

A Scientometric Study on the Analytical Hierarchy Process with Emphasis on Urban Affairs Management

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DOI: 10.24193/JSSPSI.2020.6.10

<https://doi.org/10.24193/JSSPSI.2020.6.10>

Keywords: *Analytical Hierarchy Process (AHP), scientometric analysis, multi-criteria decision-making analysis*

ABSTRACT

Analytical hierarchy process (AHP) is among the most widely used multi-criteria decision-making (MCDM) methods that have been employed by researchers in various scientific areas all over the world to find the most appropriate solutions for complex and multi-variable problems. Despite the popularity of this method, there is no scientometric study on AHP applications in the literature. To fill this gap, the present study aims to present a scientometric analysis on the use of AHP for various applications, in general, and particularly for making the best decisions when dealing with urban management. Current scientific trends in this area were also identified and presented through an in-depth analysis of the findings regarding contributing countries, journals and authors. In addition, the main keywords introduced to the field and the existing categories were explored and identified. Results demonstrated that out of the 37,000 scientific works (including journal articles, proceedings, books, etc.) published so far on the employment of AHP in various fields, only 7% contributed to the urban affair management issues, whilst China and Iran hold the highest share. Results also indicated that AHP has been efficiently combined with Geographic Information System (GIS) to address the scientific needs in this area. This paper also provides recommendations for relevant future studies.

1. INTRODUCTION

Analytic Hierarchy Process (AHP) has been widely used as a well-known Multi-Criteria Decision-Making (MCDM) approach in a wide range of scientific areas (Ghavami et al., 2020). AHP was initially introduced by Saaty (1980) to provide a systematic approach for making science-based decisions (Falah et al., 2020). An expert panel with sufficient knowledge in a specific field of science and technology is assisted in order to analyse the involving criteria and sub-criteria and prioritize them based on pairwise comparisons (Jahanshahi et al., 2019; Kamali et al., 2017). This method has been widely employed in a number of

application such as energy production and consumption (Liu and Lee, 2019; Salvia et al., 2019; Stojčević et al., 2019), sustainability (Calabrese et al., 2019; Hasheminasab et al., 2018; Hidroel, 2019), water and wastewater treatment (Hu et al., 2016; Pelorus and Karahalios, 2017), and urban affairs, which is the subject of this scientometric study. Over the past years, urban conditions have undergone significant changes due to rapid industrialization and urbanization (Chu and Tang, 2005). Hence, urban subsystems are experiencing major challenges in terms of their structure and function (Natale et al., 2015). In this context, enough attention has to be paid to the development of urban infrastructures and the related

processes initiated to meet the needs of the current generation and to be also able to satisfy the requirements of the future generations. On the other hand, urban development should comply with the sustainable development principles. To this end, AHP has been efficiently used to make suitable decisions for effective urban management activities.

Scientometric studies are generally designed to explore the history and the progress made in a certain area of science and technology (Coccia, 2018). They can also be used to trace the trends in the studied field and identify the existing gaps in order to provide recommendations for further studies (Mingers and Leydesdorff, 2015). This method can also be used to demonstrate the contribution of countries, journals and authors to the knowledge in a specific scientific area (Konur et al., 2018). AHP has been widely employed in urban management affairs such as site selection of urban facilities (Tan et al., 2014), urban waste management (Sener et al., 2010) and urban land use planning (Mosadeghi et al., 2015). However, to our knowledge, there has been no scientometric study on the overall application of analytical hierarchy processes.

2. METHODOLOGY

This study is a scientometric analysis on the utilization of analytical hierarchy process for various scientific applications with emphasis on urban management. To this end, the following steps were followed aiming to gather and analyse the data required for the study, as followed in most of the scientometric papers in the literature (Bernabò et al., 2017; Davarazar et al., 2020; Hosseini et al., 2018):

a). Selection of the most appropriate database for the extraction of scientific papers of various types (see 3.2.2). There are several databases that can be used for this purpose, namely Google Scholar, Scopus, Web of Science (WoS), etc. Among the mentioned databases, WoS core collection was selected for this study since it contains all high quality journals, conference proceeding papers, etc. (Jiang et al., 2018; Olawumi and Chan, 2018; Wang et al., 2016).

b). Adoption of a computer-based program to manage and analyse the obtained data. There are a number of programs that can be used for this purpose, such as BibExcel, HistCite, CiteSpace, etc. (Cobo, et al., 2011). In this study, CiteSpace (5.3.R4) software was employed to visualize outputs and illustrate the results achieved (Chen, 2017). It is worthy to mention that WoS core collection outputs are compatible with CiteSpace (Kuo, 2008).

c). Application of a combination of keywords including Ts = (“analytical hierarchy process” or AHP or “analytical network process” or ANP) in the advanced search mode of WoS. TS means that the topic of published studies (title, abstract and keywords) were

searched for the mentioned combination of keywords. All of the English published studies were collected based on the appearance of mentioned keywords.

d). Use of a combination of keywords including Ts= ((“analytical hierarchy process” or AHP or “analytical network process” or ANP) and (urban* or city or cities or *town* or *municip*)) in order to extract the works whose topic was the application of analytical hierarchy process for urban management. In this case, Fuzzy string represented as “*” was used to provide wider ranges of words related to applied keywords.

e). Precise screening of the extracted papers to ensure their relevancy.

f). The extracted documents were then saved as “marked list” of WoS.

g). The marked list was then exported from WoS database as “plain text” to be analysed by the CiteSpace (5.3.R4) using the criteria identified for this scientometric analysis.

h). Selection of scientometric criteria including: publication type, publication over years, contributing countries, keywords, authors’ affiliation, cited authors, cited journals, categories, and cited documents.

3. RESULTS AND DISCUSSION

3.1. AHP application in various scientific fields

3.1.1. Publications over years

All of the published documents including research results in the literature after the introduction of AHP methodology by Saaty (1980) (Falah et al., 2020) were extracted from WoS using a set of appropriate keywords mentioned in methodology section. The results obtained according to scientometric criteria indicated that a total number of 37,097 papers have been already published on the application of analytical hierarchy method in various scientific areas. Figure 1 presents all the published works over the corresponding years.

