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Bibliometric analysis of scientific production on methods to aid decision making in the last 40 years

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Abstract

Purpose: Multicriteria methods have gained traction in both academia and industry practices for effective decision-making over the years. This bibliometric study aims to explore and provide an overview of research carried out on multicriteria methods, in its various aspects, over the past forty-four years.

Design/Methodology/Approach: The Web of Science (WoS) and Scopus databases were searched for publications from January 1945 to April 29, 2021, on multicriteria methods in titles, abstracts, and keywords. The bibliographic data were analyzed using the R bibliometrix package.

Findings: This bibliometric study asserts that 29,050 authors have produced 20,861 documents on the theme of multicriteria methods in 131 countries in the last forty-four years. Scientific production in this area grows at a rate of 13.88 per year. China is the leading country in publications with 14.14%; India with 10.76%; and Iran with 8.09%. Islamic Azad University leads others with 504 publications, followed by the Vilnius Gediminas Technical University with 456 and the National Institute of Technology with 336. As for journals, Expert Systems With Applications; Sustainability; and Journal of Cleaner Production are the leading journals, which account for more than 4.67% of all indexed literature. Furthermore, Zavadskas E. and Wang J have the highest publications in the multicriteria methods domain regarding the authors. Regarding the most commonly used multicriteria decision-making methods, AHP is the most favored approach among the ten countries with the most publications in this research area, followed by TOPSIS, VIKOR, PROMETHEE, and ANP.

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Practical implications: The bibliometric literature review method allows the researchers to explore the multicriteria research area more extensively than the traditional literature review method. It enables a large dataset of bibliographic records to be systematically analyzed through statistical measures, yielding informative insights.

Originality/value: The usefulness of this bibliometric study is summed in presenting an overview of the topic of the multicriteria methods during the previous forty-four years, allowing other academics to use this research as a starting point for their research.

Paper type: Literature Review

Keywords: Multicriteria; MCDA; MCDM; bibliometric analysis, AHP, TOPSIS, VIKOR, PROMETHEE, ANP

1. Introduction

With the constant growth of the dissemination of scientific knowledge in its most varied fields of knowledge, the literature review becomes a challenging task for the researcher, as reported by (Basilio et al., 2021). The challenge finds adherence in the volume of research published monthly by the thousands of academic publication vehicles. Based on the theory of limited rationality by (Simon, 1955), it can be said that a researcher, like any other human being, has his rationality limited by three dimensions: the information available; the cognitive limitation of the individual mind; and the time available for decision making.

Decision-making is essential for human activities. All such decisions are made based on the assessment of individual decision options, usually based on preferences, experience, and other data available to the decision maker (Sałabun et al., 2020; Basilio and Pereira, 2020). Some decisions are simple, while others are complex (Behzadian et al., 2012). According to (Kahraman et al., 2015; Govindan and Jepsen, 2016), decisions may be relatively simple, especially if the consequences of a wrong decision are not significant, while others may be highly complex and have substantial outcomes. Real-life problem solving generally involves several conflicting points of view, which must be considered together to reach a reasonable decision (Wang et al., 2008). Formally, a decision can be defined as a choice made based on the available information, or a method of action aimed at solving a specific decision problem (Greco et al., 2016). In practice, multiple-criteria decision analysis (MCDA) evaluates a collection of possible courses of action or options by selecting a preferred option or sorting the options from best to worst (Basilio et al., 2019; Basilio and Pereira, 2020a; Basilio et al., 2020, Moreira et al., 2022). In daily practice, the application of MCDA is crucial in signalling the best rational alternative for the decision maker, so that he can allocate finite resources between competing and alternative interests. Because in simple or complex decisions, whether in the organizational or domestic environment, the decision maker is always faced with several paths and few resources. Researchers refer to multiple criteria methods in different ways. Such methods are frequently referred to as multicriteria decision-making or multiple criteria decision-making (MCDM). Some authors prefer the term multiple-criteria decision aid or aiding (MCDA), while others prefer to use the term multiple-criteria decision analysis (Roy, 1990).

(Zyoud and Fuchs-Hanusch, 2017; Sałabun et al., 2020) highlight the most used MCDA methods, which are basically grouped into two "schools": the American and the European. The methods of the American school of decision support are based on a functional approach, namely, the use of value or usability. These methods usually do not take into account the uncertainty, inaccuracy, and uncertainty that can occur in data or decision-maker preferences. This group of methods is strongly connected with the operational approach using a single synthesized criterion. The basic methods of the American school are MAUT, AHP, ANP, SMART, UTA, MACBETH, and TOPSIS. The methods of the European School use a relational model. Thus, they use a synthesis of criteria based on the relation of outranking. This relation is characterized by transgression between pairs of decision options. Among the methods of the European School of Decision Support, the groups of ELECTRE and PROMETHEE methods should be mentioned above all. Other examples of methods from the European MCDA field are NAIADE, ORESTE, REGIME, ARGUS, TACTIC, MELCHIOR, and PAMSSEM. Many multi-criteria methods combine the approaches of the American and European decision support school, as an example we can mention the following methods: EVAMIX, QUALIFLEX, PCCA, MAPPAC, PRAGMA, PACMAN, IDRA, COMET, and

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DRSA. Furthermore, as stated by (Behzadian et al., 2010; Govindan and Jepsen, 2016; Basilio et al., 2017; Zyoud and Fuchs-Hanusch, 2017), MCDA methods are used to solve decision-making problems in several areas, including the information and communication technology; business intelligence; environmental risk analysis; environmental impact assessment and environmental sciences; water resource management; solid waste management; remote sensing; flood risk management; health technology assessment; healthcare; transport; nanotechnology research; climate change; energy; international law and policy; human resources; financial management; performance and benchmarking; supplier selection; e-commerce and m-commerce; agriculture and horticulture; chemical and biochemical engineering; software evaluation; network selection; education and social policy; heating, ventilation, and air conditioning and small-scale energy management systems; and public security.

