are to provide an overview of the current insight of the topic, an overview of the most MDCA method and fuzzy method used, and to provide a gap for further research. Data analysis in this paper is divided into two sections, i.e. bibliometric analysis and network analysis.

1. Introduction

In recent years, bibliometric analysis is widely used in literature review papers. Bibliometric is used in many scientific disciplines and is a statistical analysis to evaluate journal papers, books or other types of written communication, in a particular field.

Site selection theory was first proposed in 1909 by Alfred Weber, who focused on the selection of a depot that must be placed closest to all customers [1]. However, site selection is always an interestingly new problem. Site selection is a process to find the most appropriate site with desired conditions against a number of criteria, or considerations. Because site selection problems are influenced by several criteria, multi-criteria decision making (MCDM) method can help in solving site selection problems [2]. Various MCDM method used in site selection problem, i.e. Weighted Linear Combination (WLC), Analytical Hierarchy Process (AHP), Elimination and Choice Translating Reality (ELECTRE), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

Problems that involve an aspect of the location, either in the information used to solve them or in the solutions themselves, are termed geographic problems [3]. Site selection problem is a geographic problem that involves geographical data are referred to as geographical or spatial decision problem. GIS is often recognized as a decision support system involving the integration of spatially referenced data in a problem-solving environment, so GIS is widely used in site selection problems, especially the integration of GIS and multi-criteria decision analysis (GIS-MCDA). Discussions on GIS-MCDA

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integration, the techniques and their applications in the literature review have been carried out [4, 5]. A literature review of the use of GIS-MCDA integration for site selecting problems has been done for many fields, such as for industrial site selection [6], for solar photovoltaic power plant site selection [2,7], and for landfill site selection [8,9].

Fuzzy methods, especially fuzzy logic are widely used together with GIS and multi-criteria decision analysis for site selection. Definition of fuzzy according to Webster's dictionary is not clear, distinct, or precise; blurred. Fuzzy logic deals with reasoning that is approximate rather than fixed and exact [10]. Membership values of fuzzy logic range from 0 to 1. For example, one of the criteria in site selection is proximity to the resident area. If the distance of 1000 meters from the resident area considered as close and more than this distance considered as far, then the membership value at a distance more than 1000 meters is 0, the membership value at a distance of 0 is 1 and the membership value at distances between 0 and 1000 meters ranging from 0 to 1.

In this paper a literature review will be discussed in the form of bibliometric analysis of the use of GIS, multi-criteria decision analysis and fuzzy method for site selection problems, in order to provides:

- an overview of the progress of research using GIS-MCDA and fuzzy for site selection problem;
- overview of MCDA methods and fuzzy method used in conjunction with GIS
- recommended areas for further research

2. Research Methodology

Fahimnia et al. [11] used a five-step methodology for their literature review, i.e. defining the appropriate search terms, initial search results, refinement of the search results, initial data statistics and data analysis. The methodology used in this paper is similar to the methodology presented by Fahimnia et al. [11], but only four steps are used to provide an overview of current insights on the use of GIS-MCDA and fuzzy method for site selection problems and get research gaps for further research. The total process methodology of this paper is shown in figure 1.