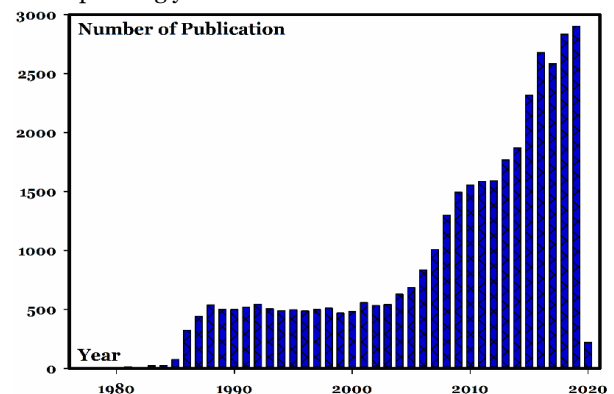


Fig. 1. The number of published works on the application of AHP in various scientific areas.

As it can be observed in this figure, the number of published works on AHP utilization shows a growth in a very short time span after its introduction to the scientific community.

The annual number of publications also showed a rapid increase after 2005. In addition, the cumulative number of published documents followed a sigmoidal pattern of growth meaning that the increase in the number of publications on the employment of AHP in various analyses has reached a certain point of maturity and after that it usually declines. Such a trend has been previously revealed by scientometric studies related to other scientific areas such as underground carbon dioxide storage (Davazarar et al., 2019) and membrane bioreactors for wastewater treatment (Zandi et al., 2019).

Figure 1 presents the annual and cumulative number of works published in this scientific field.

3.1.2. Keyword analysis

CiteSpace was also utilized to extract the main keywords presented in the literature for studies on the use of AHP processes in various scientific areas. As demonstrated in Figure 2 and Table 1, the most widely used keywords in this field are those describing the methodology itself such as “analytical hierarchy process”, potential applications, namely “decision-making” and the combination of this methodology with other multi-criteria decision making processes, such as Topsis (Choudhary et al., 2012; Pelorus and Karahalios, 2017).

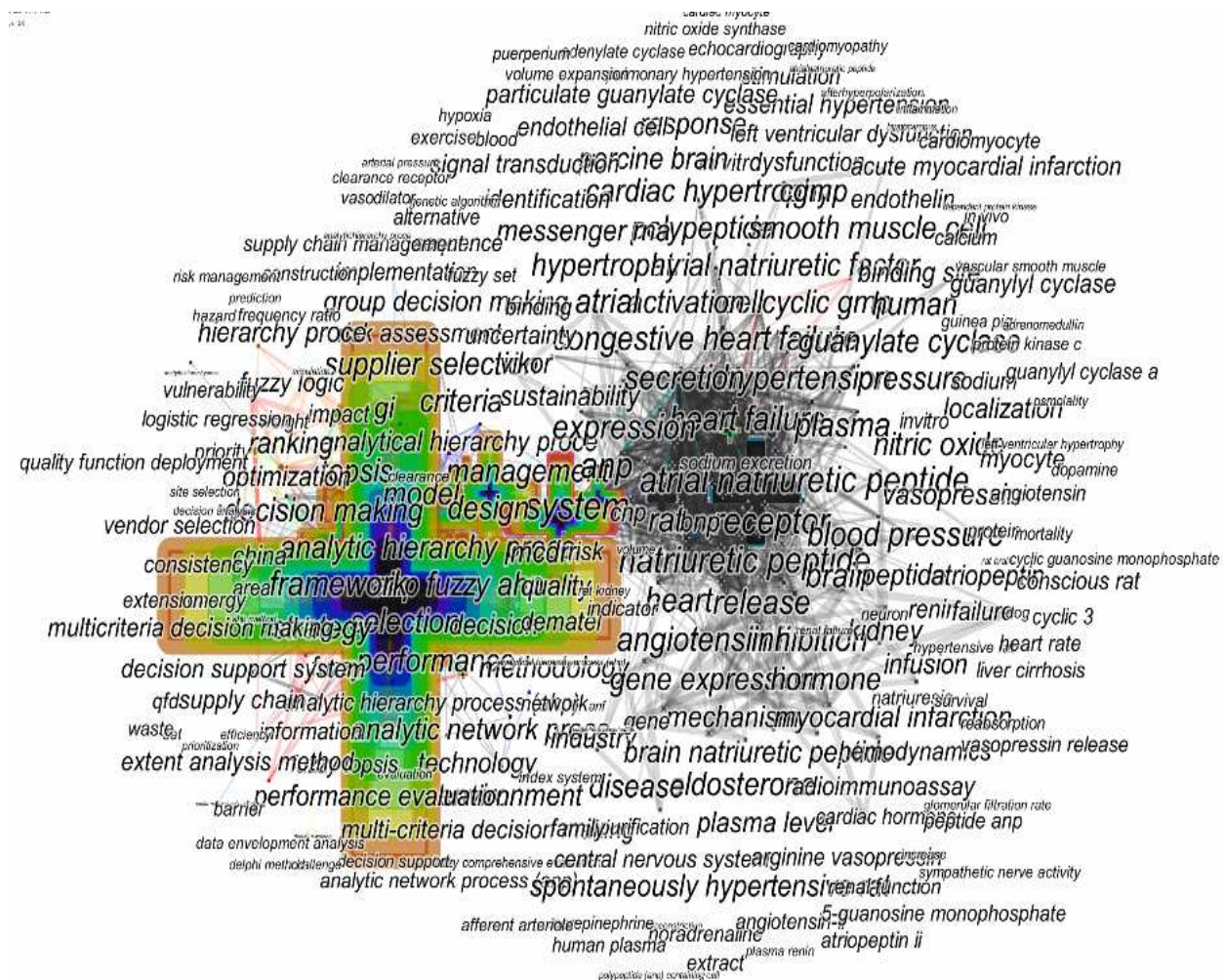


Fig. 2. A schematic representation of co-occurring analysis of the keywords appeared in studies published on the application of AHP in various scientific fields.

The integration of AHP with mathematical logics such as fuzzy principles (Aydi et al., 2016; Cheng et al., 1999; Du et al., 2016; Liu and Lee, 2019) was also identified among most of the resources studied. In addition, keywords analysis can demonstrate that the

combination of AHP with data management and analysis such as geographic information system (GIS) for spatial planning purposes (Case et al., 2017; Kamali et al., 2015; Uyan, 2013) has attracted a huge attention among the scientific community.

