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Article

Three Decades of Fuzzy AHP: A Bibliometric Analysis

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Abstract: For decades, Fuzzy Sets Theory (FST) has been consistently developed, and its use has spread across multiple disciplines. In this process of knowledge transfer, fuzzy applications have experienced great diffusion. Among them, Fuzzy Analytic Hierarchy Process (fuzzy AHP) is one of the most widely used methodologies today. This study performs a systematic review following the PRISMA statement and addresses a bibliometric analysis of all articles published on fuzzy AHP in journals indexed in Web of Science, specifically in Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI). The analyzed database includes 2086 articles published between 1994 and 2022. The results show the thematic clusters, the evolution of the academic conversation and the main collaboration networks. The main contribution of this article is to clarify the research agenda on fuzzy AHP. The results of the study allow academics to detect publication opportunities. In addition, the evidence found allows researchers and academics setting the field's agenda to advise the editors of high-impact journals on gaps and new research trends.

Keywords: fuzzy AHP; FAHP; decision making; bibliometric; VOSviewer; publication opportunities

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1. Introduction

In recent decades, the recurring persistence of VUCA environments has intensified [1–4]. Its impact is increasing within the business, political and social contexts. Contemporary challenges make it increasingly necessary for corporate managers and political decision-makers to analyze and make rational, fast and effective decisions [5,6]. According to new military planning needs [7], from 1970, scientists and academics were developing the Analytic Hierarchy Process (AHP) method. The double objective of the accelerated development of this methodology was (a) to facilitate the decision-making process in complex circumstances, and (b) to have a means to identify the relevant facts and their interrelationships [8]. In essence, the model is made up of three parts: (1) identify and organize decision goals, (2) define criteria, and (3) pose constraints and structure alternatives [9]. AHP can be classified as a multi-criteria decision-making method applied to determine the weight of criteria and priorities of alternatives based on pairwise comparison [10], involving human subjectivity for decision making under uncertainty [11]. A later development of the AHP methodology arises from the interest in mitigating the impact of human subjectivity. In this sense, Liu et al. [10] indicate that the judgment during the comparison can be subjective, therefore, it is necessary to combine fuzzy logic with the AHP method and in this way transform the AHP into Fuzzy AHP (FAHP). Fuzzy set theory allows decision makers to make interval judgments and account for uncertainty [12]. Introducing the method, Zadeh [13] mentions that most of the concepts found in various domains of human knowledge are too complex to admit a simple or precise definition. In fact, a decade earlier, this same author had defined the fuzzy set [14] as a class of objects with a continuous degree of membership.

According to Ho [15], the fields of application of both the AHP and FAHP methods are wide, characterized by ease of use and are combined with mathematical programming tools, the implementation of quality functions and data envelopment analysis. Al-Aziz et al. [16], compare the AHP and FAHP methods, and point out that both deal with stochastic data and can be used to determine the outcome of the decision through a multi-criteria decision-making process. FAHP is also called fuzzy-MPDM (Multi Person Decision Making) or fuzzy-MPPC (Multi Person Preference Criteria), and has taken different variations based on its great adaptability. Some authors extend the AHP and the FAHP, expanding them to configure the intuitionistic fuzzy AHP (IFAHP) [17]. This type of model allows preferences to be represented by intuitionistic fuzzy values and, with this evolution, they can be applied to the resolution of more complex problems. In these cases, the decisionmaker expresses uncertainty when assigning preference values to the objects considered, and the method's development has allowed for the addressing of the solutions of problems in multiple fields, such as indicators of Human Capital [18], allowing, in these application cases, the consideration of the positive attributes and the negative attributes of the Human Capital indicators at the same time through expert judgments that are guided with IFAHP. Other authors propose a fuzzy variant of AHP, in which *"the pairwise comparison of decision elements by domain experts is expressed with triangular fuzzy numbers that allow the degree of expert confidence to be quantified and to reconcile inconsistencies in judgment within the domain. the limits of the fuzzy numbers to generate reasonable values for the weighting factors"* [19].

Sipahi and Timor [20] present a review of the application of the AHP method and the FAHP modification; of the articles published between 2005 and 2009, among the most dominant application scenarios are: manufacturing, environmental management and agriculture, the energy industry, the transportation industry, the construction industry and health care. In addition, they present other fields of application that include education, logistics, electronic commerce, information technology, innovation, the telecommunications industry, finance and banking, urban management, the defense and military industry, government, marketing, tourism and leisure, archeology, auditing and the mining industry. Other examples of application of the methodology can be seen in the field of urban management [21], for example, a geographic information system-based model for wind farm site selection that uses an interval type two fuzzy analytical hierarchy process to determine suitable sites for wind farms in Nigeria. In the same line, Beskese et al. [22] address the decision of the location of possible landfills in Istanbul using fuzzy AHP. For their part, Abbasi and Sarabadan [23] present an evaluation model for tactical missile systems based on the AHP and the Technique for Order Preference by Similarity of an Ideal Solution (TOPSIS) in a fuzzy environment where imprecision and subjectivity are managed with linguistic values parameterized by triangular fuzzy numbers, in line with what Cheng proposed [24] for the evaluation of naval tactical missile systems under fuzzy AHP models.

The academic literature has analyzed the relevant risks for the effective adoption and implementation of Green Supply Chain (GSC) practices from the industrial point of view to the extent that they use fuzzy AHP [25]. The human subjectivity and ambiguity involved in the risk analysis process have led to the suggestion of fuzzy multi-criteria decision-making methodologies for selection among renewable energy alternatives, leading them to determine the most suitable renewable energy alternative for Turkey [26]. Equally, Ren and Ren [27] develop a multi-attribute decision analysis framework for prioritizing the sustainability of energy storage technologies, developing a system of criteria in four categories (economic, performance, technological and environmental) which permits the reduction of energy storage costs.

Another example of the fields of application of methodologies based on fuzzy AHP is the process of selecting suppliers that report the greatest satisfaction for the client of a company in Turkey [28]. Fouladgar et al. [29] propose an integrated model to prioritize the strategies of the Iranian mining sector using fuzzy AHP and Fuzzy Technique for Order Preference by Similarity of an Ideal Solution (FTOPSIS), whose results show that improving exploitation and production capacity are priority strategies to boost the sector. Wang et al. [30] build a system of criteria (environmental, technological, economic and social) and perform an evaluation and prioritization of seven bioenergy technologies to select optimal technologies among multiple alternatives using a combination of the VIKOR method to determine the sequence of sustainability of the bioenergy and fuzzy AHP technologies.

Samuel et al. [31] address heart failure with the purpose of predicting risks for prevention and treatment. Accordingly, they used the fuzzy AHP technique to calculate the global weights of the relevant attributes based on the individual contribution of each attribute, and applied the global weights representing the contributions of the attributes to train an artificial neural network (ANN) classifier for risk prediction of heart failure in patients, with an average prediction accuracy of 91.10%, resulting in a 4.40% more efficient process compared to the conventional ANN method.

The purpose of this study is to determine the structure of the research agenda on fuzzy AHP, and identify the existing links in the academic literature of the area. In addition, this research identifies the authors, universities and countries with the most significant generation of knowledge about fuzzy AHP, its analysis from a bibliometric-spatial approach and the main international collaboration networks. Lastly, this study aims to discover the research with the greatest impact on fuzzy AHP and its contexts of application, specifically, the most relevant thematic areas and the bibliographic coupling process of the seminal works in the field of study for each of the clusters identified.

The main novelty of this research is to offer an updated global vision on the construction of the fuzzy AHP research agenda, and to carry out an evaluation of the unclosed gaps in the academic literature, identifying new trends detected in the different association clusters within conceptual academic discourse on fuzzy AHP. The results of this research allow scholars to take advantage of the publication opportunities detected. In addition, journal editors can guide the design of special issues based on the evidence found, understanding and taking advantage of the internal structure of high-impact research in the field.

The article is structured as follows: first, the materials and methods used in this research are presented; second, the results are reported and discussed; third, important recommendations are offered on emerging areas of fuzzy AHP application, gaps not closed by academia, and high-impact publication opportunities underlying the evolution of the research agenda; and, finally, fourth, the conclusions of this study are formulated and developed, proposing future lines of research suggested for the scientific advancement of the field.

2. Materials and Methods

The research was designed following the PRISMA statement [32], the methodology proposed by Tavares Thomé et al. [33], and the bibliometric research standards proposed by Zupic & Čater [34] In short: first, design the research; second, collect bibliometric information; third, analyze and report the results; and fourth, discuss the findings and the publication opportunities detected. The search strategy performed a systematic literature review (SLR) based on the Web of Science Core Collection.

The use of other databases was rejected to avoid direct and indirect biases in the selection of the articles analyzed. Given the intertemporal analyses carried out, the inclusion of databases that were created between the first and the last article analyzed (e.g., Scopus or ESCI) would have caused a sampling bias that would invalidate the applied methodology, as well as introducing inconsistency into the results, findings and conclusions of this study [35–38]. As a consequence, the Web of Science Core Collection was chosen based on its robustness [39,40] and the continued coverage offered by this database during the 28-year period analyzed [41]. The analysis focused on the impact and academic influence of research published in high-impact journals, so chapters, books and proceedings were ignored. The search terms "fuzzy AHP" or "fuzzy-AHP" were included for title (TI), abstract (AB), author keywords (AK) or keyword plus® (KP). Journal articles from any Science Category website indexed in Journal Citation Reports® (JCR) according to the Social Sciences Citation Index (SSCI) and Scientific Citation Index Expanded (SCIE) were considered. The search was carried out during Q2 of 2022 and the results included articles published between 1994 and June 2022, according to the reported Boolean criteria. The database built by this procedure included 2086 articles. Congruent with the PRISMA statement, Figure 1 reports the research strategy followed. The "other reasons" that prompted the removal of records (n = 6) on the first list were associated with the academic integrity of the articles, based on critical rejection criteria applied by journals in accordance with best practices in terms of academic integrity and transparency.

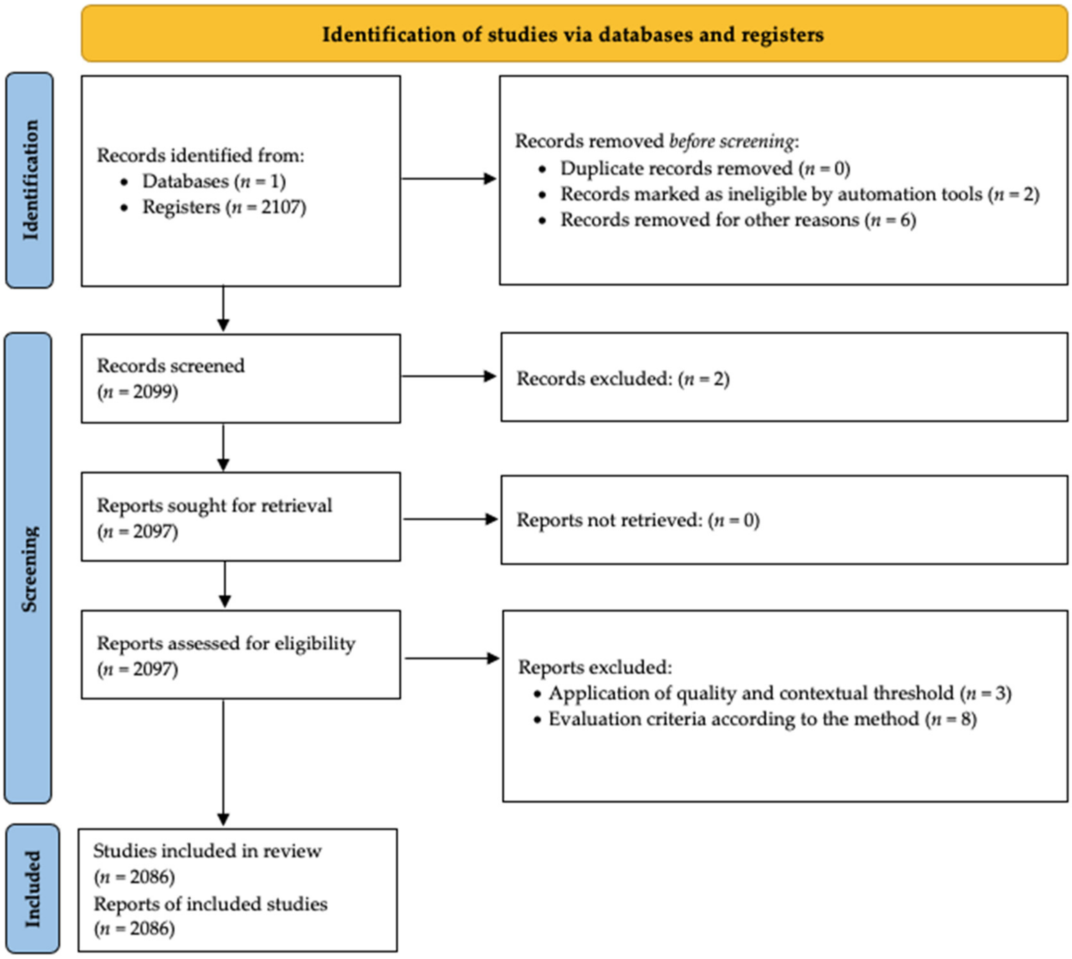

Figure 1. Systematic literature review strategy for bibliometric analysis.