As Sałabun et al. (2020) asserts, despite the large number of MCDA methods, it should be remembered that no method is perfect and cannot be considered suitable for use in every decision-making situation or for solving every decision problem (Guitouni and Martel, 1998). Therefore, using different multi-criteria methods may lead to different decision recommendations (Zanakis et al., 1998). It should be noted, however, that if different multi-criteria methods achieve contradictory results, then the correctness of the choice of each of them is questioned (Gershon, 1984). In such a situation, the choice of a decision support method appropriate to the given problem (Watróbski et al., 2019; Basilio et al., 2019) becomes an important research issue, as only an adequately chosen method allows one to obtain a correct solution reflecting the preferences of the decision maker (Cinelli, 2020).

Human beings make decisions daily, and decision-making is an intrinsic part of their nature. Some decisions are straightforward and have minimal influence on people's lives; others, on the other hand, directly impact people's lives, cities, and nations. In this regard, and in light of the importance of multi-criteria methods in assisting decision-makers in various fields, the current study seeks to answer the following questions and develop a reference framework on academic productivity about multi-criteria decision-making methods:

Q1: Who are the most influential authors and researchers in terms of their scientific productivity on the subject area of multicriteria decision-making methods?
Q2:What is the annual scientific publication growth in the multicriteria methods of decision-making?
Q3:Which countries have the most significant production of articles on the multicriteria methods of decision support?
Q4:Which journals do the researchers mainly publish their articles on?
Q5:What are the conceptual structures of the multicriteria methods of decision support?

Throughout this research process, 342 systematic literature reviews on the theme of multicriteria methods have been identified as per the ten largest categories classified by the Web of Science, i.e., green sustainable science technology (Fossile *et al.*, 2020); energy fuels (Siksnelyte-Butkiene et al., 2020); environmental sciences (Akhtar *et al.*, 2021); operations research and management science (Syan and Ramsoobag, 2019; Costa et al., 2021); computer science and artificial intelligence (Salih *et al.*, 2019); management (Pelissari *et al.*, 2021); economics (Moreno-Calderón et al., 2020); engineering environmental (Heidari *et al.*, 2021); computer science and interdisciplinary applications (Cunha *et al.*, 2021); engineering civil (Serugga et al., 2020).

This article is structured as follows: Section 2 provides a brief description of the methods and materials. Section 3 presents the preliminary bibliometric results and visualizes the collaborative relationships between countries, and authors, using R and the VOSviewer software. Keyword co-occurrences are analyzed, and strategic diagrams are constructed in the same section to reveal thematic trends on the multi-criteria decision support theme. The main conclusions are summarized in Section 4.

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2. Methods and data

In this study, a topical query on April 29, 2021 was conducted in the Web of Science (WoS) and Scopus database, using the following search query: **((** "MULTI-ATTRIBUTE DECISION MAKING" OR “MADM” OR “MCDA” OR “MODM” OR “MCDM” OR "MULTICRITERIA" OR "MULTI-CRITERIA" OR "MULTIPLECRITERIA" **)** **AND** **(** “AHP” OR “TODIM” OR "TOPSIS" OR "PROMETHEE" OR "ELECTRE" OR "VIKOR" OR "MAUT" OR "FITRADEOFF" OR "DEMATEL" OR "COPRAS" OR "MULTIMOORA" OR "SWARA" OR "ANALYTICAL NETWORK PROCESS" OR “ANP” OR "FUZZY DECISION MAKING" OR "HYBRID MCDM" OR "FUZZY SET THEORY" OR “FST” OR "SIMPLE MULTI-ATTRIBUTE RATING TECHNIQUE" OR “SMART” OR "GOAL PROGRAMMING" OR "THOR" OR “CBR” OR “SAW” OR “BORDA” OR “CONDORCET” OR "DOMINANCE-BASED ROUGH SET APPROACH" OR “DRSA” OR “GAIA” OR “GRA” OR "MEASURING ATTRACTIVENESS BY A CATEGORICAL BASED EVALUATION TECHNIQUE" OR “MACBETH” OR "MULTI-ATTRIBUTE GLOBAL INFERENCE OF QUALITY" OR “MAGIQ” OR "NEW APPROACH TO APPRAISAL" OR “PAPRIKA” OR "WEIGHTED PRODUCT MODEL" OR “WPM” OR “WSM” OR “UTADIS” OR “WASPAS” **))**.