Table 1. Output of keywords co-occurring analysis and parameters of scientometric analysis.

Rank	Keyword	Sigma	Centrality	Burst	Frequency
1	AHP	2.68	0.05	20.22	6845
2	Analytic Hierarchy Process	1.27	0.06	4.18	3651
3	Model	6.25	0.03	60.52	2926
4	System	1	0.57	0	2151
5	Atrial Natriuretic Peptide	1.24E+08	0.04	504.64	2049
6	Selection	5.06	0.04	43.47	1818
7	Management	5.53	0.03	50.99	1766
8	Decision Making	1.24	0.03	8.19	1557
9	ANP	1.15	0.3	0.52	1554
10	Analytical Hierarchy Process	1.19	0.03	6.7	1389
11	Performance	1.85	0.02	36.81	1196
12	Fuzzy AHP	1.16	0.01	17.17	1159
13	GIS	90.26	0.05	99.8	1151
14	Topsis	3.48	0.01	84.51	1110
15	Heart Failure	355.59	0.05	110.73	948
16	Rat	9451.23	0.03	273.02	846
17	Framework	11.67	0.04	56.27	838
18	Analytic Hierarchy Process (AHP)	1.01	0	8.1	782
19	Expression	4.96	0.02	80.06	775
20	Design	1.2	0.03	7.26	737
21	Natriuretic Peptide	1.1	0.04	2.59	692
22	Receptor	1824745	0.08	183.66	675
23	Decision	1.16	0.01	14.78	674
24	Criteria	1.51	0.02	21.69	632
25	Analytic Network Process	1.64	0.01	51.4	616

These keywords are most widely used to represent scientific papers published so far on the application of AHP in various scientific areas.

3.1.3. The application of AHP in scientific areas

In Figure 3 and Table 2 we may note the most visible scientific fields in which analytical hierarchy process has been successfully employed. It is evident

from the results achieved that engineering, computer engineering, environmental science and engineering and management are among the main scientific fields in which the application of analytical hierarchy process as a methodical approach holds the highest share.



Fig. 3. Contribution of categories in the production of scientific results on the application of AHP in various scientific areas.

Table 2. Information regarding the categories of published studies obtained from WoS.

Rank	Categories	Burst	Frequency
1	Engineering	0.00	9478
2	Computer Science	50.42	6178
3	Business & Economics	37.72	3867
4	Operations Research & Management Science	140.92	3200
5	Cardiovascular System & Cardiology	642.99	2950
6	Electrical & Electronic Engineering	4.26	2843
7	Environmental Sciences & Ecology	293.84	2817
8	Management	34.53	2808
9	Artificial Intelligence Computer Science	17.86	2711
10	Environmental Sciences	270.38	2340
11	Cardiac & Cardiovascular Systems	401.56	2234
12	Industrial Engineering	15.73	1986
13	Information Systems Computer Science	9.36	1892
14	Interdisciplinary Applications Computer Science	52.42	1855
15	Science & Technology - Other Topics	309.43	1717
16	Physiology	622.93	1694
17	Pharmacology & Pharmacy	399.98	1672
18	Biochemistry & Molecular Biology	282.19	1544
19	Theory & Methods Computer Science	21.00	1462
20	Neurosciences & Neurology	361.56	1328

3.2. AHP for urban management

This section has been designed to explore the scientific progress that has been made in the use of AHP for urban management. To this end, some keywords mentioned in the methodology section of this paper were used to extract the relevant publications from WoS, as the most appropriate source database.

3.2.1. Literature over the years

By using the mentioned set of keywords, some 2,585 documents were extracted from WoS database. Figure 4 illustrates the annual and cumulative number of studies published in the literature on the application of analytical hierarchy process for urban related issues.

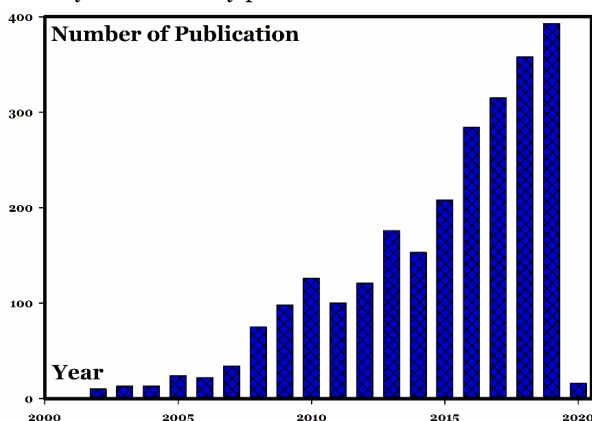


Fig. 4. The number of published studies on the application of AHP in urban management.

As indicated in this figure, research in this field has been initiated since the beginning of 2000 and

it has followed an increasing trend over the years. It occurred especially after 2008 and the number of published papers reached about 400 in 2019. We can note that there is an ongoing interest for the application of this methodology to overcome the issues related to urban management and their number is expected to increase over the coming years, following the same trend (Lee and Lim, 2018; Nosal and Solecka, 2014).

3.2.2. Diversity of published papers

Figure 5 presents the main types of research works published so far on the application of AHP in urban management.

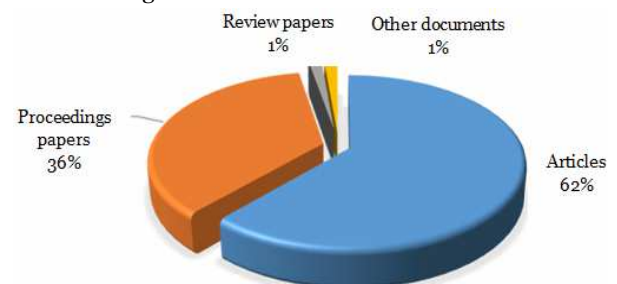


Fig. 5. Types of studies published on the application of AHP in urban management.