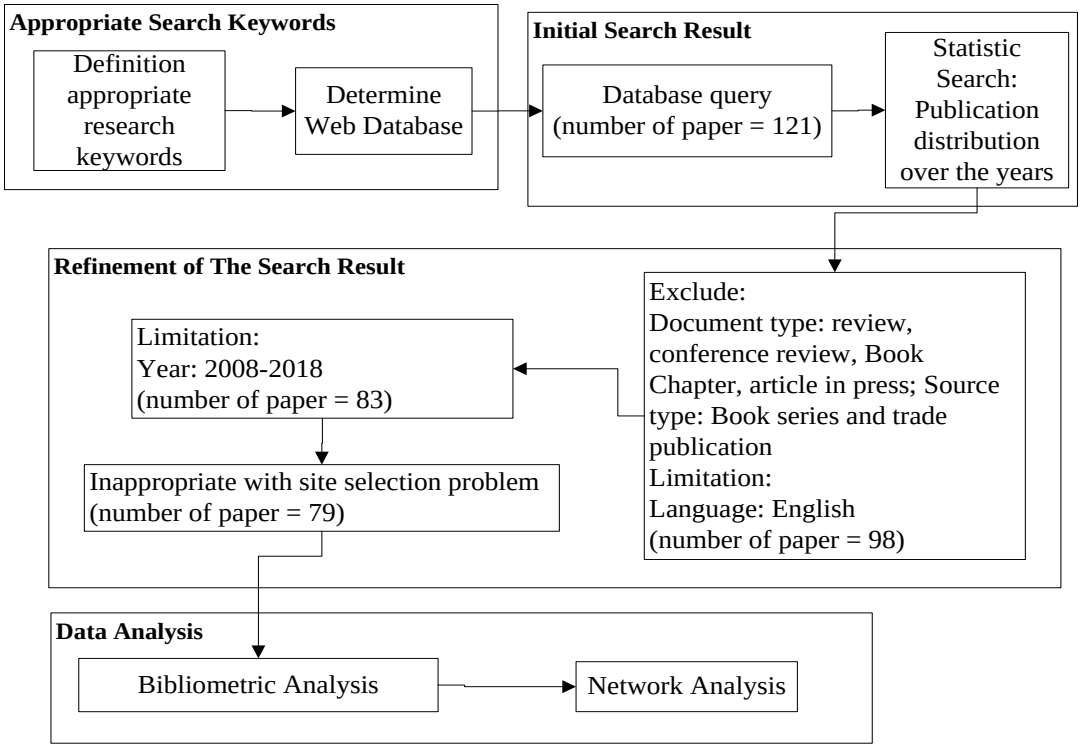


Figure 1. Methodology process

2.1. Appropriate Search Keywords

The keywords used for data collection in this paper include “GIS”, “fuzzy” and “site selection”. "Multi-Criteria decision analysis" is excluded because if "multi-Criteria decision analysis" is added to the search keyword, the number of papers obtained is only a small amount.

Scopus is used as a Web Database. In the Scopus database, searching processes are carried out on the "article title, abstract, keyword" using Search keywords GIS AND fuzzy and "site selection".

2.2. Initial Search Results

The initial search results from the Scopus database obtained 121 papers. In the initial search, the search year was not limited and it turned out that the oldest paper was a paper published in 1994. The number of the paper published from 1994 until 2019 can be shown in figure 2.

The initial search result was exported to the RIS format to include all citation information (author(s), document title, year, source title, volume, issue, pages, citation count, source and document type, and DOI), bibliographical information (affiliation, publisher), abstract and keywords, and conference information

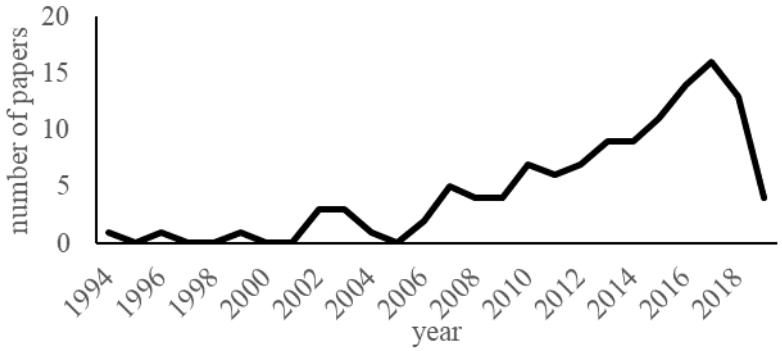


Figure 2. Distribution of publication over the years

2.3. Refinement of the Search Result

After the initial search result is obtained, the next step is to make refinement of the search by excluding inappropriate papers. Papers with document types in the form of article and conference papers were chosen by eliminating paper with document types in the form of reviews (3 papers), conference review (2 papers), Book Chapter (1 paper) and Article in press (1 paper). Papers with a source type of Book series (3 papers) and trade publications (1 paper) are excluded too. Furthermore, only papers written in English are used. After these provisions, 98 papers were obtained.

Figure 2 shows that the number of papers published before 2008 was no more than 3 papers per year and starting in 2008, the number of papers tended to rise. In 2019 the number of papers dropped because the number of papers reviewed was not even a year. Therefore, we decided to use paper published between 2008 and 2018 and obtained 83 papers.

Finally, we exclude papers that are not a site selection problem, i.e. papers that discuss mapping (2 papers), risk assessment and management (1 paper) and loading stations (1 paper). Refinement search obtained 79 papers, consisting of 9 conference papers (11% of papers) and 70 articles in journals (89% of papers).

Like the initial search result, the refinement search result was exported to the RIS format. The RIS format of the initial search and the RIS format of the refinement search are then opened with PoP software. The comparison of metrics data from PoP software between the initial search and refinement search can be seen in Table 1.