The bibliometric analysis was performed with the VOSViewer 1.6.17 software [42]. In accordance with the interest of this research in determining the shape of the research agenda, the Normalized Impact per Year (NIY) was determined for each article [43], and the average of this variable was calculated for each journal and, further, for each cluster identified in the analysis of the bibliographic coupling of articles. The NIY variable is calculated by dividing the total count of citations by the number of years that have elapsed since the publication of an article. The NIY analysis ascertains the academic efficiency of each article in an intertemporal acceleration approach [44]. In addition, NIY contributes to a better understanding of emerging trends in academic debate, identifying seminal articles and journals that mark changes in the acceleration (or deceleration) of the tendency to influence scholars [43,44].

The Documents per Year (DpY) variable was also constructed for each journal, allowing the density of interest of each journal to be reported for the field of study that is the object of this research. In addition, the Citations per Document (CpD) variable was constructed for each article, and it was additionally calculated for each country of affiliation of the authors of the articles analyzed and, further, for each cluster identified in the analysis of the bibliographic coupling of articles. CpD offers relevant information about the academic efficiency of an article, author, country, journal or certain cluster evaluated through "scientometric" analysis [43]. In addition, academic efficiency was measured by adopting a spatial bibliometric perspective based on an analysis of the level of CpD according to a world political map.

Finally, to carry out the analysis of the bibliographic coupling clusters of articles, the Window of Academic Interest and Persistence in the Research Agenda (WAIPRA) variable was constructed, which represents the time elapsed between the first and last year of publication of articles belonging to a cluster. WAIPRA shows the intensity of the thematic anchoring that the articles included in a cluster have built over the years in the academic debate. WAIPRA analysis must take into account duration, chronology and proximity (or distance) with respect to the contemporary temporal vanguard of the study area, and it is possible to categorize 5 different situations based on their value expressed in years from the first and the last article that includes the cluster: (1) If WAIPRA is very strong (greater than two decades), it reports an intense and persistent cluster over time that constitutes central academic literature for the construction of scientific debate. (2) If WAIPRA is strong (greater than a decade), it provides information about the structure of articles underlying the configuration of the research agenda. (2.a) If the year of publication of the last article included in the cluster is close to the present time (less than a decade), the cluster includes articles that scholars are making central to the research agenda and that are becoming mainstream. On the other hand, (2.b) if the year of publication of the last article included in the cluster is far from the current moment (more than a decade), the interest of the academy has decreased, given the dearth of new articles on the thematic field, but the articles included in the cluster are still relevant to configure the researchers' discourse. (3) A weak WAIPRA (less than a decade) refers to seminal articles that report intense trends for the configuration of academic thought but that were short-lived in their generation. Analogously, (3.a) if the year of publication of the last article included in the cluster is far from the current moment (more than a decade), they are seminal articles whose window of persistence and prevalence was very fleeting but they constitute central elements to articulate the academic debate on the area. On the other hand, (3.b) if the window of academic production is very close to the current moment, it reports emerging trends that are in bloom, not yet fully developed, and that present opportunities for publication in two large areas: (1) in development, configuration and permeabilization of the macro-, meso- or micro-theory; (2) in the application to cases, improving the cross-sectional granularity of the study area and its managerial implications.

3. Results and Discussion

This section reports the results of the systematic literature review (SLR) based on articles published in SSCI and SCIE (n = 2086) and discusses the findings of the bibliometric analysis based on the practical implications for researchers. First, the documents are analyzed from a longitudinal perspective, their distribution based on the main categories of the Web of Science and their main funding agencies are recorded. Second, the journals with the highest production and academic impact and the most relevant articles in the area of knowledge are reported. Third, the academic production by country and the international collaboration networks detected are analyzed. Fourth, the cluster analysis of bibliographic coupling of articles is reported, evaluating emerging trends in each cluster and discussing opportunities for publication in high-impact journals.

3.1. Preliminary Analysis

The results of the preliminary analysis of articles show a growing trend (R^2 = 0.9598) in the scientific production of articles on fuzz-AHP from 2008 (Figure 2). From 2008 on, the previous trend on the use and diffusion of decision-making tools was accelerated. Table 1 reports the Top 25 Web of Science categories in which academic articles were published on the area of study analyzed.

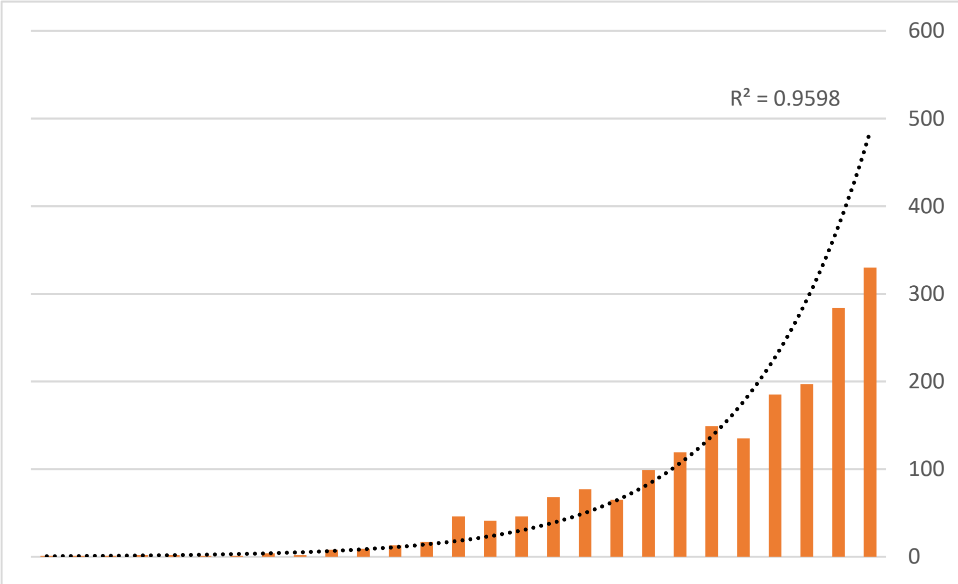

Figure 2. Articles publication trend for the period 1994–2022.

Table 1. Top 25 Web of Science categories.

Web of Science Categories	Record Count
Computer Science Artificial Intelligence	391
Environmental Sciences	326
Operations Research Management Science	302
Green Sustainable Science Technology	205
Computer Science Interdisciplinary Applications	193
Engineering Industrial	188
Engineering Electrical Electronic	176
Environmental Studies	144
Management	142
Computer Science Information Systems	131
Engineering Manufacturing	131
Engineering Multidisciplinary	112
Energy Fuels	111
Engineering Environmental	104
Engineering Civil	103
Geosciences Multidisciplinary	103
Water Resources	84
Economics	74
Business	61
Computer Science Theory Methods	56
Construction Building Technology	54
Automation Control Systems	53
Telecommunications	52
Mathematics Interdisciplinary Applications	50
Multidisciplinary Sciences	47

Source: Authors' elaboration.

Management, Business or Economics areas occupied modest positions in the ranking, and the areas with the greatest diffusion and interest in the field were related to computing, operations or sciences applied to the environment and sustainability. The evaluation of the main funding agencies (Table 2) that promoted the academic debate on fuzzy AHP highlights the role of institutions from China and Taiwan, relegating European organizations to modest positions. Specifically, the National Natural Science Foundation of China was followed at a great distance by the Ministry of Science and Technology Taiwan or the

Fundamental Research Funds for the Central Universities. The European Commission funded 10 times less research than did the National Natural Science Foundation of China.

Table 2. Top 25 Funding Agencies.

Funding Agencies	Record Count
National Natural Science Foundation of China	173
Ministry of Science and Technology Taiwan	39
Fundamental Research Funds for the Central Universities	33
European Commission	18
China Postdoctoral Science Foundation	12
King Saud University	12
National Basic Research Program of China	11
Conselho Nacional De Desenvolvimento Cientifico e Tecnologico	10
National Key R D Program of China	10
National Key Research and Development Program of China	10
China Scholarship Council	8
Spanish Government	8
Turkiye Bilimsel Ve Teknolojik Arastirma Kurumu Tubitak	8
Coordenacao de Aperfeicoamento de Pessoal de Nivel Superior Capes	7
Ministry of Education Science Technological Development Serbia	7
Ministry of Science and Technology China	7
Yildiz Technical University	7
Department of Science Technology India	6
National High Technology Research and Development Program of China	6
Specialized Research Fund for the Doctoral Program of Higher Education	6
University of Tehran	6
City University of Hong Kong	5
Grant Agency of The Czech Republic	5
National Natural Science Foundation of Guangdong Province	5
National Science Foundation	5

Source: Authors' elaboration.

3.2. Production and Academic Impact

The variables of analysis of academic production and impact by total count of citations allowed the determination of the top 25 journals based on their total academic production (Table 3). The ranking is ordered according to the number of articles on fuzzy AHP published by each journal. The year of publication of the first article is also reported, offering information relevant to the journal's experience in the field. Finally, the DpY of the journal is reported, showing the academic efficiency achieved by the journal.

A detailed analysis of the first five journals classified in the Top 25 Journals by Articles shows that *Expert Systems with Applications* is in the first position of the ranking, with more than one hundred published documents. It is followed by *Sustainability* with 85% of the academic production, and, at a greater distance, continuing in the third, fourth, and fifth position, *Journal of Intelligent & Fuzzy Systems*, *Journal of Cleaner Production*, and *Applied Soft Computing*. The journal included in the Top 25 Journals by Articles that has the most experience in the fuzzy AHP area is the *European Journal of Operational Research*, whose first publication was in 1996. Among those included in the Top 25 Journals by Articles, there are three journals that had their first publication on fuzzy AHP at a very recent date, in 2019: *IEEE Access Mathematics*, and *Environment Development and Sustainability*. These are three journals that, despite having a short history of publication on fuzzy AHP, with less than 3 years since the first publication, manage to be included in the Top 25 for publication of articles, which demonstrates the topic's relative importance and the intensity of the process of extension of the journals' domain in the area of knowledge. These three magazines are linked to technical areas of engineering and mathematics, as well as to the environment and issues of sustainability.

Table 3. Top 25 Journals by Articles.