As demonstrated in this figure, original research articles, proceedings papers, meeting abstracts, review papers, etc. are the main types that have been published in this regard. Among all these types, basic original research papers hold the highest share (62%). Proceedings papers are ranked second, with 36% share, while review papers represent only 1% of all the related WoS indexed documents. The high

percentage of proceedings papers on the application of AHP (Davarazar et al., 2019; Davarazar et al., 2020; Jiang et al., 2018; Konur, 2012; Zhao, 2017) can be considered an indicator for the tendency of researchers to share their latest achievements and discuss them in the scientific meetings to enrich their findings. It can be also attributed to the nature of the AHP method, which is based on the necessity of reaching the consensus among experts participating in a given study.

3.2.3. Contributing countries

Figure 6 presents the most contributing countries in the production of scientific results based on the use of AHP for the management of urban issues.

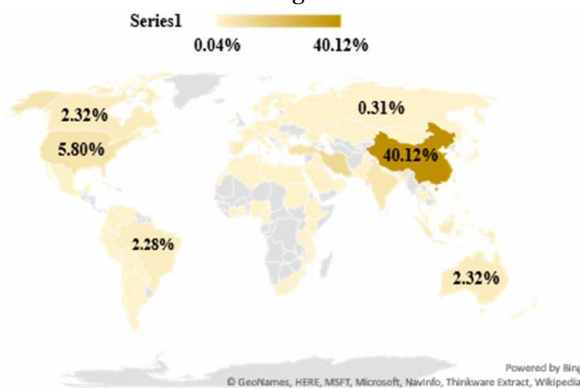


Fig. 6. Contribution of various countries worldwide to the production of scientific papers on the application of AHP in urban management.

Table 3. Contributing countries to the number of published studies on the application of AHP in urban management.

Rating	Country	Count (no.)	Contribution (%)
1	China	1,037	40.12
2	Iran	274	10.60
3	Turkey	173	6.69
4	USA	150	5.80
5	India	123	4.76
6	Taiwan	95	3.68
7	Spain	78	3.02
8	Italy	68	2.63
9	Malaysia	63	2.44
10	Australia	60	2.32
11	Canada	60	2.32
12	Indonesia	60	2.32
13	Brazil	59	2.28
14	South Korea	58	2.24
15	England	49	1.90
16	Japan	43	1.66
17	Serbia	37	1.43
18	Greece	34	1.32
19	Lithuania	33	1.28
20	Germany	32	1.24

As it can be observed, China is the most contributing country in this regard with more than of 40% of the published works, seconded by Iran, with about 10% of all the published articles (Table 3).

The high contribution of China was also observed in other scientometric studies (Bernabò et al., 2017; Darko et al., 2019; Gandia et al., 2019; Ouyang et al., 2018). Such high amount of studies can be fundamentally based on some reasons such as the high number of population of this country, as well as the successful development programs designed and implemented in China in recent years such as “special economic zones of the People’s Republic of China” (Crane et al., 2018) and the “economic and technological development zones” (Zhao, 2008).

3.2.4. Keyword analysis

Figure 7 presents the evolution of keywords related to the application of AHP in studies on urban management. As the figure illustrates, the first keyword that appeared in the literature is the “analytical hierarchy process” in 1996. For a while, no new relevant keyword was highlighted. In 2005, new keywords occurred, namely analytical network process, followed by others related to the management of urban issues such as traffic safety, waste management, fuzzy logic, risk management, which can be classified in clusters including soil loss, transportation measures, technological innovation ability, priority scale, water resource, heavy metal accumulation, etc. Figure 8 also reveals the most frequently keywords used for the application of AHP in urban management. Table 4 presents the related detailed information in this regard. Accordingly, AHP registered the highest frequency, followed by GIS, as the most common complementary tool for the application of analytical hierarchy process.

3.2.5. Author analysis

The number of works published by individual authors is considered another scientometric criterion that can demonstrate the scientific contribution of researchers in the field. As it can be observed, Zavadskas E.K., Zhang Y., and Kahraman C. with 0.74%, 0.62% and 0.58% hold the highest shares in the number of articles published in this field (Table 5).

Despite the number of studies published by individual authors, the citations received by these papers can be considered an even more important scientometric criterion, which can clearly demonstrate the impact of the each individual publication among the scientific community. Figure 9 illustrates authors whose results on the application of analytical hierarchy process for the management of urban affairs were the most cited. Figure 10 illustrates the clusters of the most cited authors.

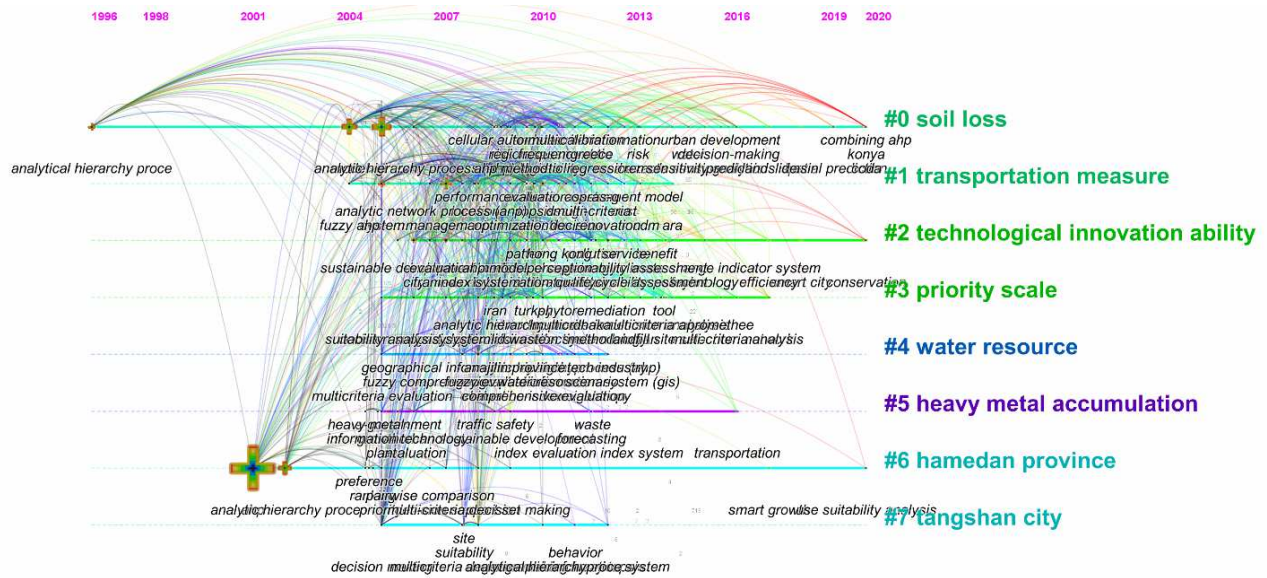


Fig. 7. Appearance of time-line of keywords applied to represent the scientific results published on the application of AHP in urban management.