The search query was used for obtaining results only from articles, titles, abstracts, and keywords. The query was limited to publications made between 1945 and 2021. In the WoS database, the search was done only on the Core Collection. The search started with 31,932 records resulting from the query made to the WoS and Scopus databases. After downloading the records, the bibliometrix package version 1.2.1335 of RStudio was installed on the Win64 operating system. The bibliometrix R package was used to perform the bibiometric analysis and obtain the answers for questions Q1 to Q5. Then, we used the bibliometrix tool’s functions to create descriptive and co-citation networks, respectively. The function convert2df embedded in the bibliometrix package was used to extract and create a data frame corresponding to the unit of analysis within the exported files from WoS and Scopus databases. After creating the data frames from the WoS and Scopus files, the mergeDbSources function merged the WoS and Scopus data frames and excluded duplicate records from both files. 11,071 duplicate records were removed, resulting in a data frame with 20,861 records for bibliometric analysis. The process of obtaining the bibliographic records file can be seen in Figure 1.

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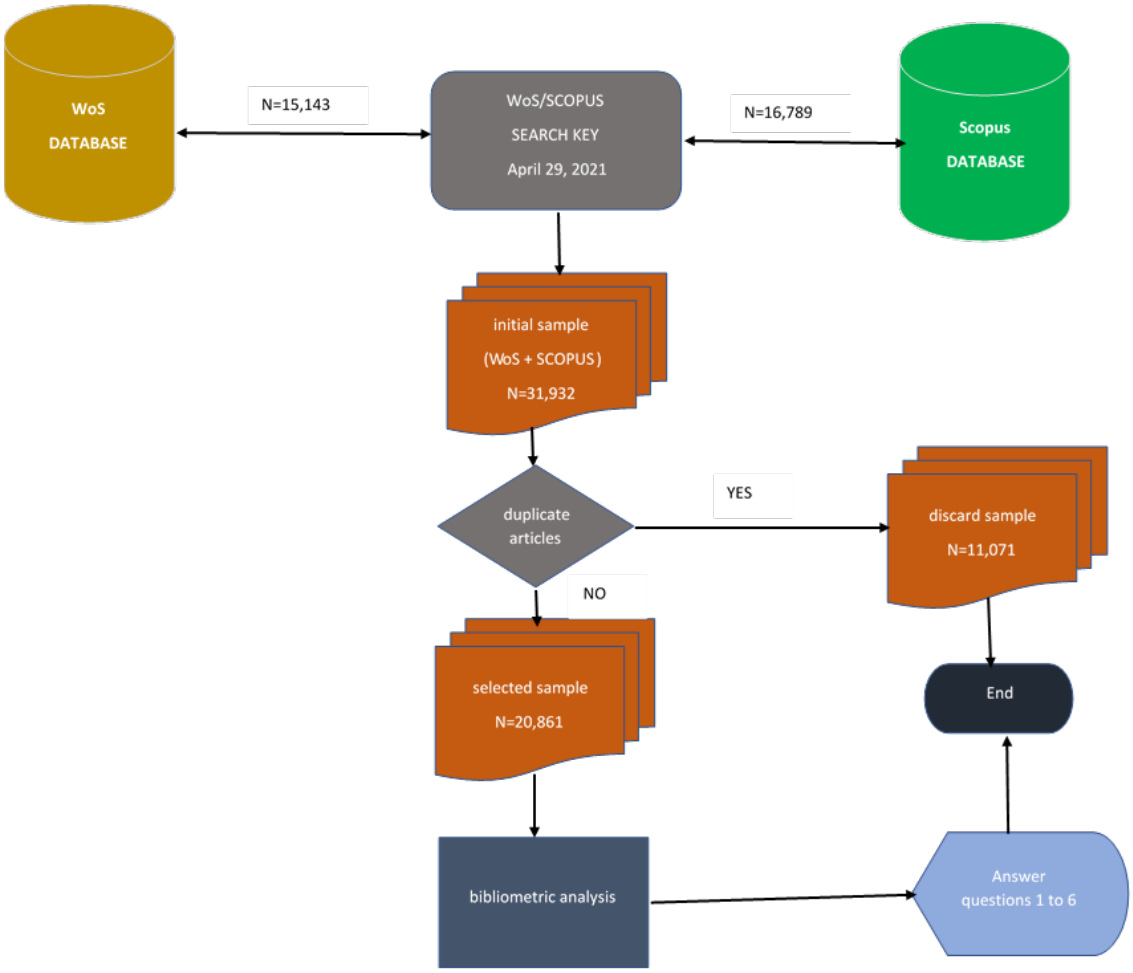

Figure 1: Search strategy and extraction of data.
Source: Prepared by the authors based on (Basilio et al., 2021a; Ghosh and Prasad, 2021)

3. Finding and discussion

The results from the bibliometric analysis show that 29,050 authors produced 20,861 documents in the period from January 1, 1977, to April 29, 2021. The types of documents identified in the sample, despite the limitations described in the methods and data section, were as follows: 71.12% are article (14,837); 1.64% are review (342); 7.04% are conference paper (1,469); 1.47% are article-proceedings paper (307); 1.39% are article-early access (290); 15.19% are proceedings paper (3,169); and others. Regarding academic production, studies on multicriteria methods of decision support had their genesis in 1977. Figure 2 illustrates the trajectory of publications up to April 2021. Observing the graph, it appears that the growth began from 1986 with a small degree of inclination. In this period, the number of average publications was 7.3 documents per year. From 1987 to 1996, the average document increased to 28.3 documents per year. In the following ten years, this average jumped to 123.2 documents per year, and finally, from 2007 to 2021, the average was 1265.73, thus showing a high degree of interest on the part of researchers in the topic. Considering the total period, publications on multicriteria decision support methods reached an annual percentage growth rate of 13.88365. Figures 3 and 4 illustrate the average total citations per year (16.06) and the average years from publication (6.36), respectively. The volume of publications resulted in a total of 472,345 references.