Journal	Articles	First Year	DpY
Expert Systems with Applications	105	2007	7.0
Sustainability	88	2015	12.6
Journal of Intelligent & Fuzzy Systems	66	2005	3.9
Journal of Cleaner Production	60	2009	4.6
Applied Soft Computing	43	2008	3.1
International Journal of Production Research	42	2006	2.6
Computers & Industrial Engineering	30	1999	1.3
Mathematical Problems in Engineering	26	2013	2.9
Soft Computing	26	2009	2.0
International Journal of Advanced Manufacturing	25	2006	1.6
IEEE Access	24	2019	8.0
Technological and Economic Development of Economy	24	2011	2.2
Journal of Multiple Valued Logic and Soft Computing	23	2008	1.6
Safety Science	21	2008	1.5
Environmental Science and Pollution Research	19	2014	2.4
Mathematics	19	2019	6.3
Annals of Operations Research	17	2018	4.3
International Journal of Information Technology & Decision Making	17	2005	1.0
Energy	16	2008	1.1
Energies	15	2013	1.7
Environment Development and Sustainability	15	2019	5.0
Environmental Earth Sciences	15	2012	1.5
European Journal of Operational Research	15	1996	0.6
International Journal of Computatioal Intelligence Systems	15	2009	1.2
Tehnicki Vjesnik Technical Gazette	15	2011	1.4

Source: Authors' elaboration.

The detailed analysis of the DpY reports a high efficiency of academic publication per year for five journals that are above the average of the Top 25 Journals by Articles: *Sustainability* (DpY = 12.6), *IEEE Access* (DpY = 8), *Expert Systems with Applications* (DpY = 7); *Mathematics* (DpY = 6.3); and *Environment Development and Sustainability* (DpY = 5). These are journals whose scope is linked to areas of knowledge such as sustainability, technical aspects of engineering and mathematical sciences, and the environment.

The evidence found shows that the journals that have articulated a more intense expansion strategy in recent years in the field of fuzzy AHP are linked to technical and environmental areas, both in absolute terms (total number of articles published) and in relative terms (average number of articles per year; DpY). On the other hand, the Top 25 Journals by Citations (Table 4) were also determined. This ranking classifies and ranks the journals based on their ability to impact the academic community, expressed as the total count of citations achieved by all the articles published in the fuzzy AHP area. The year of the first publication is also reported and the NIY average is constructed, as the average of the NIY of all the articles published by each journal.

The results show important differences in classification in terms of citations obtained, compared to the classification in terms of published articles. For example, the *European Journal of Operational Research* was ranked 24th for the number of articles published on fuzzy AHP, and in the ranking for academic impact expressed as a total count of citations, this journal was ranked second in the ranking, with 5110 citations. Another paradigmatic example is *Sustainability*, which occupies the second position in the ranking by articles, but is located in the twelfth position in the ranking by citations. This comparison allows us to verify the efficiency gap of many journals, given the significant distances in the trade-off between the number of published articles and the real impact of these articles on the scientific community.

Table 4. Top 25 Journals by Citations.

Journal	Cites	First Year	NIY Average
Expert Systems with Applications	9034	2007	9.7
European Journal of Operational Research	5110	1996	18.5
Applied Soft Computing	3076	2008	11.6
Journal of Cleaner Production	2505	2009	11.7
International Journal of Production Research	1927	2006	5.9
International Journal of Production Economics	1770	2004	18.7
Safety Science	1426	2008	12.6
Computers & Industrial Engineering	1297	1999	9.0
Information Sciences	1160	2005	8.4
International Journal of Advanced Manufacturing Technology	1009	2006	4.1
Energy	921	2008	10.2
Sustainability	855	2015	3.9
Journal of Intelligent Manufacturing	720	2002	5.7
Technological and Economic Development of Economy	650	2011	4.6
Mathematical and Computer Modelling	607	2004	9.7
Automation in Construction	573	2008	10.7
Soft Computing	568	2009	9.7
Journal of Intelligent & Fuzzy Systems	562	2005	1.7
Resources Conservation and Recycling	540	2012	16.8
International Journal of Hydrogen Energy	509	2008	10.7
IIE Transactions	460	2003	12.5
Journal of Construction Engineering and Management	453	2007	11.3
Stochastic Environmental Research and Risk Assessment	441	2006	10.7
Production Planning & Control	440	2010	7.5
International Journal of Computational Intelligence Systems	415	2009	3.3

Source: Authors' elaboration.

On the other hand, the Normalized Impact per Year (NIY), taken as an average of all the articles in a journal, reports information relevant to the determination of average academic efficiency within an intertemporal scheme of scientific production. This variable must be taken into consideration together with the year of publication of the first article, since a high NIY for a recent year (e.g., the age of the first article published in the journal is less than 10 years) reports that the journal has a strong trend within the area of knowledge of fuzzy AHP. This indicator represents a signal of temporal acceleration for a subperiod, confirming that the journal takes up a relevant participation in the configuration of the research structure on the area. *Resources Conservation and Recycling* (First year: 2012; NIY = 16.8) has generated an accelerated relative impact on the research agenda in recent years.

Other journals with a high NIY Average report a year of publication of the first article on fuzzy AHP prior to the last decade. Based on the evidence found, these journals should be considered seminal in the area of knowledge, since they report a high performance in academic efficiency, demonstrating a capacity for persistent impact within the academic community. In this sense, compare the *European Journal of Operational Research* (First year: 1996; NIY = 18.5), the *International Journal of Production Economics* (First year: 2004; NIY = 18.7), *Stochastic Environmental Research and Risk Assessment* (First year: 2006; NIY = 10.7), the *Journal of Construction Engineering and Management* (First year: 2007; NIY = 11.3), *Safety Science* (First year: 2008; NIY = 12.6), *Applied Soft Computing* (First year: 2008; NIY = 11.6), *International Journal of Hydrogen Energy* (First year: 2008; NIY = 10.7), *Automation in Construction* (First year: 2008; NIY = 10.7), *Energy* (First year: 2008; NIY = 10.2), the *Journal of Cleaner Production* (First year: 2009; NIY = 11.7), and *Soft Computing* (First year: 2009; NIY = 9.7). These are journals focused on multiple areas (operations, production, environment, construction engineering, computing and energy), evidencing the thematic transversality of the persistent development of the field of knowledge object of this study.

The results confirm that from the time that the Great Financial Crisis (GFC) began their publications on fuzzy AHP, many of the journals that are classified in the ranking with the highest relative impact expressed similar interest based on the NIY. The systemic change represented by the GFC acted as an accelerator in the interest of scholars in the fuzzy AHP area, and in the speed and transversality of the diffusion of the area over academics. In fact, the threshold set in 2008 has been used in multiple bibliometric articles (e.g., Bai et al. [45] or Kocak et al. [46]) to study the strong trend change experienced among scholars, being especially relevant in the fields of business and management [47].

Table 5 reports the articles with the most impact within the study area on fuzzy AHP and its applications. In the Top 25 Articles by Citations are articles oriented to the analysis of applications of exempt analysis method on fuzzy AHP [48], supplier selection [49–51], fuzzy AHP for evaluating performance of IT departments in the manufacturing industries [52], selection of optimum maintenance strategies [53], behavior-based safety management [54], catering service companies [55], prioritization of human capital measurement indicators [56] or evaluation of the weights of customer requirements in quality function deployment [57], and weights in quality function deployment (QFD) process [58]. Other high-impact articles studied extent analysis methods [59], consistency in fuzzy AHP [60] and failure in fuzzy TOPSIS-based fuzzy AHP [61], or made revisions [15,62], compared fuzzy AHP and TOPSIS [63–65], integrated both methodologies [66,67], combined axiomatic design and AHP [68] or fuzzy AHP [26], applied the AHP method through intuitionistic fuzzy extensions [17] or compared AHP and Analytic Networks Process (ANP) [20].

Following the approach proposed by Castelló-Sirvent [43], a detailed analysis of the NIY reports an average of 30 citations per year for the 25 articles included in the ranking (Table 5). Thus, taking the articles published in the last decade that are included in the Top 25 Articles by Citations, all the articles show a NIY above the threshold established as average. The academic efficiency of two investigations that widely exceed the average of the most cited articles on fuzzy AHP stands out ([51], NIY = 75; [64], NIY = 54). In these cases, the trend acceleration indicator represented by the NIY [43,44] confirms that both articles have contributed to the articulation of the academic debate, configuring turning points for recent academic literature. In both cases, the mainstream area of interest is the application of fuzzy AHP methodologies to the supply chain. Less than five years old, the article by Luthra et al., in application of an analysis for sustainable supplier selections [51] becomes mainstream within the research agenda, and with an antiquity of less than 8 years, the article by Lima et al., in application of comparison between fuzzy AHP and fuzzy TOPSIS methods to supplier selection [64] performs a similar function within the literature.

Table 5. Top 25 Articles by Citations.

Article Title	Authors	Year	Journal	Cites	NIY
Applications of the Extent Analysis Method on Fuzzy AHP [48]	Chang, D.Y.	1996	European Journal of Operational Research	2436	93.7
Integrated Analytic Hierarchy Process and its Applications—A Literature Review [15]	Ho, W.	2008	European Journal of Operational Research	552	39.4
Multi-Attribute Comparison of Catering Service Companies Using Fuzzy AHP: The case of Turkey [55]	Kahraman, C.; Cebeci, U.; Ruan, D.	2004	International Journal of Production Economics	467	25.9
On the Extent Analysis Method for Fuzzy AHP and its Applications [62]	Wang, Y.M.; Luo, Y.; Hua, Z.	2008	European Journal of Operational Research	437	31.2
A Comparison Between Fuzzy AHP and Fuzzy TOPSIS Methods to Supplier Selection [64]	Lima, F.R.; Osiro, L.; Carpinetti, L.C.R.	2014	Applied Soft Computing	432	54.0
Global Supplier Selection: A Fuzzy AHP Approach [50]	Chan, F.T.S.; Kumar, N.; Tiwari, M.K.; Lau, H.C.W.; Choy, K.L.	2008	International Journal of Production Research	389	27.8
A Performance Evaluation Model by Integrating Fuzzy AHP and Fuzzy TOPSIS Methods [66]	Sun, C.C.	2010	Expert Systems with Applications	372	31.0
Supplier Selection Using Fuzzy AHP and Fuzzy Multi-Objective Linear Programming for Developing Low Carbon Supply Chain [49]	Shaw, K.; Shankar, R.; Yadav, S.S.; Thakur, L.S.	2012	Expert Systems with Applications	369	36.9
An Integrated Framework for Sustainable Supplier Selection and Evaluation in Supply Chains [51]	Luthra, S.; Govindan, K.; Kannan, D.; Mangla, S.K.; Garg, C.P.	2017	Journal of Cleaner Production	375	75.0
Fuzzy Failure Modes and Effects Analysis by Using Fuzzy TOPSIS-based Fuzzy AHP [61]	Kutlu, A.C.; Ekmekcioglu, M.	2012	Expert Systems with Applications	343	34.3
On Consistency and Ranking of Alternatives in Fuzzy AHP [60]	Leung, L.C.; Cao, D.	2000	European Journal of Operational Research	316	14.4
A Fuzzy AHP and BSC Approach for Evaluating Performance of IT Department in the Manufacturing Industry in Taiwan [52]	Lee, A.H.I.; Chen, W.C.; Chang, C.J.	2008	Expert Systems with Applications	328	23.4
A Discussion on Extent Analysis Method and Applications of Fuzzy AHP [59]	Zhu, K.J.; Jing, Y.; Chang, D.Y.	1999	European Journal of Operational Research	312	13.6
Determining the Importance Weights for the Customer Requirements in QFD Using a Fuzzy AHP with an Extent Analysis Approach [58]	Kwong, C.K.; Bai, H.	2003	IIE Transactions	305	16.1
Construction Projects Selection and Risk Assessment by Fuzzy AHP and Fuzzy TOPSIS Methodologies [65]	Taylan, O.; Bafail, A.O.; Abdulaal, R.M.S.; Kabli, M.R.	2014	Applied Soft Computing	303	37.9
Fuzzy Multi-Attribute Selection Among Transportation Companies Using Axiomatic Design and Analytic Hierarchy Process [68]	Kulak, O.; Kahraman, C.	2005	Information Sciences	296	17.4
Evaluation of Hazardous Waste Transportation Firms by Using a Two Step Fuzzy AHP and TOPSIS Methodology [63]	Gumus, A.T.	2009	Expert Systems with Applications	304	23.4
Selection of Optimum Maintenance Strategies Based on a Fuzzy Analytic Hierarchy Process [53]	Wang, L.; Chu, J.; Wu, J.	2007	International Journal of Production Economics	300	20.0
Developing a Fuzzy Analytic Hierarchy Process (AHP) Model for Behavior-Based Safety Management [54]	Dagdeviren, M.; Yuksel, I.	2008	Information Sciences	284	20.3