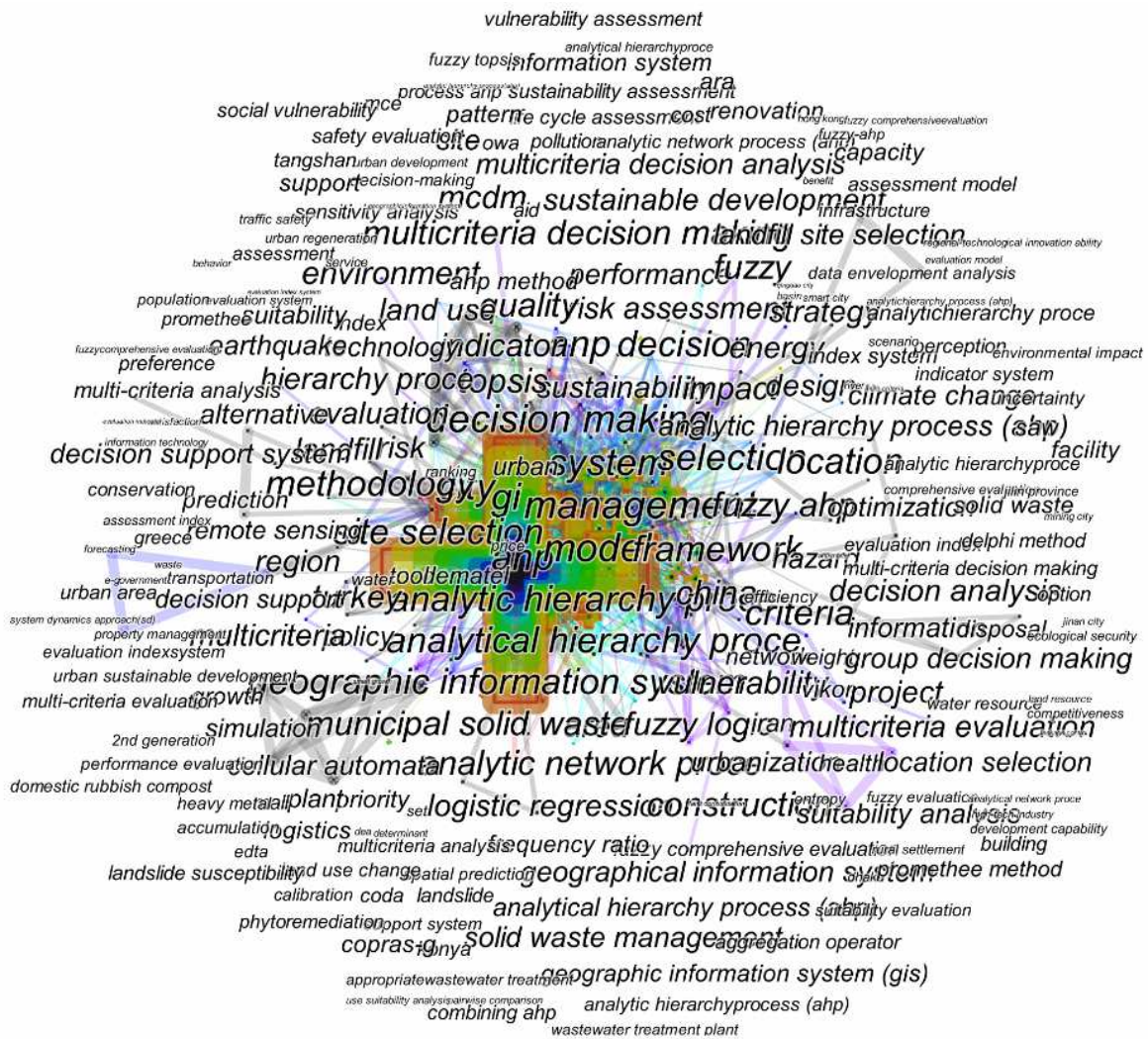


Fig. 8. A schematic representation of co-occurring analysis of the keywords appeared in scientific works published on the application of AHP in urban management.

Table 4. Output of keywords co-occurring analysis and parameters of scientometric analysis on the application of AHP in urban management.

Rank	Keyword	Sigma	Centrality	Burst	Frequency
1	AHP	3.10	0.13	9.04	719
2	GIS	1.10	0.11	0.87	374
3	Analytic Hierarchy Process	1.44	0.04	9.45	323
4	Model	1.36	0.11	3.05	302
5	Management	1.00	0.11	0.00	218
6	Analytical Hierarchy Process	1.31	0.08	3.66	200
7	System	1.08	0.10	0.74	189
8	Decision Making	1.32	0.14	2.11	160
9	City	1.05	0.08	0.62	157
10	Selection	1.00	0.03	0.00	135
11	Sustainability	1.05	0.01	5.38	100
12	Framework	1.25	0.04	5.23	91
13	Fuzzy AHP	1.04	0.05	0.73	90
14	China	1.74	0.10	5.76	84
15	Site Selection	1.00	0.04	0.00	81
16	Geographic Information System	1.04	0.04	1.10	80
17	Analytic Hierarchy Process (AHP)	1.07	0.03	2.56	77
18	Area	1.00	0.04	0.00	75
19	Decision	1.10	0.05	1.96	73
20	ANP	1.06	0.07	0.86	73
21	Topsis	1.06	0.01	4.06	73
22	Impact	1.02	0.02	0.84	72
23	Methodology	1.10	0.05	1.84	68
24	Municipal Solid Waste	1.00	0.06	0.00	68
25	Vulnerability	1.12	0.02	5.07	66

Regarding citation count, the top ranked item is Saaty T. L. (1987) in Cluster #1, with a citation frequency of 1302. Regarding the citation burst, the top ranked item is Saaty T. L. (1987) in Cluster #1, with a value of 15.36. The centrality analysis also demonstrates that Chang N. B. (2008) in Cluster #2 is the top ranked item, with a centrality value of 0.22. Finally, in terms of sigma, Saaty T. L. (1987) in Cluster #1 with a sigma of 10.02 is on the first position. As it can be observed, Saaty, the developer of AHP methodology, has recorded the most important impact on the scientific community.