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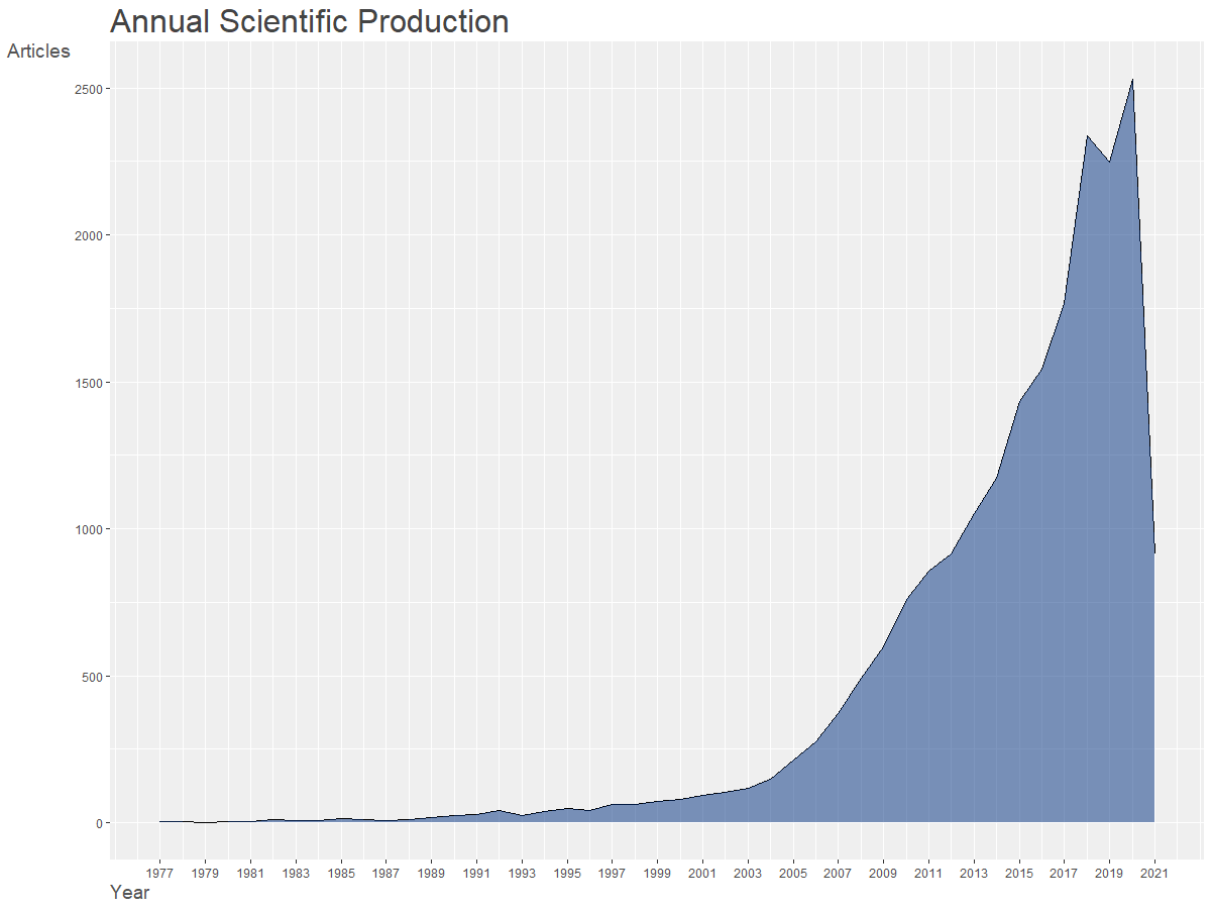

Figure 2 Graphical representation of the annual scientific production

Note: It should be noted that the data for the year 2021 corresponds to partial values quantified up to April 29, 2021.