Table 5. *Cont.*

Article Title	Authors	Year	Journal	Cites	NIY
Intuitionistic Fuzzy Analytic Hierarchy Process [17]	Xu, Z.S.; Liao, H.C.	2014	IEEE Transactions on Fuzzy Systems	273	34.1
Combining Grey Relation and TOPSIS Concepts for Selecting an Expatriate Host Country [67]	Chen, M.F.; Tzeng, G.H.	2004	Mathematical and Computer Modelling	275	15.3
A Comparative Analysis for Multiattribute Selection Among Renewable Energy Alternatives Using Fuzzy Axiomatic Design and Fuzzy Analytic Hierarchy Process [26]	Kahraman, C.; Kaya, I.; Cebi, S.	2009	Energy	282	21.7
The Analytic Hierarchy Process and Analytic Network Process: An Overview of Applications [20]	Sipahi, S.; Timor, M.	2010	Management Decision	269	22.4
A Fuzzy AHP Approach to the Determination of Importance Weights of Customer Requirements in Quality Function Deployment [57]	Kwong, C.K.; Bai, H.	2002	Journal of Intelligent Manufacturing	241	12.1
Prioritization of Human Capital Measurement Indicators Using Fuzzy AHP [56]	Bozbura, F.T.; Beskese, A.; Kahraman, C.	2007	Expert Systems with Applications	268	17.9

Source: Authors' elaboration.

3.3. Academic Production by Country and International Collaboration Networks

Since the first seminal publications in the area, the academic production in the field of fuzzy AHP has been distributed by country as shown in Table 6. The analysis includes the production of articles on fuzzy AHP that gave rise to five or more published articles in journals of the Business or Management areas indexed in JCR. The ranking of countries is reported based on the academic efficiency achieved by country according to the average count of citations per published document (CpD). According to Castelló-Sirvent [43], a high CpD reports a country with a reduced number of published articles and that achieves a great deal of relevance and influence in the academy. A reduced CpD reports a country with a large number of published articles that, in comparative terms, has little relevance and influence in the academy.

Table 6. Ranking of countries sorted by CpD. Countries with five or more published articles.

Rank	Countries	CpD	Articles	Cites	Rank	Countries	CpD	Articles	Cites
1	Belgium	82.8	9	745	28	South Korea	24.0	57	1369
2	Wales	78.3	6	470	29	France	23.3	29	676
3	Denmark	72.9	20	1458	30	South Africa	23.0	5	115
4	Singapore	44.9	13	584	31	Portugal	22.6	11	249
5	Germany	39.1	14	547	32	Switzerland	21.0	5	105
6	Austria	39.0	12	468	33	Nigeria	19.5	10	195
7	Lithuania	39.0	34	1325	34	Sweden	19.4	11	213
8	Chile	36.6	9	329	35	Vietnam	18.8	29	546
9	England	36.4	87	3164	36	Malaysia	18.8	50	939
10	Japan	35.3	22	777	37	Hungary	18.2	13	236
11	The Netherlands	33.9	12	407	38	Qatar	18.0	7	126
12	Canada	33.1	43	1424	39	Spain	17.8	46	818
13	Taiwan	32.5	216	7021	40	Serbia	17.7	61	1078
14	Turkey	32.1	398	12788	41	Bangladesh	17.5	15	262
15	Scotland	31.8	6	191	42	Egypt	16.3	8	130
16	Australia	30.2	61	1842	43	Morocco	14.2	13	184
17	Greece	30.0	19	570	44	Finland	14.1	9	127
18	USA	29.9	112	3346	45	Saudi Arabia	13.5	79	1070
19	New Zealand	29.4	8	235	46	Pakistan	12.7	29	368
20	Italy	27.9	39	1087	47	Russia	10.6	5	53
21	Poland	27.3	23	628	48	Colombia	10.2	6	61
22	India	27.3	278	7576	49	Mexico	8.7	6	52
23	China	26.6	388	10319	50	Czechia	8.0	13	104
24	Brazil	26.3	31	816	51	Slovenia	7.5	6	45
25	United Arab Emirates	25.7	9	231	52	Croatia	7.3	6	44
26	Iran	24.5	234	5730	53	Norway	6.2	12	74
27	Thailand	24.1	20	481	54	Romania	5.1	8	41

Source: Authors' elaboration.

The results of the research report on the Top 10 of maximum academic efficiency includes seven European countries (Belgium, CpD = 82.8; Wales, CpD = 78.3; Denmark, CpD = 72.9; Germany, CpD = 39.1; Austria, CpD = 39; Lithuania, CpD = 39; England, CpD = 36.6), an Asian country (Singapore, CpD = 44.9) and another LATAM country (Chile, CpD = 36.6). Given that they achieve a very high ComD as a result of very few published articles—less than 10 articles—three countries stand out for their high academic efficiency within the Top 10: Wales, Belgium, and Chile.

The classification of the final part of the ranking of countries by academic production equal to or greater than 5 articles published in the area of knowledge under study also highlights the low academic efficiency of the production of researchers whose academic affiliation is based in Saudi Arabia (CpD = 13.5), Pakistan (CpD = 12.7), Russia (CpD = 10.6), Colombia (CpD = 10.2), Mexico (CpD = 8.7), Czechia (CpD = 8), Slovenia (CpD = 7.5), Croatia (CpD = 7.3), Norway (CpD = 6.2) and Romania (CpD = 5.1).

Figure 3 reports the spatial bibliometric results of the analysis performed in this study. The academic efficiency map reports on four levels of country performance according to the Citations per Document (CpD) variable: Very high academic efficiency (CpD > 30) in red. High academic efficiency (20 < CpD < 30) in yellow. Moderate academic performance (10 < CpD < 20) in blue. Low academic efficiency (CpD < 10) in black.

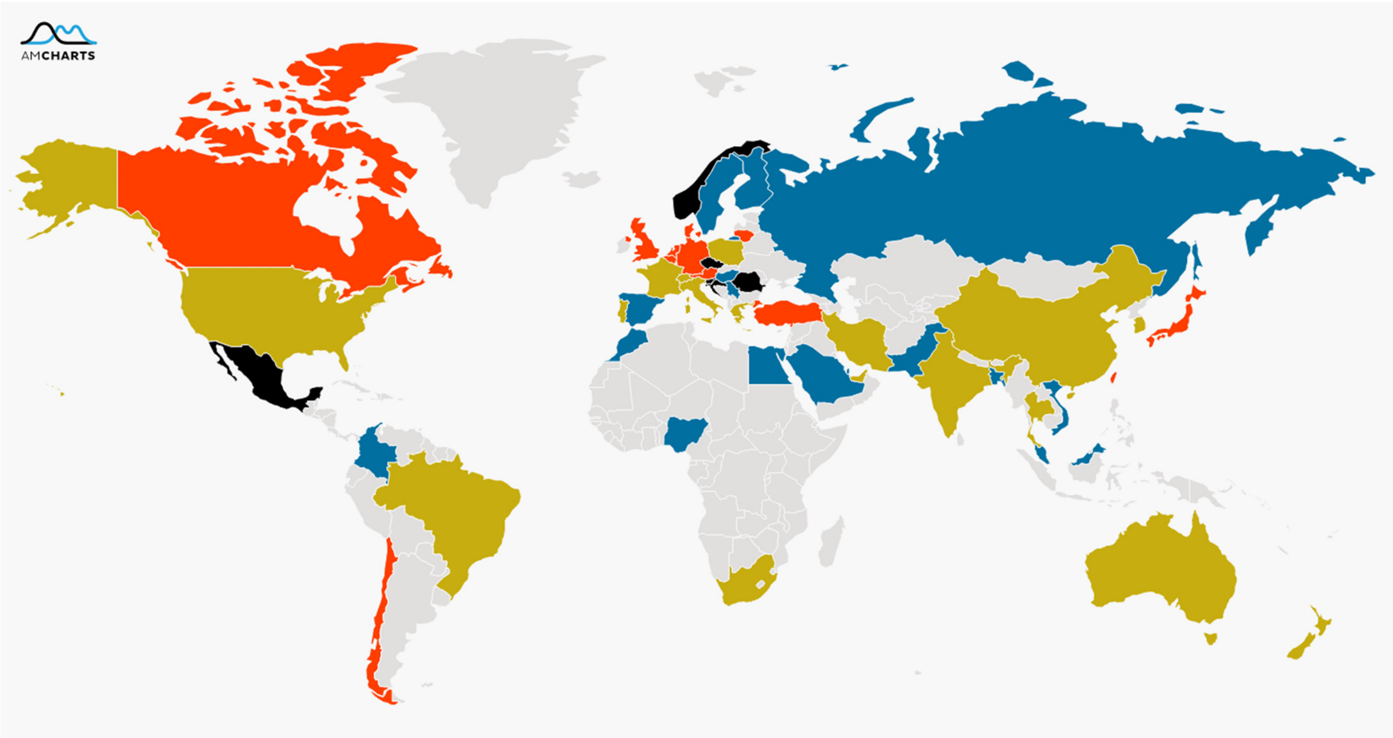

Figure 3. Academic efficiency map. Red: CpD > 30. Yellow: 20 < CpD < 30. Blue: 10 < CpD < 20. Black: CpD < 10. Source: Authors' elaboration with AMCharts.

The results of the analysis carried out for the bibliographic coupling of countries report 10 clusters of international collaboration in research on fuzzy AHP (Figure 4). The evidence found does not report homogeneous geographical links, but rather that the connections between countries are transversal between continents, or political and economic unions. The analysis carried out includes links between co-authors of researchers whose institutions are based in the countries analyzed for a minimum of five articles published in JCR on the area of knowledge under study, according to journals included in the Business or Management categories of the Web of Science.

The four main international collaborations integrate links between 41 countries: Cluster 1 includes 16 countries (Denmark, England, Germany, Greece, India, Iran, Italy, Lithuania, The Netherlands, Norway, Serbia, Slovenia, Taiwan, Turkey, USA, and Wales). Cluster 2 includes 10 countries (Australia, Austria, Canada, Croatia, Egypt, Hungary, Malaysia, New Zealand, Nigeria, and South Africa). Cluster 3 includes 8 countries (Bangladesh, Colombia, Japan Mexico, Poland, Russia, Scotland, and Spain). Cluster 4 includes 7 countries (Finland, Pakistan, China, Romania, Saudi Arabia, Thailand, and the United Arab Emirates). The 6 remaining clusters bring together a total of 13 countries (Cluster 5: Chile, Czechia, France, and Qatar; Cluster 6: Brazil, Sweden, Vietnam; Cluster 7: Morocco and Switzerland; Cluster 8: Singapore and South Korea; Cluster 9: Portugal; Cluster 10: Belgium).