Table 5. The list of contributing authors of studies including the application of AHP in urban management.

Rating	Author	Count (No.)	Contribution (%)
1	Zavadskas E.K.	19	0.74
2	Zhang Y.	16	0.62
3	Kahraman C.	15	0.58
4	Pradhan B.	14	0.54
5	Wang Y.	14	0.54
6	Chen J.	12	0.46
7	Li Y.	12	0.46
8	Liu Y.	12	0.46
9	Zhang H.	12	0.46
10	Wang L.	11	0.43

3.2.6. Journals

Journals are the main sources of studies on the application of analytical hierarchy process for urban affairs management, as well as on other scientific topics. The number of citations that journals have received for the relevant papers can also be considered an important parameter to have an overall image of the contributing parties in this scientific area. In this regard, and as indicated in Figure 12, Eur JORES (1996) in Cluster #0, with a citation counts of 823 has the most impact on the scientific community among all the contributing journals. In terms of burst, the top ranked item is SUSTAINABILITY-BASEL (2016) in Cluster #4, with a burst of 22.23. In addition, Fuzzy SETS (2004) in Cluster #0, with a centrality of 0.13 is the top ranked journal regarding the centrality criterion. Finally, when considering sigma, the top ranked item is Multicriteria D (2005) in Cluster #2, with a sigma of 5.94. Figure 13 reveals the clusters of journals that have published the scientific results on the application of analytical hierarchy process for the management of urban affairs. Also, Table 6 presents the detailed information (including the frequency, burst, centrality and sigma) of the journals that have published papers on the application of AHP in this scientific area.



Fig. 9. A schematic illustration demonstrating the most cited authors whose works included the application of AHP in urban management. Graph is with minimized overlaps. The figure containing the exact centrality has been provided in supplementary information.

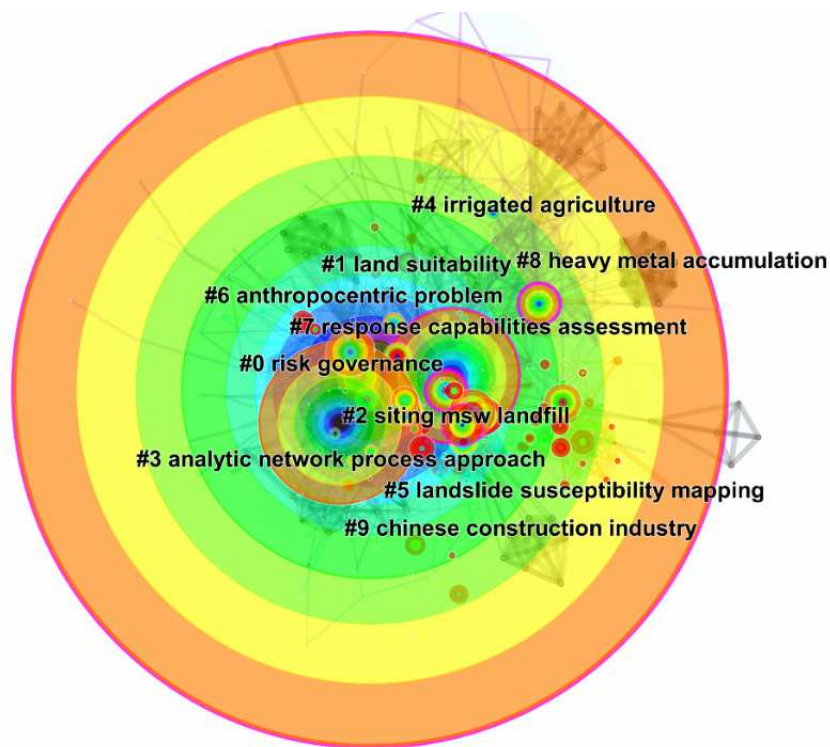


Fig. 10. Clusters of cited authors whose works included the application of AHP in urban management.

Table 6. Detailed information on the citations received by journals of which articles were collected for the present scientometric study on the application of AHP for urban management affairs and respective parameters of scientometric analysis.

Rating	Journal	Sigma	Centrality	Burst	Frequency
1	European Journal of Operational Research	1.03	0.06	0.62	823
2	Analytic Hierarchy Process	4.09	0.10	14.39	757
3	Journal of Environmental Management	1.06	0.09	0.63	545
4	Expert Systems with Applications	1.00	0.06	0.00	462
5	Thesis	1.03	0.00	17.54	339
6	Waste management	1.00	0.04	0.00	291
7	Landscape and Urban Planning	1.03	0.05	0.59	291
8	Cleaner Production	1.19	0.01	19.56	282
9	Environmental Earth Sciences	1.12	0.02	6.35	267
10	Science of the Total Environment	1.35	0.02	13.71	266
11	Environmental Monitoring and Assessment	1.00	0.03	0.00	243
12	Renewable & Sustainable Energy Reviews	1.00	0.03	0.00	235
13	Natural Hazards	1.02	0.01	1.81	232
14	Mathematical Psychology	1.05	0.04	1.26	230
15	International Journal of Geographical Information Science	1.01	0.02	0.94	223
16	Environmental Modelling & Software	1.00	0.10	0.00	222
17	Sustainability	1.14	0.01	22.23	213
18	Ecological Indicators	1.03	0.01	2.23	198
19	Environmental Geology	1.03	0.02	2.17	198
20	Land Use Policy	1.00	0.01	0.00	195



Fig. 12. The cited journals publishing papers on the application of AHP for urban affairs management. This figure is with minimum overlap obtained from CiteSpace. The size of the fonts represent the position of the journal among the cited journals in this scientific field.