Cite/year and cite/author for refinement search are higher than initial search, this means that many papers excluded have low citations. But there are some papers that have high citations also excluded, and papers like this are usually written by authors who have written many papers in this field. Then if

one of the author's posts is excluded, it can cause their h-index and g-index to drop. It is understood that h-index and g-index in the search refinement are lower than the initial search.

Table 1. The comparison metrics

Metrics	Initial search	Refinement search
Publication years	1994-2019	2008-2018
Citation years	26	11
apers	121	76
Citations	1803	1379
Cites/years	16.35	125.36
Cites/paper	14.90	17.46
Cites/author	564.63	417.67
Papers/author	40.06	26.8
Authors/paper	3.41	3.42
h-index	20	17
g-index	40	36
hI,norm	11	10
hI, annual	0.42	0.91

2.4. Data Analysis

Data analysis is divided into two parts, bibliometric analysis and network analysis which will be presented in Sections 3 and 4.

3. Bibliometric Analysis

The refinement search is analyzed according to the following aspects: (1) distribution of research by publications and publishers; (2) distribution of research by countries; (3) distribution of research area; (4) the most used method; (5) the most subjects frequently discussed in case studies; (6) the most cited papers. Data analysis is presented in graphs and tables.

3.1. Distribution of Research by Publications and Publishers

The refinement search articles were published in 48 journals. Ten journals with the most publications are Environmental Earth Sciences, Applied Energy, Arabian Journal of Geoscience, Energies, Environmental Monitoring and Assessment, Global Journal of Environmental Science and Management, Hydrogeology Journal, Journal of Environmental Management, Journal of Settlements and Spatial Planning (JSSP) and Journal of Theoretical and Applied Information Technology (JATIT) and are shown in Figure 3.

All of the journals are published by 34 publishers. Elsevier and Springer are the two most-often appearing publishers. Distribution of research by the publisher can be seen in Figure 4.

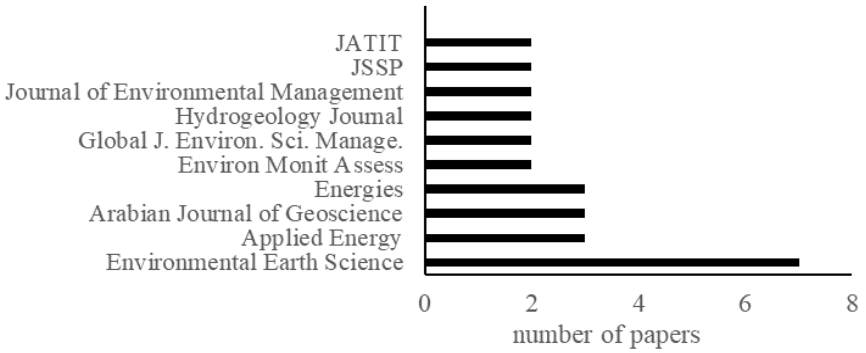


Figure 3. Distribution of research by publications

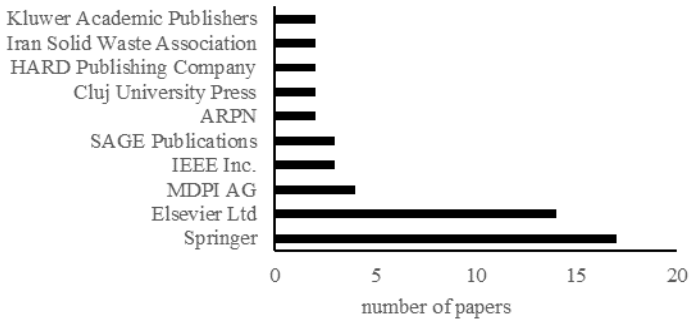


Figure 4. Distribution of research by publishers

3.2. Distribution of Research by Countries

From the 79 papers of the refinement search results, there were papers written by several authors with different nationalities. In such a situation, these papers simultaneously belong to different countries. Figure 5 shows the top ten productive countries.

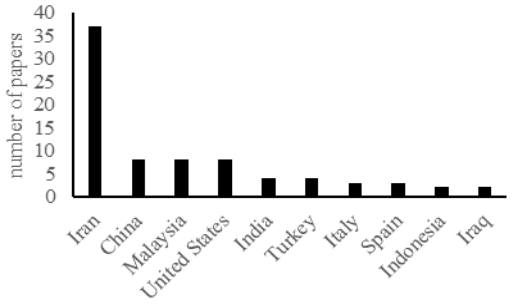


Figure 5. Distribution of research by countries

3.3. Distribution of Research Area

Figure 6 shows the top ten research area. Environmental science is the most subject area often discussed in the refinement search papers, which is 31%. Others research areas that are not mentioned in Figure 6 are decision sciences; physics and astronomy; biochemistry, genetics and molecular biology; business, management and accounting; multidisciplinary; pharmacology, toxicology and pharmaceutics.