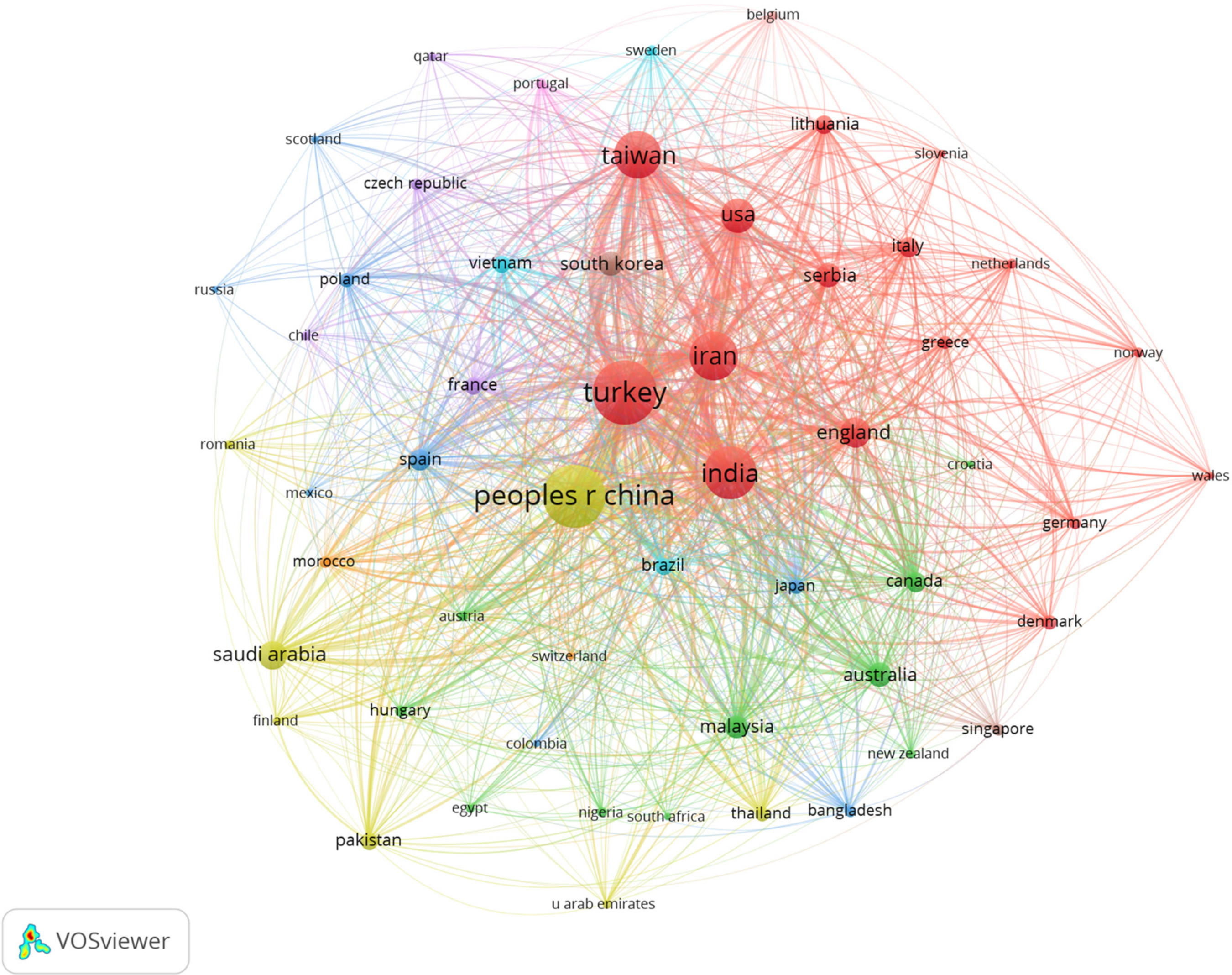

Figure 4. International collaboration networks. Bibliographic coupling of countries. More than five citations per country.

3.4. Bibliographic Coupling of Articles, Emerging Trends and High-Impact Publication Opportunities

The detailed analysis of the academic discourse allows the understanding of the internal structure of the research agenda in the field. The results of the evaluation of the bibliographic coupling of articles report six clusters (Figure 5). Table 7 focuses on the detail of articles, year of publication of the first and last article, total number of citations obtained and NIY average for each cluster.

Cluster 1 [11,17,26,53–60,62,63,68–100] is the most active in number of articles and total citations. This cluster also has the strongest WAIPRA of all the clusters identified in the article bibliographic coupling analysis, although the NIY Average of the articles included in this cluster is the lowest of all. It is confirmed that the 46 articles included in cluster 1 are persistent over time and the development of the academic literature that offers articulation to the academic debate from this cluster is still under development, given that the last article included in the cluster is from 2020. The results of cluster 1 (Appendix A; Table A1) address important publication opportunities relevant to the analysis of strategic decisions [84], airline industries [83] risk assessment [69], urban land-use planning [73], power distribution systems [92] and renewable energy [70], potential flood prone areas mapping [75] and landslide susceptibility mapping [74], passenger shipping [85] or teaching performance [72], among others.

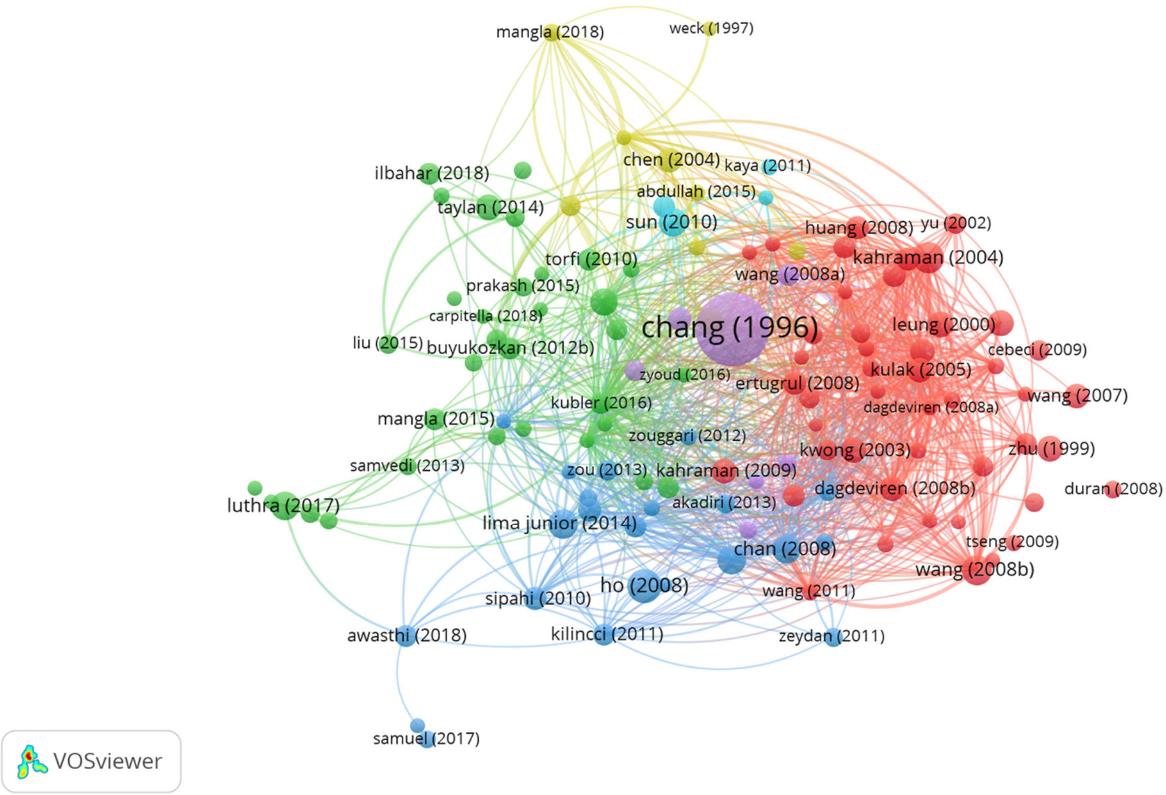

Figure 5. Bibliographic coupling of articles.

Table 7. Bibliographic coupling of articles.

Cluster	Articles	First Year	Last Year	WAIPRA	Cites	NIY Average
1	46	1999	2020	21	9222	17.2
2	33	2002	2020	18	5771	25.9
3	22	2006	2019	13	4796	24.8
4	9	1997	2018	21	1587	19.0
5	7	1994	2013	19	3513	23.2
6	4	2010	2012	2	855	18.5

Source: Authors' elaboration.

Cluster 2 [22,25,51,61,65,101–127] registers a WAIPRA significantly lower than cluster 1. It includes 33 articles and a NIY Average 50% higher than cluster 1. The results suggest a higher persistence. Given that the year of publication of the last article included in this cluster is close to the present time, the evidence found informs about trending topics that are in development, but unlike cluster 1 they have a higher internal prevalence, since they have greater capacity academic impact and influence on the research agenda. Cluster 2 allows researchers to be advised on research opportunities (Appendix A; Table A2) linked to risk assessment [106,108,114,124,125], water loss management in developing countries [112], renewable strategic renewable energy resources selection [123], automotive components remanufacturing industry [101], or logistics barriers [126], and supply chains [51].

Cluster 3 includes 22 items [15,20,28,31,49,50,64,128–142] and it registers a strong WAIPRA, over a decade, whose last article was published 3 years ago (Appendix A; Table A3). The absence of more recent articles suggests that, despite having a high NIY Average (NIY Average = 24.8), and reporting an intense trend of influence on the academic debate, the thematic field seems stagnant to configure a line of development of the literature, although it is central to support the construction of the internal structure of the area of knowledge. However, some seminal works of the cluster should be taken into account as inspiration for the design of new research on sustainability as a guide for strategic decision-making [143] and for the configuration of green supply chains [140].

Clusters 4, 5 and 6 (Appendix A; Tables A4–A6) record few articles, but they are very important for the configuration of the academic debate. Cluster 4 includes nine items [52,67,144–150] and registers a WAIPRA equal to cluster 1, but the distance from the temporal vanguard suggests that the central contributions to the debate included in that cluster have already been made. However, cluster 4 evinces support for new research linked to specific methodologies such as SWOT [145], fuzzy DEMATEL [147] or fuzzy WASPAS [146], and applications to health [148], information technologies [52] or circular supply chain management in developing countries [144]. Cluster 5 includes seven items [24,48,143,151–154]. The last article published within the cluster is nine years old. This cluster registers the third highest NIY Average of the 6 clusters identified in the article bibliographic coupling analysis. The results suggest that cluster 5 includes very important articles for the construction of the academic debate on basic and applied research on fuzzy AHP, highlighting the article by Chang [48] (Citations = 2436; NIY = 93.7) and other core-articles for the methodological configuration of the area based on linguistic preferences [151] and in application to ICT service industries [143] or military issues [24,154]. Cluster 6 only includes four articles and a very small WAIPRA of only 2 years. The four articles included in this cluster were published between 2010 and 2012. The NIY average is also very low. The results suggest that the items included in cluster 6 are niche and highly specialized. These are relevant articles for the configuration of the research agenda in the integration of very specific methodological fields (e.g., fuzzy AHP and fuzzy TOPSIS to help the industrial practitioners for the performance evaluation in a fuzzy environment where the vagueness and subjectivity are handled with linguistic values parameterized by triangular fuzzy numbers [66]; fuzzy Delphi method and fuzzy AHP to select recycling technologies and policy for waste lubricant oil [155]; fuzzy AHP and ELECTRE methodologies to improve the Environmental Impact Assessment (EIA), considering possible impacts that a proposed project may have on the natural, social and economic aspects [156]; fuzzy AHP and fuzzy DEMATEL method in Human Resource for Science and Technology (HRST) [157]).