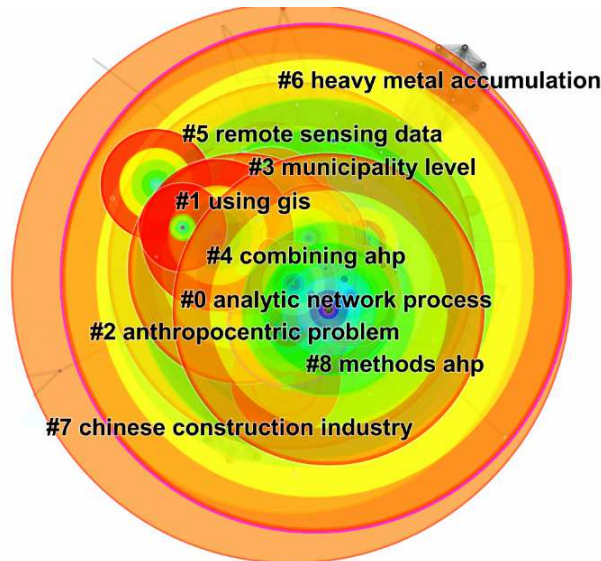


Fig. 13. Clusters of cited journals for the papers they have published on the application of AHP for urban affairs management.

3.2.7. Categories

This scientometric indicator can demonstrate the various fields that have received the most focus. As demonstrated in Figure 14, engineering, environmental

science and ecology and environmental science are the most important categories in this scientific area. Table 7 also illustrates the categories in this field with the related information including frequencies, bursts, centralities, and sigmas.

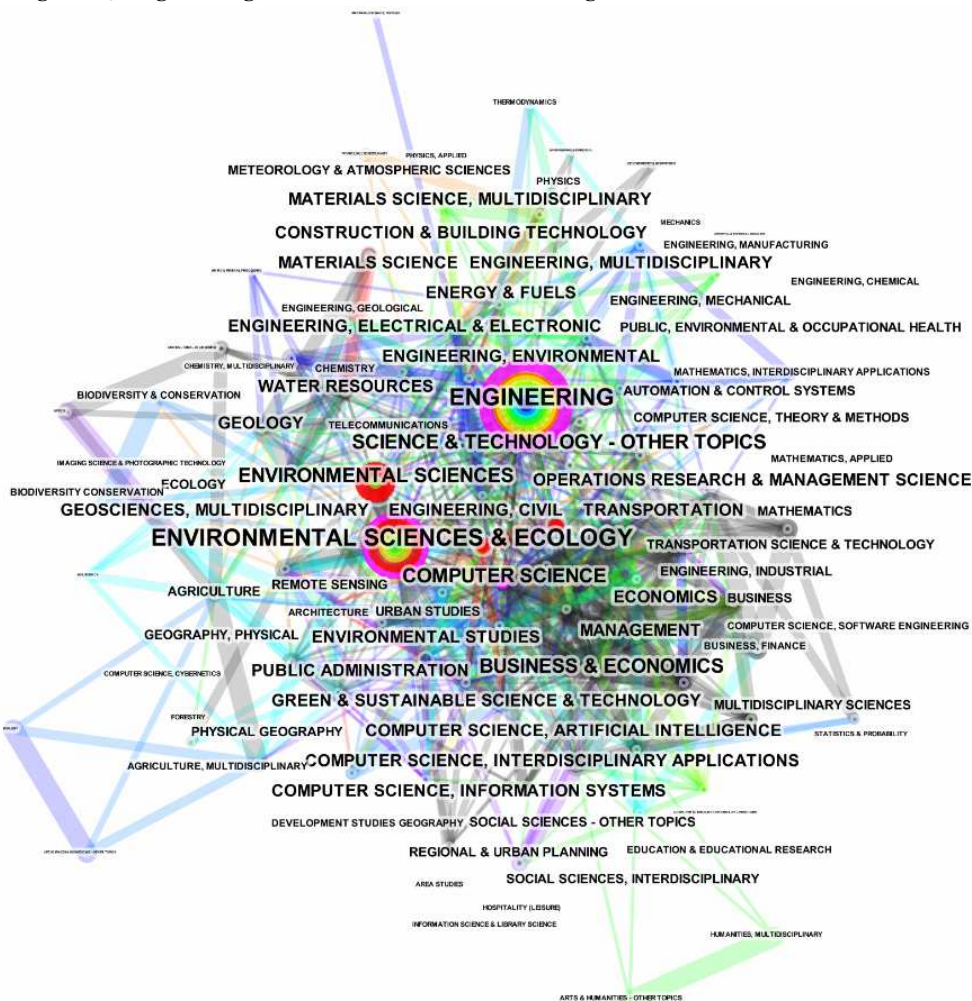


Fig. 14. Contribution of categories in the production of scientific papers on application of AHP for urban affairs management.

Table 7. Information regarding the categories of published studies on the application of AHP for urban affairs management, obtained from WoS.

Rank	Categories	Burst	Frequency
1	Engineering	0.00	815
2	Environmental Sciences & Ecology	6.97	745
3	Environmental Sciences	11.51	619
4	Computer Science	22.25	341
5	Science & Technology - Other Topics	29.38	264
6	Business & Economics	25.73	248
7	Civil Engineering	7.90	226
8	Water Resources	0.00	218
9	Environmental Engineering	1.77	210
10	Geology	4.76	208
11	Multidisciplinary Geosciences	4.97	206
12	Environmental Studies	12.30	201
13	Green & Sustainable Science & Technology	29.12	199
14	Management	35.65	174
15	Electrical & Electronic Engineering	10.90	164
16	Operations Research & Management Science	21.99	144
17	Energy & Fuels	0.72	134
18	Artificial Intelligence Computer Science	5.84	126
19	Interdisciplinary Applications Computer Science	2.10	119
20	Transportation	4.57	119

4. CONCLUSION

This paper aimed to present a scientometric analysis on the application of Analytical Hierarchy Process in various areas, and especially on the use of this method for urban management affairs. It was observed that only 7% of all the published documents in this field studied the application of this method for urban management, mainly for the management of environmental issues such as site selection of urban facilities and so on. Although this method has proved its potential to deal a wide range of complex problems, it has not been widely implemented in some countries such as the USA. The integration of AHP with fuzzy logic and effective tools such as geographic information system has also received attention in the literature. The analysis also demonstrated that Saaty, who developed this method, has been the most effective author in the scientific community regarding the scientometric criteria. The category analysis as well as the keywords evolution trend can also clearly indicate that AHP has been used in the analysis of a number of urban affairs despite the fact this method was developed around 35 years ago.