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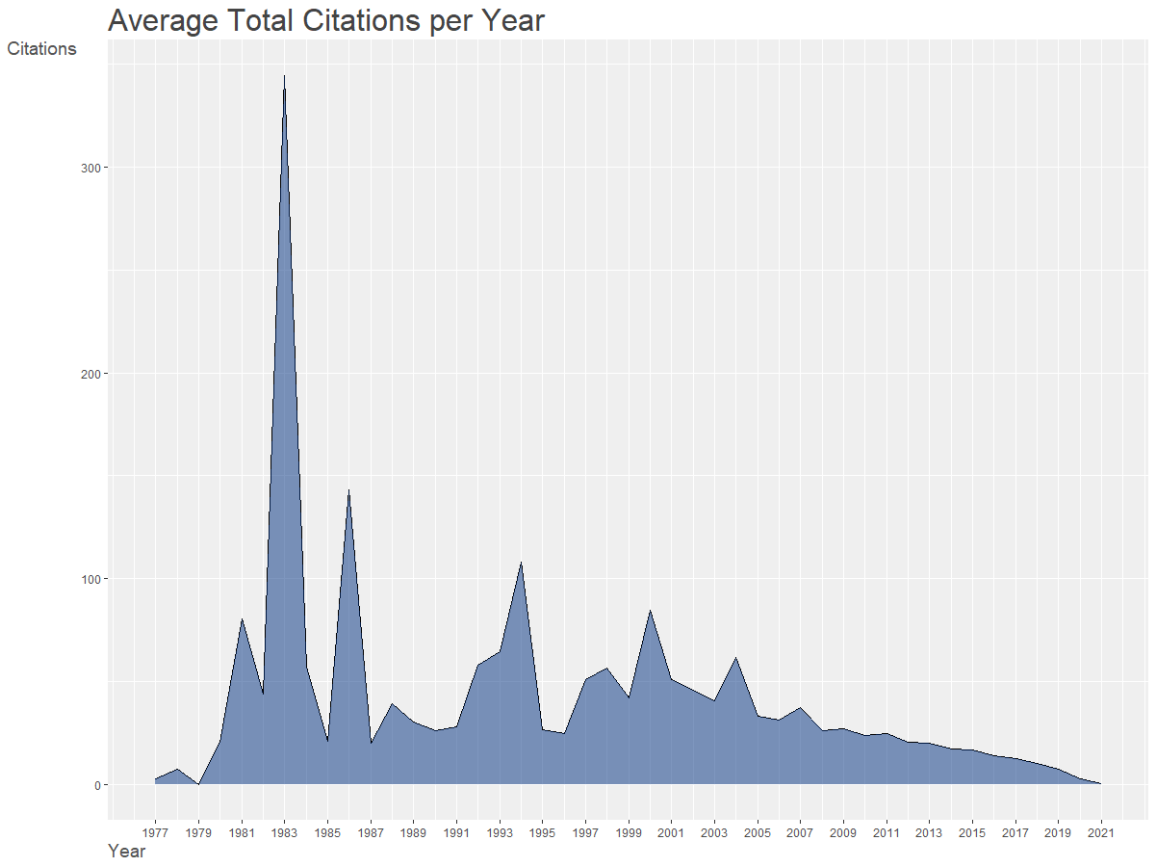

Figure 3 Graphical representation of the average total citations per year

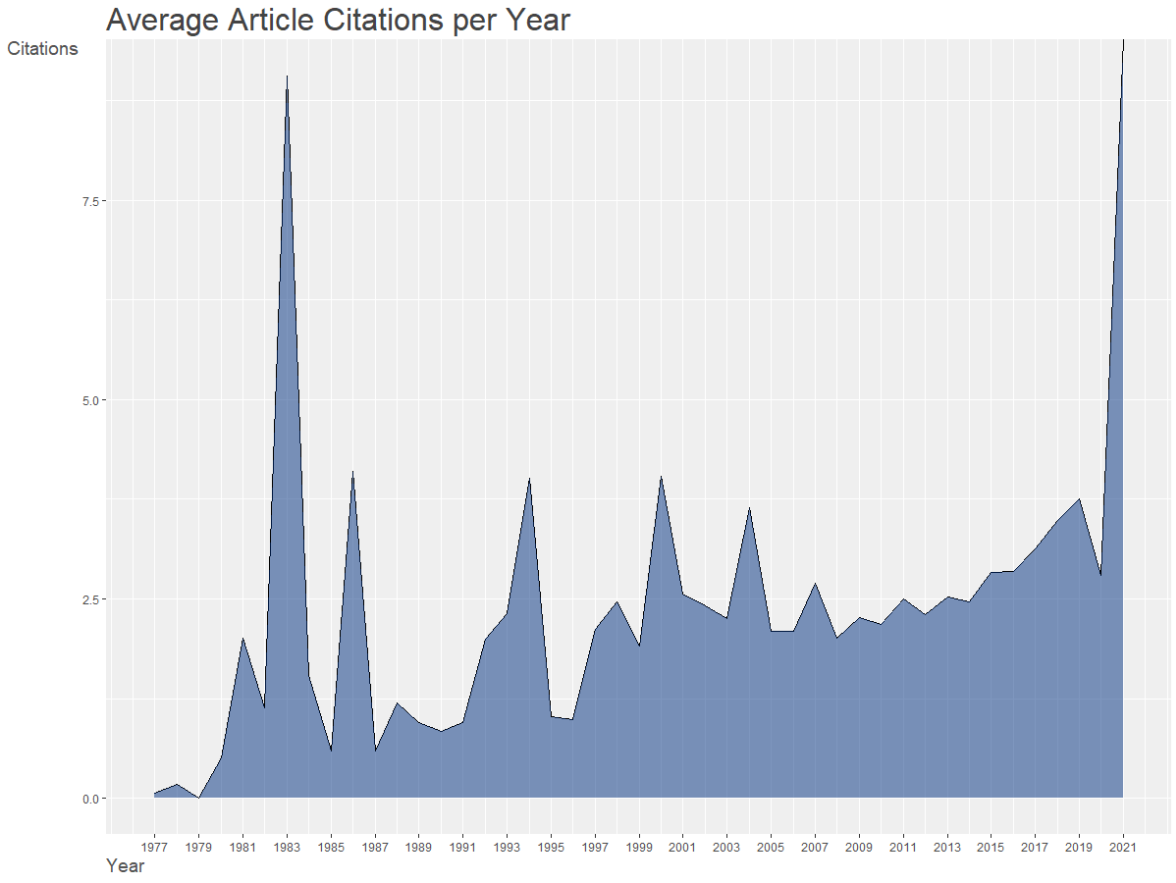

Figure 4 Graphical representation of the average article citations per year

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3.1 Monitoring of scientific production around the world