Liu et al. (2020) present a synthesis of the choice of fuzzy sets by answering the following questions: when is the fuzzy set applicable? What does it describe? How is it defined? in addition to a classification of the complexity of the method according to the difficulty of its arithmetic operations as shown in the following table. In this sense, Appendix B (Table A7) reports the main fuzzy AHP methodologies according to Liu et al. [10]. It is possible to observe a detailed analysis for the different typologies, as well as the most influential articles for each of them. On the other hand, the Appendix (Table A8) includes details of seminal articles that compare and/or hybridize fuzzy AHP with other MCDM methodologies.

4. Conclusions

Increasingly, decisions are more complex and the information more scarce. This study generates an important ordering of three decades of research in this area to facilitate the future investigation for different disciplines and application fields. The recent succession of changes that have taken place in the VUCA environment force managers to make quick decisions that minimize the implicit risk of insufficient and uncertain information. Fuzzy AHP methodologies have evolved in recent years and academics and experts have extended their development and broadened their fields of application. The new trends detected in this research offer important suggestions so that scholars can guide their future research on fuzzy AHP. The results show that sectors such as renewable energies, new urban developments and water management, green supply chain, circular economy applied to components of automotive industries, and many other activities, such as health, tourism, airline industries, military issues, or information technologies are amenable to fuzzy AHP technologies. Some trends of interest to the academy arise from the hybridization and comparison of methodologies. Some developments in this sense combine fuzzy AHP with fuzzy TOPSIS, fuzzy Delphi method, ELECTRE or DEMATEL. The Top 25 Web of Science categories (this ranking classifies and ranks the journals based on their impact within the academic community) in which academic articles were published on the area of study analyzed is led by Computer Science Artificial Intelligence with 391 articles, which is a field in full growth worldwide.

Another important contribution is that the literature suggests identifying the appropriate method to apply to a specific field. This will depend on its mathematical complexity, the level of precision of the opinions and, of course, the method of application.

What has justified this bibliometric research on fuzzy AHP is, firstly, that this methodology enables the inclusion of circumstances and determining factors in decision-making that are difficult to incorporate in other decision-making procedures and algorithms. Fuzzy AHP is a method characterized by its amplitude and flexibility in admitting different data on the conditioning factors of the environment in which the decisions of a company, a government project or any other social initiative must be taken. This is what makes valuable a method which, without renouncing the advantages of mathematical and formal procedures, considers multiple aspects of reality.

The bibliometric study carried out in this article shows the importance of the AHP fuzzy methodology through the significance of academic publications on this subject. To this end, this article presents a bibliographic review, incorporating different analysis tools (NIY, Normalized Impact per Year; DpY, Documents Published per Year; CpD, Citations per Document; WAIPRA, Window of Academic Interest and Persistence in the Research Agenda), and establishes which articles become the mainstream of the research agenda. The results of the study show that AHP can be applied in numerous areas, such as renewable energies, urban developments, water management or supply chain management with success and is a technique whose full deployment is still present as a trend, so it is an attractive field for research and publication. Besides the business industries where AHP can be applied, the cluster analysis shows (see Figure 5 and Table 7) five great theoretical areas of application: analysis of strategic decisions, risk assessment, sustainability, basic and applied research on fuzzy, and methodologies (SWOT, fuzzy DEMATEL or fuzzy WASPAS).

Secondly, and even more importantly in terms of fuzzy AHP trends, these trends are linked to the culture of companies and, in a more general sense, to the culture of management, to the culture of research in decision-making, and to the culture of society as a whole. In this way, the evidence found does not report homogeneous geographical links, but rather that the connections between countries are transversal between continents, or political and economic unions, which is convenient for future research collaborations between different research centers and collaboration networks.

In this way, the bibliometric study becomes a support tool for sociological research, and contributes to a better understanding of fuzzy AHP that can lead to a different culture: ways of decision-making that better combine formal rigor with variety and flexibility; changing the forms and procedures of decision-making and how this affects the scientific community and, through it, the procedures of management in the business world; and how, through its impact on this broad area of society, it changes society itself as a whole. It is important too to have a whole picture of where and how the appropriate techniques for building AHP models are implemented [10].

This is what gives the present research its greatest significance. The previous paragraphs suggest future lines of research that can make bibliometrics a more widely used tool for understanding trends and patterns of behavior in society that are reflected in different publications, which is a challenge that must be faced in the coming years.

On the other hand, there are limitations of the present work that are due to the state of the art in the current development of bibliometric analysis techniques. As these techniques become more developed, the interpretation of the material studied may become more useful, more usable as a reliable reflection of some of the cultural characteristics and practices of society.

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Nomenclature

AB	Abstract
AHP	Analytical Hierarchy Process
ANN	Artificial Neural Network
ANP	Analytic Networks process
AK	Author keywords
DpY	Documents per Year
FAHP	Fuzzy Analytical Hierarchy Process
F-AHP	Fuzzy Analytical Hierarchy Process
fsQCA	Fuzzy-set Qualitative Comparative Analysis
Fuzzy AHP	Fuzzy Analytical Hierarchy Process
fuzzy-MPDM	Fuzzy Multi Person Decision Making
fuzzy-MPPC	Fuzzy Multi Person Preference Criteria
FTOPSIS	Fuzzy Technique for Order Preference by Similarity of an Ideal Solution
GSC	Green Supply Chain
GFC	Great Financial Crisis
IFAHP	Intuitionistic fuzzy Analytical Hierarchy Process
IT	Information Technology
JCR	Journal Citation Reports®
KP	Keyword Plus®
NIY	Normalized Impact per Year
SSCI	Social Sciences Citation Index
SCIE	Science Citation Index Expanded
TI	Title
TOPSIS	Technique for Order Preference by Similarity of an Ideal Solution
TS	Topic
VUCA	Volatility (V), Uncertatinty (U), Complexity (C) and Ambiguity (A)
WAIPRA	Window of Academic Interest and Persistence in the Research Agenda

Appendix A. Bibliographic Coupling per Documents—Cluster Analysis

Table A1. Articles included in Cluster 1 sorted by NIY.

Article Title	Authors	Year	Journal	Cites	NIY
Risk Assessment Using a New Consulting Process in Fuzzy AHP [69]	Lyu, H.M.; Sun, W.J.; Shen, S.L.; Zhou, A.N.	2020	Journal of Construction Engineering and Management	103	51.5
A Novel Spherical Fuzzy Analytic Hierarchy Process and Its Renewable Energy Application [70]	Gundogdu, F.K.; Kahraman, C.	2020	Soft Computing	101	50.5
Intuitionistic Fuzzy Analytic Hierarchy Process [17]	Xu, Z.S.; Liao, H.C.	2014	IEEE Transactions on Fuzzy Systems	273	34.1
On the Extent Analysis Method for Fuzzy AHP and its Applications [62]	Wang, Y.M.; Luo, Y.; Hua, Z.	2008	European Journal of Operational Research	437	31.2
Fuzzy Analytic Hierarchy Process with Interval Type-2 Fuzzy Sets [71]	Kahraman, C.; Oztaysi, B.; Sari, I.U.; Turanoglu, E.	2014	Knowledge-based Systems	229	28.6
Evaluating Teaching Performance Based on Fuzzy AHP and Comprehensive Evaluation Approach [72]	Chen, J.F.; Hsieh, H.N.; Do, Q.H.	2015	Applied Soft Computing	189	27.0
Multi-attribute Comparison of Catering Service Companies Using Fuzzy AHP: The Case of Turkey [55]	Kahraman, C.; Cebeci, U.; Ruan, D.	2004	International Journal of Production Economics	467	25.9
Comparison of Fuzzy AHP and AHP in a Spatial Multi-criteria Decision Making Model for Urban Land-use Planning [73]	Mosadeghi, R.; Warnken, J.; Tomlinson, R.; Mirfenderesk, H.	2015	Computers Environment and Urban Systems	181	25.9
Evaluation of Hazardous Waste Transportation Firms by Using a Two Step Fuzzy AHP and TOPSIS Methodology [63]	Gumus, A.T.	2009	Expert Systems with Applications	304	23.4
A Comparative Analysis for Multiattribute Selection Among Renewable Energy Alternatives Using Fuzzy Axiomatic Design and Fuzzy Analytic Hierarchy Process [26]	Kahraman, C.; Kaya, I.; Cebi, S.	2009	Energy	282	21.7
A GIS-based Extended Fuzzy Multi-criteria Evaluation for Landslide Susceptibility Mapping [74]	Feizizadeh, B.; Roodposhti, M.S.; Jankowski, P.; Blaschke, T.	2014	Computers & Geosciences	170	21.3
Developing a Fuzzy Analytic Hierarchy Process (AHP) Model for Behavior-based Safety Management [54]	Dagdeviren, M.; Yuksel, I.	2008	Information Sciences	284	20.3
Selection of Optimum Maintenance Strategies Based on a Fuzzy Analytic Hierarchy Process [53]	Wang, L.; Chu, J.; Wu, J.	2007	International Journal of Production Economics	300	20.0
Multi-Criteria Analysis Framework for Potential Flood Prone Areas Mapping [75]	Papaioannou, G.; Vasiliades, L.; Loukas, A.	2015	Water Resources Management	139	19.9
Optimal Preventive Maintenance Policy for Electric Power Distribution Systems Based on the Fuzzy AHP Methods [76]	Firouz, M.H.; Ghadimi, N.	2016	Complexity	119	19.8
Comparison of Fuzzy AHP and Fuzzy TOPSIS Methods for Facility Location Selection [77]	Ertugrul, I.; Karakasoglu, N.	2008	International Journal of Advanced Manufacturing Technology	256	18.3

Table A1. *Cont.*

Article Title	Authors	Year	Journal	Cites	NIY
Hospital Site Selection Using Fuzzy AHP and Its Derivatives [78]	Vahidnia, M.H.; Alesheikh, A.A.; Alimohammadi, A.	2009	Journal of Environmental Management	234	18.0
Prioritization of Human Capital Measurement Indicators Using Fuzzy AHP [56]	Bozbura, F.T.; Beskese, A.; Kahraman, C.	2007	Expert Systems with Applications	268	17.9
A Fuzzy AHP Application in Government-sponsored R&D Project Selection [79]	Huang, C.C.; Chu, P.Y.; Chiang, Y.H.	2008	Omega-International Journal of Management Science	247	17.6
Fuzzy Multi-attribute Selection Among Transportation Companies using Axiomatic Design and Analytic Hierarchy Process [68]	Kulak, O.; Kahraman, C.	2005	Information Sciences	296	17.4
Determining the Importance Weights for the Customer Requirements in QFD Using a Fuzzy AHP with an Extent Analysis Approach [58]	Kwong, C.K.; Bai, H.	2003	IIE Transactions	305	16.1
A Fuzzy AHP Approach to Personnel Selection Problem	Gungor, Z.; Serhadlioglu, G.; Kesen, S.E.	2009	Applied Soft Computing	202	15.5
Fuzzy AHP-based Decision Support System for Selecting ERP Systems in Textile Industry by Using Balanced Scorecard [80]	Cebeci, U.	2009	Expert Systems with Applications	197	15.2
On the Invalidity of Fuzzifying Numerical Judgments in the Analytic Hierarchy Process [82]	Saaty, T.L.; Tran, L.T.	2007	Mathematical and Computer Modelling	227	15.1
Development of a Fuzzy ANP Based SWOT Analysis for the Airline Industry in Turkey [83]	Sevkli, M.; Oztekin, A.; Uysal, O.; Torlak, G.; Turkyilmaz, A.; Delen, D.	2012	Expert Systems with Applications	149	14.9
On Consistency and Ranking of Alternatives in Fuzzy AHP [60]	Leung, L.C.; Cao, D.	2000	European Journal of Operational Research	316	14.4
Strategic Decision Selection Using Hesitant Fuzzy TOPSIS and Interval Type-2 Fuzzy AHP: A case study [84]	Onar, S.C.; Oztaysi, B.; Kahraman, C.	2014	International Journal of Computational Intelligence Systems	112	14.0
A Discussion on Extent Analysis Method and Applications of Fuzzy AHP [59]	Zhu, K.J.; Jing, Y.; Chang, D.Y.	1999	European Journal of Operational Research	312	13.6
Selecting a Cruise Port of Call Location Using the Fuzzy AHP Method: A Case Study in East Asia [85]	Wang, Y.; Jung, K.A.; Yeo, G.T.; Chou, C.C.	2014	Tourism Management	104	13.0
Fuzzy AHP Approach for Selecting the Suitable Bridge Construction Method [86]	Pan, N.F.	2008	Automation in Construction	182	13.0
A Fuzzy AHP Approach to Evaluating Machine Tool Alternatives [87]	Ayag, Z.; Ozdemir, R.G.	2006	Journal of Intelligent Manufacturing	206	12.9
Fuzzy Analytic Hierarchy Process: A Logarithmic Fuzzy Preference Programming Methodology [88]	Wang, Y.M.; Chin, K.S.	2011	International Journal of Approximate Reasoning	140	12.7
A Fuzzy AHP Approach to the Determination of Importance Weights of Customer Requirements in Quality Function Deployment [57]	Kwong, C.K.; Bai, H.	2002	Journal of Intelligent Manufacturing	241	12.1