The results of author analysis also demonstrated that the working groups on this scientific field have been well-formed and organized and also the collaboration among the scientific community in this area has been very effective. Such observations can be linked to the types of the published works where authors prefer to present their latest findings in scientific meetings, when compared to other scientific

fields. Also, the results of this scientometric analysis can reveal the possibility of the combination of AHP with sustainability principles to make sustainable decisions especially on specific urban areas, for instance providing the clean resources (such as water treatment facilities) as well as management of traffic issues.

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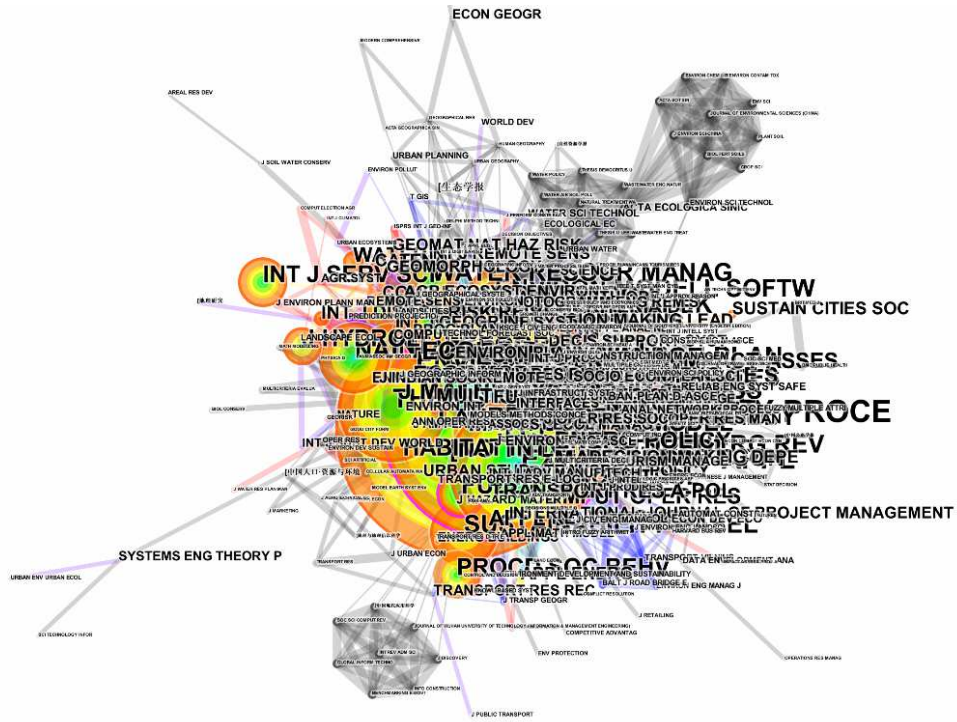


Fig. A.3. The cited journals analysis with minimum overlap obtained from CiteSpace with actual centrality.

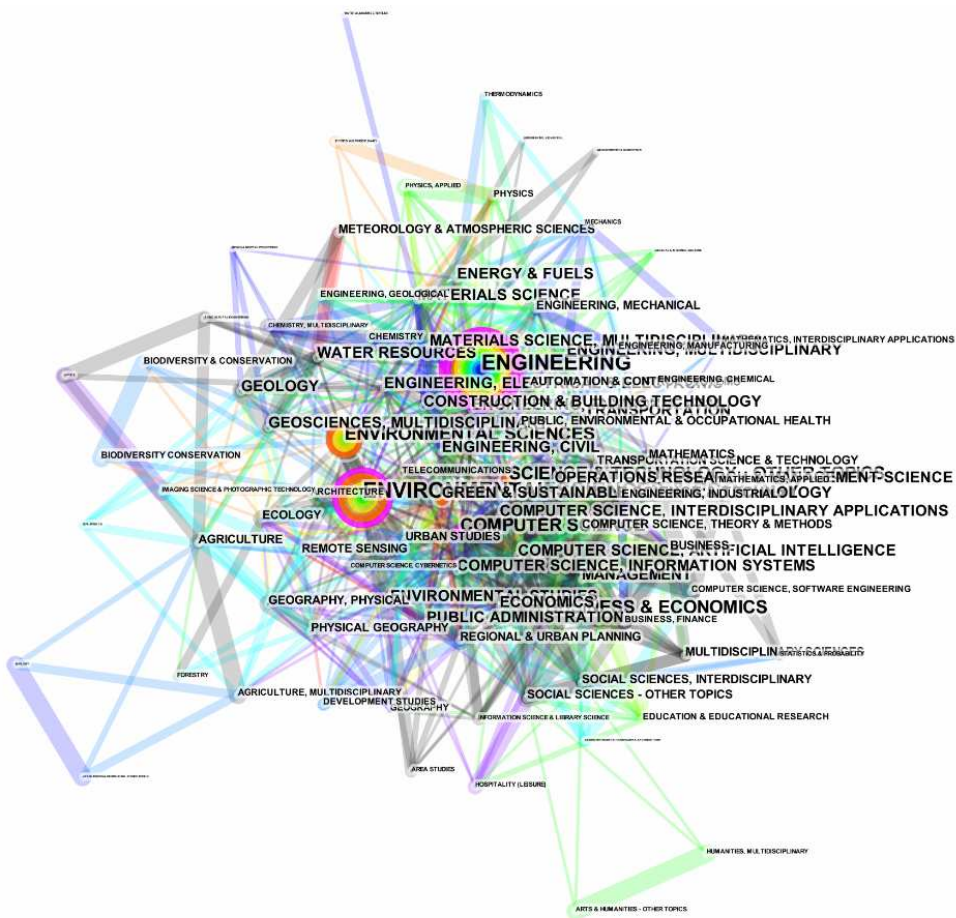


Fig. A.4. A schematic illustration on the categories of scientific papers.