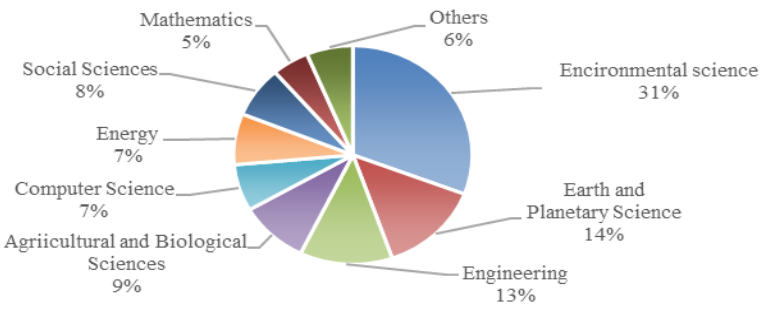


Figure 6. Distribution of research area

3.4. The most used method

GIS and fuzzy logic are the most frequently used methods, both used alone (15 papers) and integrated with other MDCA methods, including the Analytical Hierarchy Process (AHP) (5 papers); AHP, Weighted Linear Combination (WLC) (5 papers); WLC (3 papers); AHP, Ordered Weighted Average (OWA) (2 papers); OWA (2 papers); AHP, Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) (1 paper); AHP, Simple Additive Weighting (SAW) (1 paper); AHP, Delphi (1paper); AHP, WLC, Elimination and Choice Translating Reality III (ELECTRE III) (1 paper); Analytic Network Process (ANP), OWA (1 paper); Boolean logic, ANP (1 paper),

Besides being used in conjunction with fuzzy logic, GIS is also often used in conjunction with fuzzy-AHP (8 papers). GIS and fuzzy-AHP are also combined with other MDCA methods, namely AHP (2 papers); Fuzzy-ANP (2 papers), OWA (1 paper); Preference Ranking of Organization Method for Enrichment Evaluation (PROMETHEE) (1 paper); fuzzy-TOPSIS (1 paper) and are also combined with Genetic Algorithm (1 paper)

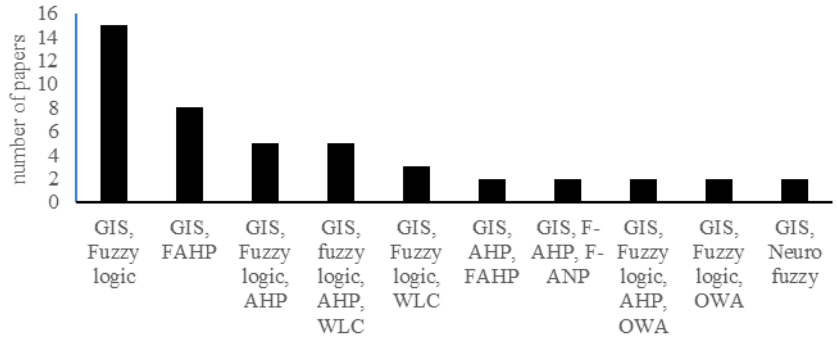


Figure 7. The most used method

3.5. The Most Subject of Case Studies

The subjects used as case studies for site selection problems in this review numbered 38 subjects, namely landfills, wind farms, solar farms/solar power plants, hospitals, industries, dams, etc. Figure 8 shows the most subject used as case studies for site selection problem.