Table A1. *Cont.*

Article Title	Authors	Year	Journal	Cites	NIY
Computer-aided Machine-tool Selection Based on a Fuzzy AHP Approach [89]	Duran, O.; Aguilo, J.	2008	Expert Systems with Applications	160	11.4
Fuzzy AHP-based Multicriteria Decision Making Systems Using Particle Swarm Optimization [90]	Javanbarg, M.B.; Scawthorn, C.; Kiyono, J.; Shahbodaghkhan, B.	2012	Expert Systems with Applications	109	10.9
Fuzzy AHP-based Study of Cleaner Production Implementation in Taiwan PWB Manufacturer [91]	Tseng, M.L.; Lin, Y.H.; Chiu, A.S.F.	2009	Journal of Cleaner Production	140	10.8
Critical Component Identification in Reliability Centered Asset Management of Power Distribution Systems Via Fuzzy AHP	Dehghanian, P.; Fotuhi-Firuzabad, M.; Bagheri-Shouraki, S.; Kazemi, A.A.R.	2012	IEEE Systems Journal	100	10.0
A GP-AHP Method for Solving Group Decision-making Fuzzy AHP Problems [92]	Yu, C.S.	2002	Computers & Operations Research	193	9.7
A Web-based Decision Support System for Multi-criteria Inventory Classification Using Fuzzy AHP Methodology [94]	Cakir, O.; Canbolat, M.S.	2008	Expert Systems with Applications	128	9.1
Application of Fuzzy Extended AHP Methodology on Shipping Registry Selection: The case of Turkish maritime industry [95]	Celik, M.; Er, I.D.; Ozok, A.F.	2009	Expert Systems with Applications	116	8.9
Assessing Contractor Selection Criteria Weights with Fuzzy AHP Method Application in Group Decision Environment [96]	Jaskowski, P.; Biruk, S.; Bucon, R.	2010	Automation in Construction	106	8.8
A Fuzzy Analytic Network Process (ANP) Model to Identify Faulty Behavior Risk (FBR) in Work System [97]	Dagdeviren, M.; Yuksel, I.; Kurt, M.	2008	Safety Science	113	8.1
A Fuzzy AHP-based Simulation Approach to Concept Evaluation in a NPD Environment [98]	Ayag, Z.	2005	IIE Transactions	137	8.1
Risk-based Environmental Decision-making Using Fuzzy Analytic Hierarchy Process (F-AHP) [11]	Tesfamariam, S.; Sadiq, R.	2006	Stochastic Environmental Research and Risk Assessment	123	7.7
Operating System Selection Using Fuzzy Replacement Analysis and Analytic Hierarchy Process [99]	Tolga, E.; Demircan, M.L.; Kahraman, C.	2005	International Journal of Production Economics	124	7.3
Quality Function Deployment Implementation Based on Analytic Network Process with Linguistic Data: An application in automotive industry [100]	Ertay, T.; Buyukozkan, G.; Kahraman, C.; Ruan, D.	2005	Journal of Intelligent & Fuzzy Systems	101	5.9

Source: Authors' elaboration.

Table A2. Articles included in Cluster 2 sorted by NIY.

Article Title	Authors	Year	Journal	Cites	NIY
An Integrated Framework for Sustainable Supplier Selection and Evaluation in Supply Chains [51]	Luthra, S.; Govindan, K.; Kannan, D.; Mangla, S.K.; Garg, C.P.	2017	Journal of Cleaner Production	375	75.0
Strategic Renewable Energy Resources Selection for Pakistan: Based on SWOT-Fuzzy AHP Approach [123]	Wang, Y.; Xu, L.; Solangi, Y.A.	2020	Sustainable Cities and Society	114	57.0
A Novel Approach to Risk Assessment for Occupational Health and Safety using Pythagorean Fuzzy AHP & Fuzzy Inference System [124]	Ilbahar, E.; Karasan, A.; Cebi, S.; Kahraman, C.	2018	Safety Science	219	54.8
Risk Evaluation Using a Novel Hybrid Method Based on FMEA, Extended MULTIMOORA, and AHP Methods Under Fuzzy Environment [125]	Fattahi, R.; Khalilzadeh, M.	2018	Safety Science	171	42.8
Construction Projects Selection and Risk Assessment by Fuzzy AHP and Fuzzy TOPSIS Methodologies [65]	Taylan, O.; Bafail, A.O.; Abdulaal, R.M.S.; Kabli, M.R.	2014	Applied Soft Computing	303	37.9
Fuzzy Failure Modes and Effects Analysis by Using Fuzzy TOPSIS-based Fuzzy AHP [61]	Kutlu, A.C.; Ekmekcioglu, M.	2012	Expert Systems with Applications	343	34.3
Fuzzy AHP-TOPSIS Approaches to Prioritizing Solutions for Reverse Logistics Barriers [126]	Sirisawat, P.; Kiatcharoenpol, T.	2018	Computers & Industrial Engineering	133	33.3
Risk Analysis in Green Supply Chain Using Fuzzy AHP Approach: A case study [25]	Mangla, S.K.; Kumar, P.; Barua, M.K.	2015	Resources Conservation and Recycling	228	32.6
A State-of-the-art Survey & Testbed of Fuzzy AHP (FAHP) Applications [127]	Kubler, S.; Robert, J.; Derigent, W.; Voisin, A.; Le Traon, Y.	2016	Expert Systems with Applications	189	31.5
Operation Patterns Analysis of Automotive Components Remanufacturing Industry Development in China [101]	Tian, G.D.; Zhang, H.H.; Feng, Y.X.; Jia, H.F.; Zhang, C.Y.; Jiang, Z.G.; Li, Z.W.; Li, P.G.	2017	Journal of Cleaner Production	143	28.6
A Novel Approach for Failure Mode and Effects Analysis Using Combination Weighting and Fuzzy VIKOR Method [102]	Liu, H.C.; You, J.X.; You, X.Y.; Shan, M.M.	2015	Applied Soft Computing	186	26.6
A Combined Multi-criteria Approach to Support FMECA Analyses: A real-world case [103]	Carpitella, S.; Certa, A.; Izquierdo, J.; La Fata, C.M.	2018	Reliability Engineering & System Safety	105	26.3
Integration of AHP-TOPSIS Method for Prioritizing the Solutions of Reverse Logistics Adoption to Overcome its Barriers Under Fuzzy Environment [104]	Prakash, C.; Barua, M.K.	2015	Journal of Manufacturing Systems	183	26.1
A Fuzzy AHP-TOPSIS Framework for Ranking the Solutions of Knowledge Management Adoption in Supply Chain to Overcome its Barriers [105]	Patil, S.K.; Kant, R.	2014	Expert Systems with Applications	204	25.5
An Extended VIKOR Method ased on Entropy Measure for the Failure Modes Risk Assessment—A case study of the geothermal power plant (GPP) [106]	Mohsen, O.; Fereshteh, N.	2017	Safety Science	120	24.0
A Combined Fuzzy AHP and Fuzzy TOPSIS Based Strategic Analysis of Electronic Service Quality in Healthcare Industry [158]	Buyukozkan, G.; Cifci, G.	2012	Expert Systems with Applications	235	23.5

Table A2. *Cont.*

Article Title	Authors	Year	Journal	Cites	NIY
A New Approximation for Risk Assessment Using the AHP and Fine Kinney Methodologies [108]	Kokangul, A.; Polat, U.; Dagsuyu, C.	2017	Safety Science	117	23.4
Analyzing the Drivers of Green Manufacturing with Fuzzy Approach [109]	Govindan, K.; Diabat, A.; Shankar, K.M.	2015	Journal of Cleaner Production	154	22.0
Assessment of Regions Priority for Implementation of Solar Projects in Iran: New application of a hybrid multi-criteria decision making approach [110]	Vafaeipour, M.; Hashemkhani Zolfani, S.; Varzandeh, M.H.M.; Derakhti, A.; Eshkalag, M.K.	2014	Energy Conversion and Management	173	21.6
Fuzzy AHP to Determine the Relative Weights of Evaluation Criteria and Fuzzy TOPSIS to Rank the Alternatives [111]	Torfi, F.; Farahani, R.Z.; Rezapour, S.	2010	Applied Soft Computing	239	19.9
A Framework for Water Loss Management in Developing Countries Under Fuzzy Environment: Integration of Fuzzy AHP with Fuzzy TOPSIS [112]	Zyoud, S.H.; Kaufmann, L.G.; Shaheen, H.; Samhan, S.; Fuchs-Hanusch, D.	2016	Expert Systems with Applications	119	19.8
Measuring Operational Performance of OSH Management System—A demonstration of AHP-based selection of leading key performance indicators [113]	Podgorski, D.	2015	Safety Science	125	17.9
Interrelationships of Risks Faced by Third Party Logistics Service Providers: A DEMATEL based approach [114]	Govindan, K.; Chaudhuri, A.	2016	Transportation Research Part E-logistics and Transportation Review	107	17.8
Quantifying Risks in a Supply Chain Through Integration of Fuzzy AHP and Fuzzy TOPSIS [115]	Samvedi, A.; Jain, V.; Chan, F.T.S.	2013	International Journal of Production Research	155	17.2
Landfill Site Selection Using Fuzzy AHP and Fuzzy TOPSIS: A case study for Istanbul [22]	Beskese, A.; Demir, H.H.; Ozcan, H.K.; Okten, H.E.	2015	Environmental Earth Sciences	115	16.4
Decision Making on Business Issues with Foresight Perspective; An application of new hybrid MCDM model in shopping mall locating [116]	Hashemkhani Zolfani, S.; Aghdaie, M.H.; Derakhti, A.; Zavadskas, E.K.; Varzandeh, M.H.M.	2013	Expert Systems with Applications	147	16.3
A Two-stage Fuzzy AHP Model for Risk Assessment of Implementing Green Initiatives in the Fashion Supply Chain [117]	Wang, X.J.; Chan, H.K.; Yee, R.W.Y.; Diaz-Rainey, I.	2012	International Journal of Production Economics	160	16.0
Selection of the Strategic Alliance Partner in Logistics Value Chain [107]	Buyukozkan, G.; Feyzioglu, O.; Nebol, E.	2008	International Journal of Production Economics	224	16.0
Risk Management in the Construction Industry Using Combined Fuzzy FMEA and Fuzzy AHP [118]	Abdelgawad, M.; Fayek, A.R.	2010	Journal of Construction Engineering and Management	161	13.4
Strategic Logistics Outsourcing: An integrated QFD and fuzzy AHP approach [119]	Ho, W.; He, T.; Lee, C.K.M.; Emrouznejad, A.	2012	Expert Systems with Applications	108	10.8
A Decision Support System for Selecting Convenience Store Location Through Integration of Fuzzy AHP and Artificial Neural Network [120]	Kuo, R.J.; Chi, S.C.; Kao, S.S.	2002	Computers in Industry	200	10.0

Table A2. *Cont.*

Article Title	Authors	Year	Journal	Cites	NIY
A Combined Fuzzy MCDM Approach for Selecting Shopping Center Site: An example from Istanbul, Turkey [121]	Onut, S.; Efendigil, T.; Kara, S.S.	2010	Expert Systems with Applications	114	9.5
An Assessment of Exploiting Renewable Energy Sources with Concerns of Policy and Technology [122]	Shen, Y.C.; Lin, G.T.R.; Li, K.P.; Yuan, B.J.C.	2010	Energy Policy	102	8.5

Source: Authors' elaboration.