All of the incorporated literature on multicriteria methods was contributed by at least 120 countries or regions, as Figure 5. China (n= 2,951) is the largest contributor to multicriteria methods research, followed by India (n=2,246), Iran (n=1,688), Turkey (n=1,617), Taiwan (n=1,092), United States (n=761), Brazil (n=732), Spain (n=590), Italy (n=545), and Malaysia (n=489). With regard to citations, Table 1 presents us with a slightly different ordering, however China remains in the first place influencing the scientific production both in production of knowledge and in reference to the scientific community: China (n=49,662), Taiwan (n=32,535), Turkey (n=28,741), Iran (n=23,613), India (n=23,530), United States (n=20,217), Lithuania (n=12,292), United Kingdom (n=10,917), Spain (n=10.071), and Italy (n=8,601). In terms of research institutions, the top 10 include the Islamic Azad University (n=504), Vilnius Gediminas Technical University (n=456), National Institute of Technology (n=336), University of Tehran (n=334), Indian Institute of Technology (n=265), and Istanbul Technical University (n=243), as seen in Table 1. Figure 6 is elaborated to observe the relationships between organizations through the Co-authorship analysis, having the universities as the unit of analysis. The following criteria were used: 1) the minimum number of documents per organization (n>=50); 2) the minimum number of citations per organization (n>=50). With the established criteria, 50 organizations out of the 7619 analyzed were separated. The nodes represent the universities, the diameter of the nodes represents the number of citations, and the thickness of the connecting lines between the nodes represent the level of cooperation between the institutions. In this way, we highlight the following organizations: Islamic Azad University and Vilnius Gediminas Technical University. Figure 7 illustrates international cooperation between countries and highlights the following leading countries: China, India, Iran, Turkey, Taiwan, United States, Brazil, Spain, Italy, and Malaysia.

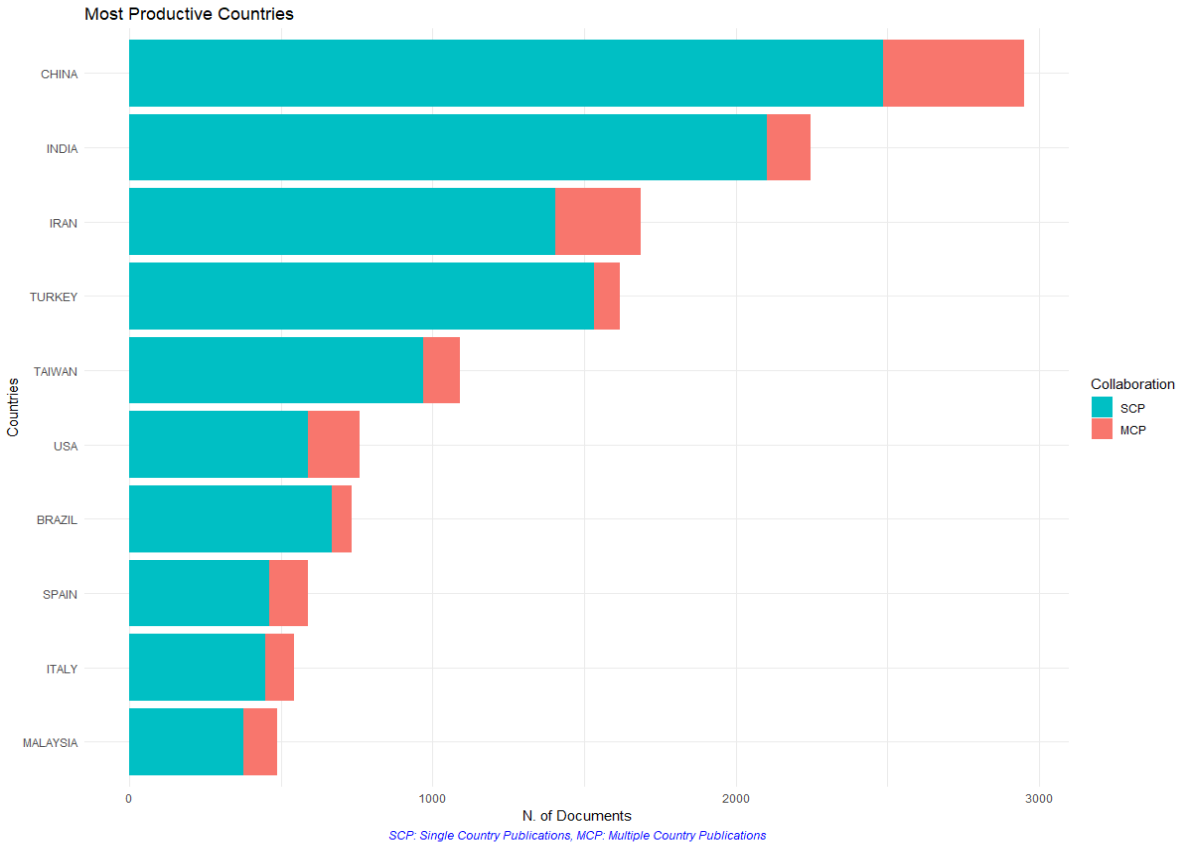

Figure 5 Graphical representation of the top 10 most productive countries

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Table 1 The top 10 countries/regions and institutions contributing to publications in multicriteria methods