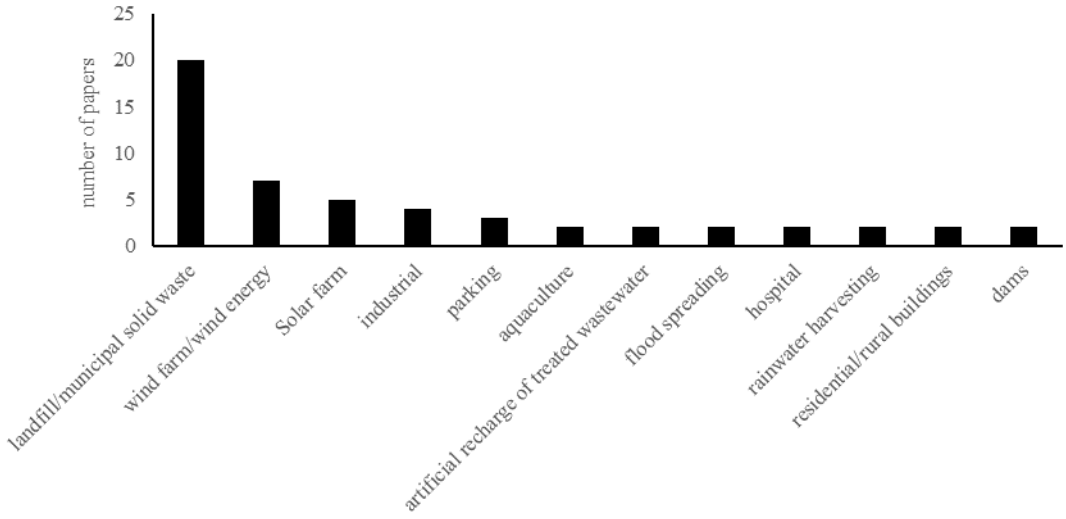


Figure 8. The most subject case studies

3.6. The Most Cited Papers

The number of citations in a paper was analysed using PoP software. From the 79 papers analysed, there were 22 papers that had not been cited and there were 10 papers with the number of citations 1. The highest number of citations in a paper was 311. All papers cited more than 25 times are present in Table 2. Cites per year and cites per author are also shown in Table 2.

Table 2. The most cited papers

Authors	Cites	Cites Per Year	Cites Per Author
Chang et al [12]	311	28.27	104
Vahidnia et al [13]	179	17.90	60
Gorsevski et al [14]	155	22.14	39
Aydin et al [15]	89	14.83	30
Gorsevski et al [16]	61	10.17	10
Jeong et al [17]	48	8.00	16
Isalou et al [18]	44	7.33	11
Donevska et al [19]	43	6.14	11
Sánchez-lozano et al [20]	36	12.00	12
Aydi et al [21]	34	5.67	11
Alesheikh et al [22]	27	2.45	7

4. Network Analysis

Network analysis is done using VOSviewer software. The RIS format of the refinement search result is opened using VOSviewer to determine what keywords were occurring frequently. The frequency of keywords can be set, for example, 1, 5, 10, 20, or other occurrences.

In creating data in the VOSviewer software, the first step is to choose the type of data. If we choose to create a map based on bibliographic data, then we will determine the file of resource data, type of analysis, unit of analysis, and minimum counting method of occurrence of a keyword. In this review, the data file response is the Refinement Search Result in RIS format, type of analysis is co-occurrence, unit of analysis is keywords, the counting method is full counting and the minimum number of occurrences set to 10, then 16 items were fulfilled. Figure 9 shows the network between 16 items. The largest circle in figure 9 is the most occurrence item in keywords.

From these 16 items, in fact, there are some items that actually have the same meaning, in example gis and geographic information systems; land fill and landfill. This is a weakness of VOSviewer because VOSviewer only looks at the number of occurrence in the keywords.

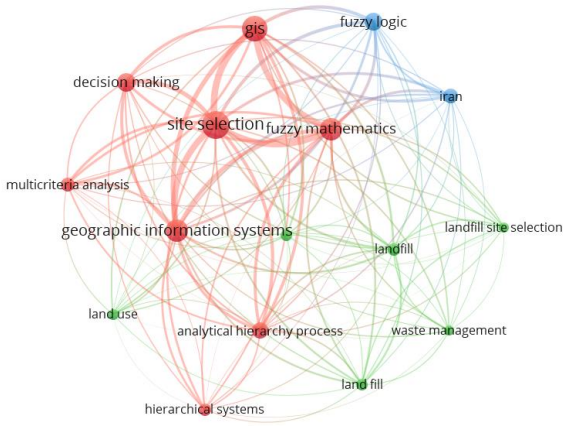


Figure 9. Network analysis based on bibliographic data

Figure 9 shows that there are three clusters identified. The first cluster (shown in pink in Figure 9), consists of 8 items, with the most occurrence items being site selection, geographic information systems, gis, fuzzy mathematics, analytical hierarchy process, hierarchy systems, decision making, multicriteria analysis. This first cluster shows the methods often used in the site selection problem.