Table A3. Articles included in Cluster 3 sorted by NIY.

Article Title	Authors	Year	Journal	Cites	NIY
Multi-tier Sustainable Global Supplier Selection Using a Fuzzy AHP-VIKOR Based Approach [140]	Awasthi, A.; Govindan, K.; Gold, S.	2018	International Journal of Production Economics	233	58.3
A Comparison Between Fuzzy AHP and Fuzzy TOPSIS Methods to Supplier Selection [64]	Lima, F.R.; Osiro, L.; Carpinetti, L.C.R.	2014	Applied Soft Computing	432	54.0
Integrated Analytic Hierarchy Process and its Applications—A literature review [15]	Ho, W.	2008	European Journal of Operational Research	552	39.4
Supplier Selection Using Fuzzy AHP and Fuzzy Multi-objective Linear Programming for Developing Low Carbon Supply Chain [49]	Shaw, K.; Shankar, R.; Yadav, S.S.; Thakur, L.S.	2012	Expert Systems with Applications	369	36.9
Integrating Sustainability into Strategic Decision-making: A fuzzy AHP method for the selection of relevant sustainability issues [141]	Calabrese, A.; Costa, R.; Levialdi, N.; Menichini, T.	2019	Technological Forecasting and Social Change	105	35.0
An Integrated Decision Support System based on ANN and Fuzzy_AHP for Heart Failure Risk Prediction [31]	Samuel, O.W.; Asogbon, G.M.; Sangaiah, A.K.; Fang, P.; Li, G.L.	2017	Expert Systems with Applications	158	31.6
Global Supplier Selection: A fuzzy AHP approach [50]	Chan, F.T.S.; Kumar, N.; Tiwari, M.K.; Lau, H.C.W.; Choy, K.L.	2008	International Journal of Production Research	389	27.8
Supplier Selection Using Fuzzy AHP and TOPSIS: A case study in the Indian automotive industry [142]	Jain, V.; Sangaiah, A.K.; Sakhuja, S.; Thoduka, N.; Aggarwal, R.	2018	Neural Computing & Applications	107	26.8
An STEEP-fuzzy AHP-TOPSIS Framework for Evaluation and Selection of Thermal Power Plant Location: A case study from India [128]	Choudhary, D.; Shankar, R.	2012	Energy	251	25.1
Comprehensive Flood Risk Assessment Based on Set Pair Analysis-variable Fuzzy Sets Model and Fuzz AHP [129]	Zou, Q.; Zhou, J.Z.; Zhou, C.; Song, L.X.; Guo, J.	2013	Stochastic Environmental Research and Risk Assessment	209	23.2
The Analytic Hierarchy Process and Analytic Network Process: An overview of applications [20]	Sipahi, S.; Timor, M.	2010	Management Decision	269	22.4

Table A3. *Cont.*

Article Title	Authors	Year	Journal	Cites	NIY
Application of a Trapezoidal Fuzzy AHP Method for Work Safety Evaluation and Early Warning Rating of Hot and Humid Environments [130]	Zheng, G.Z.; Zhu, N.; Tian, Z.; Chen, Y.; Sun, B.H.	2012	Safety Science	222	22.2
Fuzzy AHP Approach for Supplier Selection in a Washing Machine Company [28]	Kilincci, O.; Onal, S.A.	2011	Expert Systems with Applications	235	21.4
Multi-criteria Evaluation Model for the Selection of Sustainable Materials for Building Projects [131]	Akadiri, P.O.; Olomolaiye, P.O.; Chinyio, E.A.	2013	Automation in Construction	180	20.0
A Combined Methodology for Supplier Selection and Performance Evaluation [132]	Zeydan, M.; Colpan, C.; Cobanoglu, C.	2011	Expert Systems with Applications	174	15.8
Multi-criteria Supplier Segmentation Using a Fuzzy Preference Relations Based AHP [134]	Rezaei, J.; Ortt, R.	2013	European Journal of Operational Research	123	13.7
Supplier Selection in the Airline Retail Industry Using a Funnel Methodology: Conjunctive screening method and fuzzy AHP	Rezaei, J.; Fahim, P.B.M.; Tavasszy, L.	2014	Expert Systems with Applications	109	13.6
Simulation Based Fuzzy TOPSIS Approach for Group Multi-criteria Supplier Selection Problem [133]	Zouggari, A.; Benyoucef, L.	2012	Engineering Applications of Artificial Intelligence	134	13.4
Supplier Selection in Electronic Marketplaces Using Satisficing and Fuzzy AHP [136]	Chamodrakas, I.; Batis, D.; Martakos, D.	2010	Expert Systems with Applications	151	12.6
An Integrated Fuzzy Multi-criteria Group Decision-making Approach for Green Supplier Evaluation [137]	Buyukozkan, G.	2012	International Journal of Production Research	112	11.2
An Application of Fuzzy AHP for Evaluating Course Website Quality [138]	Lin, H.F.	2010	Computers & Education	131	10.9
Fuzzy Analytical Hierarchy Process for Evaluating and Selecting a Vendor in a Supply Chain Model [139]	Haq, A.N.; Kannan, G.	2006	International Journal of Advanced Manufacturing Technology	151	9.4

Source: Authors' elaboration.

Table A4. Articles included in Cluster 4 sorted by NIY.

Article Title	Authors	Year	Journal	Cites	NIY
Barriers to Effective Circular Supply Chain Management in a Developing Country Context [144]	Mangla, S.K.; Luthra, S.; Mishra, N.; Singh, A.; Rana, N.P.; Dora, M.; Dwivedi, Y.	2018	Production Planning & Control	159	39.8
A Fuzzy AHP and BSC Approach for Evaluating Performance of IT Department in the Manufacturing Industry in Taiwan [52]	Lee, A.H.I.; Chen, W.C.; Chang, C.J.	2008	Expert Systems with Applications	328	23.4
An Integrated Intuitionistic Fuzzy AHP and SWOT Method for Outsourcing Reverse Logistics [145]	Tavana, M.; Zareinejad, M.; Di Caprio, D.; Kaviani, M.A.	2016	Applied Soft Computing	118	19.7
A Hybrid Model Based on Fuzzy AHP and Fuzzy WASPAS for Construction Site Selection [146]	Turskis, Z.; Zavadskas, E.K.; Antucheviciene, J.; Kosareva, N.	2015	International Journal of Computers Communications & Control	126	18.0
Integration of Fuzzy AHP and Interval Type-2 fuzzy DEMATEL: An application to human resource management	Abdullah, L.; Zulkifli, N.	2015	Expert Systems with Applications	123	17.6
Strategic Analysis of Healthcare Service Quality Using Fuzzy AHP Methodology [147]	Buyukozkan, G.; Cifci, G.; Guleryuz, S.	2011	Expert Systems with Applications	188	17.1
Combining Grey Relation and TOPSIS Concepts for Selecting an Expatriate Host Country [67]	Chen, M.F.; Tzeng, G.H.	2004	Mathematical and Computer Modelling	275	15.3
A Framework for Measuring the Performance of Service Supply Chain Management [149]	Cho, D.W.; Lee, Y.H.; Ahn, S.H.; Hwang, M.K.	2012	Computers & Industrial Engineering	151	15.1
Evaluating Alternative Production Cycles Using the Extended Fuzzy AHP Method [150]	Weck, M.; Klocke, F.; Schell, H.; Ruenauver, E.	1997	European Journal of Operational Research	119	4.8

Source: Authors' elaboration.

Table A5. Articles included in Cluster 5 sorted by NIY.

Article Title	Authors	Year	Journal	Cites	NIY
Applications of the Extent Analysis Method on Fuzzy AHP [48]	Chang, D.Y.	1996	European Journal of Operational Research	2436	93.7
Using Fuzzy AHP to Manage Intellectual Capital Assets: An application to the ICT service industry [143]	Calabrese, A.; Costa, R.; Menichini, T.	2013	Expert Systems with Applications	145	16.1
Applying Fuzzy Linguistic Preference Relations to the Improvement of consistency of Fuzzy AHP [151]	Wang, T.C.; Chen, Y.H.	2008	Information Sciences	219	15.6
Green Supply Chain Management in the Electronic Industry [152]	Hsu, C.W.; Hu, A.H.	2008	International Journal of Environmental Science and Technology	151	10.8
Evaluating Naval Tactical Missile Systems by Fuzzy AHP Based on the Grade Value of Membership Function [24]	Cheng, C.H.	1997	European Journal of Operational Research	254	10.2
Risk Evaluation of Green Components to Hazardous Substance Using FMEA and FAHP [153]	Hu, A.H.; Hsu, C.W.; Kuo, T.C.; Wu, W.C.	2009	Expert Systems with Applications	119	9.2
Evaluating Weapon System Using Fuzzy Analytic Hierarchy Process-Based on Entropy Weight [154]	Mon, D.L.; Cheng, C.H.; Lin, J.C.	1994	Fuzzy Sets and Systems	189	6.8

Source: Authors' elaboration.

Table A6. Articles included in Cluster 6 sorted by NIY.

Article Title	Authors	Year	Journal	Cites	NIY
A Performance Evaluation Model by Integrating Fuzzy AHP and Fuzzy TOPSIS Methods [66]	Sun, C.C.	2010	Expert Systems with Applications	*372*	31.0
The Application of Fuzzy Delphi Method and Fuzzy AHP in Lubricant Regenerative Technology Selection [155]	Hsu, Y.L.; Lee, C.H.; Kreng, V.B.	2010	Expert Systems with Applications	*236*	19.7
An Integrated Fuzzy AHP-ELECTRE Methodology for Environmental Impact Assessment [156]	Kaya, T.; Kahraman, C.	2011	Expert Systems with Applications	*137*	12.5
Evaluating the Criteria for Human Resource for Science and Technology (HRST) Based on an Integrated Fuzzy AHP and Fuzzy DEMATEL Approach [157]	Chou, Y.C.; Sun, C.C.; Yen, H.Y.	2012	Applied Soft Computing	*110*	11.0

Source: Authors' elaboration.

Appendix B. Summary of Fuzzy Sets Applied in Fuzzy AHP and Articles That Hybridize and/or Compare Fuzzy AHP with Other MCDM Methodologies

Table A7. Summary of fuzzy sets fuzzy sets applied in fuzzy AHP.

Fuzzy Set	Approach
Triangular Fuzzy Numbers TFN	[48,50,54,55,58,62,66,69,86,91,93,138,147]
Trapezoidal Fuzzy Number TraFN	[129,130]
Trapezoidal interval tope-2 fuzzy set	[159,160]
Intuitionistic fuzzy set	[22,61,63–67,77,84,104,105,107,111,112,115,121,126–128,135,158]

Table A8. Articles that hybridize and/or compare the fuzzy AHP methodology with other MCDM methodologies.

Method	Approach
Fuzzy TOPSIS	[61,64–66,77,111,158]
Fuzzy Delphi	[149,155]
Fuzzy AHP—VIKOR	[102,140,161,162]
Pythagorean fuzzy AHP & fuzzy inference system	[124]
Fuzzy AHP and artificial neural network	[120]

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