Rank	Country/ Region	Article counts	Percentage (N/20,861), %	Total Citations	Percentage (TNC/335.028), %	Average Article Citations	Freq	SCP	MCP	MCP_Ratio	Institutions	Country	Article counts	Percentage (N/20,861), %
1	China	2,951	14.14	49,662	14.82	16.829	0.1472	2,487	464	0.1572	Islamic Azad University	Iran	504	2.41
2	India	2,246	10.76	23,530	7.02	10.476	0.1120	2,102	144	0.0641	Vilnius Gediminas Technical University	Lithuania	456	2.18
3	Iran	1,688	8.09	23,613	7.04	13.989	0.0842	1,404	284	0.1682	National Institute of Technology	India	336	1.61
4	Turkey	1,617	7.75	28,741	8.57	17.774	0.0806	1,533	84	0.0519	University of Tehran	Iran	334	1.60
5	Taiwan	1,092	5.23	32,535	9.71	29.794	0.0545	969	123	0.1126	Indian Institute of Technology System	India	265	1.27
6	USA	761	3.64	20,217	6.03	26.566	0.0380	591	170	0.2234	Istanbul Technical University	Turkey	243	1.16
7	Brazil	732	3.50	5,681	1.69	7.761	0.0365	669	63	0.0861	University of Belgrade	Serbia	180	0.86
8	Spain	590	2.82	10,071	3.00	17.069	0.0294	462	128	0.2169	Yildiz Technical University	Turkey	176	0.84
9	Italy	545	2.61	8,601	2.56	15.782	0.0272	448	97	0.1780	Sichuan University	China	157	0.75
10	Malaysia	489	2.34	6,700	1.99	13.701	0.0244	375	114	0.2331	Central South University	China	150	0.71
	TOTAL	12,711	60.93	209,351	62.48								2,801	11.79

Note: SCP: Single Country Publications; MCP: Multiple Country Publications

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In this section, an overview of the bibliometric findings is presented concisely. In the following ten subsections, the study is expanded and characterized on multi-criteria methods as per the top ten countries that stand out in this sample. Furthermore, a cluster with the five most prominent research areas is prepared based on the WoS taxonomy, universities; financing sources; authors; and the most used methods.

3.1.1 A view of scientific production in China

With 14.14 percent of all global output in the previous 40 years, China ranks first in scientific production for exploring the use of multicriteria decision support methods. The research was done in the following areas: computer science (Zhang and Xu, 2014a; Ren et al., 2016; Wu et al., 2018; Sarwar et al., 2021; Yuan et al., 2021); engineering (Kou *et al.*, 2012; Wang et al., 2016; Akram et al., 2019; Fei et al., 2019; Leung *et al.*, 2021); environmental sciences and ecology (Liao et al., 2015; Liu and Li, 2018; Liu *et al.*, 2019; Rafi *et al.*, 2020; Hong et al., 2021); operations research and management science (Deng *et al.*, 2014; Qin et al., 2017; Yu et al., 2018; Zhou et al., 2019; Liu and Ma, 2021); and science technology other topics (Tian *et al.*, 2017; Nie *et al.*, 2018; Du *et al.*, 2020; He et al., 2020; Liang *et al.*, 2021). Regarding the top universities having the highest productivity about the research on multi-criteria methods, the following five universities with the three most cited publications are Sichuan University (Zhang and Xu, 2014a, 2014b; Liao, Xu and Zeng, 2015; Ren et al., 2016; Liang and Xu, 2017); Central South University (Tan, 2011; Peng *et al.*, 2014; Wang *et al.*, 2016; Wen et al., 2016; Tian *et al.*, 2017); North China Electric Power University (Wang *et al.*, 2008; Guo and Zhao, 2015, 2017; Wu *et al.*, 2016; Wu et al., 2018); Hong Kong Polytechnic University (Ngai and Chan, 2005; Chan *et al.*, 2008; Wong and Li, 2008; Deng and Chan, 2011; Chai et al., 2013); and the Chinese Academy Of Sciences (Dai et al., 2001; Hua et al., 2008; Wen et al., 2016; Sangaiah *et al.*, 2018; Tien Bui *et al.*, 2018). In terms of research sponsors, the top five Chinese funding sources that have considerably contributed to the growth of scientific production on the topic of multi-criteria methods are as follows: The National Natural Science Foundation of China (48.75%); Fundamental Research Funds For The Central Universities (7.77%); China Postdoctoral Science Foundation (3.6%); Ministry of Education China (2.68%); and China Scholarship Council (1.9%). Together, these five institutions account for nearly 65% of all research funding related to multi-criteria methods in China.

Regarding the authors, the top five researchers who stand out in the area of multi-criteria methods in terms of academic production in China are Jian-Qiang Wang, H-index (53), with 91 publications, the most cited work: (Wang *et al.*, 2016); Zeshui Xu, H-index (95), with 75 publications, the most cited work: (Xu and Zhang, 2013); Hu-chang Liao, H-index (44), with 59 publications, the most cited work: (Liao et al., 2015); Pei-De Liu, H-index (51), with 49 publications, the most cited work: (Liu and Wang, 2018); and Jing Wang, H-index (24), with 49 publications, the most cited work: (Wang et al., 2016). Furthermore, the top five most researched multicriteria methods done by the above researchers in their studies are TOPSIS, AHP; VIKOR, DEMATEL; and ANP.