The second cluster (shown in green in Figure 9), consists of 6 items, i.e. geographic information system, land fill, landfill, landfill site selection, land use and waste management. This second cluster shows landfill, landfill site selection and waste management are relatively frequent occurrences, which means that many papers discuss landfills as case study subjects. Land use is also an item in this second group. This shows that land use is a criterion often referred to as location detection problems, especially landfill selection problems.

The third cluster (shown in blue in Figure 9) consists of two items, i.e. fuzzy logic and Iran. This shows that Iran is the country that most often appears as a keyword in site selection problems, in other words, many case study subjects are conducted in Iran. Fuzzy logic in a cluster with Iran shows that fuzzy logic is a method often used in case studies in Iran.

By creating a map based on text data, extracting from the title and abstract fields, full counting with the minimum number of occurrences set to 10, and excluding some items, we get 14 items, as shown in Figure 10. Three clusters are formed in this way. The first cluster is shown in pink consists of city, fuzzy logic, geographical information systems, land use, slope, and road. The second cluster (shown in green) consists of ahp, fahp, fuzzy set theory and weighted linear combination, while the third cluster (shown in blue) consists of iran, landfill, owa and multi criteria decision making.

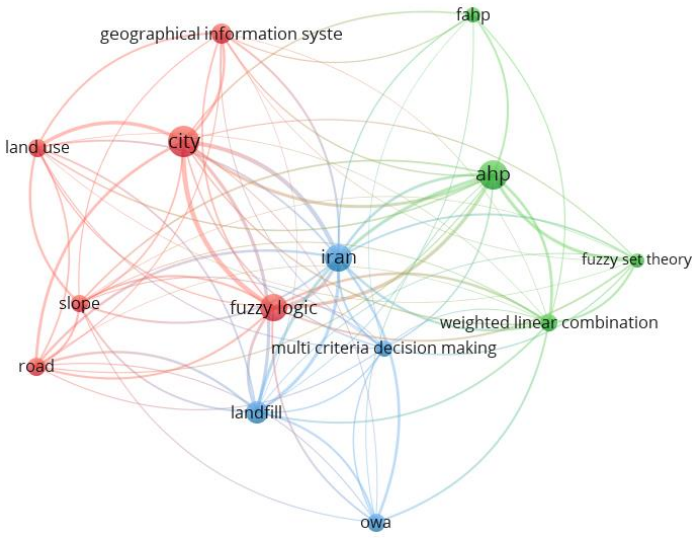


Figure 10. Network analysis based on text data

There are land use items, slope, city and road in the first cluster indicating that the criteria that are often used in site selection problems are land use, slope, distance to the city, and distance to the road network. Figure 10 shows that AHP, F-AHP, weighted linear combination, fuzzy set theory, fuzzy logic, geographical information systems and OWA are items with a high occurrence, which means that items are methods often used for site selection problem.

5. Discussion

Research on site selection problem by using the integration of GIS-MCDA with fuzzy methods has increased for recent years (shown in Figure 1). Figure 7 shows GIS and fuzzy logic are the most widely used methods. Fuzzy logic considers uncertainties related to criteria/sub-criteria assessment. Fuzzy membership function in fuzzy logic is an effective tool for standardizing criteria [8].

AHP and F-AHP are widely used to determine the weight of each criterion in multi-criteria decision making. AHP provides a tool for pair-wise comparison of various criteria and sub-criteria considered for site selection problem. Comparison of two criteria determines more important criteria and how much a criteria is more important than the other criteria. The diagonal comparison matrix is formed to obtain the weight of each criterion. AHP involves subjectivity in pairwise comparisons. F-AHP is made to deal with the inherent obscurity of human thought.

Decision rules help decision-makers to evaluate available alternatives for selection based on their suitability. The most decision rules commonly used are the Weighted Linear Combination (WLC) and Ordered Weighted Averaging (OWA).

Landfill site selection is a problem that is often solved in the site selection problem, followed by wind farm and solar farm site selection. The use of GIS-MCDA for location selection in the supply chain field, for example, to determine the location of the warehouse or distribution center location, is still rarely done. Studies on site selection in the supply chain are mostly done using mathematical models. This is an opportunity for further research to use GIS-MCDA for site selection problems in the supply chain field.

6. Conclusions

The current study reviewed 79 papers for evaluating site selection problems using GIS-MCDA and fuzzy method. Of the 79 papers, 25.3% of them discussed landfill site selection and more than 40% of case studies were conducted in Iran. Therefore, further research can cover other fields. These is also an opportunity for researchers from other countries to conduct a study of site selection using the integration of GIS-MCDA and fuzzy method.

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