3.1.2 A view of scientific production in India

Following China, India ranks second in scientific productivity on the multicriteria decision support method research topic, contributing 10.76 percent of the total global academic output since the last 40 years. The research areas where the majority of the multicriteria decision-making related studies are done: engineering (Luthra et al., 2017; Kumar, 2021); computer science (Ravi et al., 2005; Majumdar *et al.*, 2021); environmental sciences and ecology (Ramanathan, 2001; Roy et al., 2021); business economics (Pati et al., 2008; Jaiswal *et al.*, 2021); science technology and other topics (Pohekar and Ramachandran, 2004; Saraswat and Digalwar, 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are the National Institute of Technology (Lakshmana et al., 2011; Jeya Girubha and Vinodh, 2012; Kumar *et al.*, 2017); Indian Institute of Technology (Ravi et al., 2005; Choudhary and Shankar, 2012; Luthra *et al.*, 2017); Jadavpur University (Chatterjee et al., 2011; Chatterjee and Chakraborty, 2012; Chakraborty and Zavadskas, 2014); Birla Institute of Technology Science Pilani (Pohekar and Ramachandran,

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2004; Raju and Kumar, 2006; Vashishtha and Ramachandran, 2006); and National Institute of Technology Tiruchirappalli (Lakshmana et al., 2011; Jeya et al., 2012; Vinodh et al., 2014). The top five funding sources that have considerably contributed to the growth of scientific production on the topic of multi-criteria methods are the Department of Science Technology India (2.097%); University Grants Commission India (1.258%); Council of Scientific Industrial Research India (0.779%); National Natural Science Foundation of China (0.479%); and Ministry of Human Resource Development Government of India (0.359%). Together, these five institutions account for nearly 5% of all funding for research related to multi-criteria methods in India.

In terms of the authors, the top five researchers who have vastly contributed in the area of multi-criteria methods in terms of academic production in India are Harish Garg, H-index (53), with 32 publications, the most cited work: (Garg, 2017); Ashwani Kumar, H-index (4), with 32 publications, the most cited work: (Kumar and Dixit, 2018); Sanjay Kumar, H-index (37), with 30 publications, the most cited work: (Joshi and Kumar, 2016); Shankar Chakraborty, H-index (27), with 28 publications, the most cited work: (Chatterjee and Chakraborty, 2012); and Samarjit Kar, H-index (10), with 28 publications, the most cited work: (Chatterjee and Kar, 2018). The top five most researched multicriteria methods done by the above researchers in their studies are AHP, TOPSIS; VIKOR; PROMETHEE; and DEMATEL.

3.1.3 A view of scientific production in Iran

Iran is third in this ranking in scientific production on multicriteria decision support methods and applications, accounting for 8.1 percent of global academic output. The research areas where the majority of the multicriteria decision-making related studies are done: engineering (Behzadian *et al.*, 2012; Hatefi, 2021); computer science (Shemshadi *et al.*, 2011; Kadhim and Mardukhi, 2021); environmental sciences and ecology (Govindan et al., 2013; Boloorani *et al.*, 2021); business economics (Rezaeisaray et al., 2016; Khalilzadeh *et al.*, 2021); and science technology other topics (Kannan *et al.*, 2013; Ghasemi *et al.*, 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are Islamic Azad University (Jahanshahloo et al., 2006; Sanayei et al., 2010; Behzadian *et al.*, 2012); University of Tehran (Hashemi et al., 2015; Rahmati *et al.*, 2015; Banaeian *et al.*, 2018); Amirkabir University Of Technology (Ghodsypour and O"Brien, 1998; Farahani, SteadieSeifi and Asgari, 2010; Torfi, Farahani and Rezapour, 2010); Tarbiat Modares University (Aalami et al., 2010; Behzadian *et al.*, 2010; Sanayei et al., 2010); and Iran University Science Technology (Ashtiani *et al.*, 2009; Sayadi et al., 2009; Hashemi *et al.*, 2018). With regards to the top 5 funding sources that have significantly contributed to the development of research on multi-criteria methods, the following institutes in Iran are identified: University of Tehran (0.925%); National Natural Science Foundation of China (0.727%); Austrian Science Fund (0.661%); Islamic Azad University (0.528%); And Iran National Science Foundation(0.462%). These five institutions together fund nearly 3.03% of all research related to multi-criteria methods in Iran.

Regarding the authors, the top five researchers who stand out in the area of multi-criteria methods in terms of academic production in Iran are Seyed Meysam Mousavi, H-index (32), with 42 publications, with the most cited work being (Vahdani et al., 2011); Maghsoud Amiri, H-index (26), with 28 publications, the most cited work: (Keshavarz Ghorabaee *et al.*, 2016); Reza Tavakkoli-Moghaddam, (46), with 261 publications, the most cited work: (Vahdani et al., 2011); Behnam Vahdani, H-index (32), with 25 publications, the most cited work: (Vahdani *et al.*, 2013); and Abdolreza Yazdani-Chamzini, H-index (19), with 21 publications, the most cited work: (Fouladgar *et al.*, 2012). The top five most researched multicriteria methods done by the above researchers in their studies are AHP, TOPSIS; VIKOR, PROMETHEE; and DEMATEL.

3.1.4 A view of scientific production in Turkey

Turkey is ranked fourth in this study, with 7.75 percent of global scientific production on multicriteria decision support methods and applications. The research areas where the majority of the multicriteria decision-making related studies are done: computer science (Boran *et al.*, 2009; Cicioğlu, 2021); engineering (Büyüközkan and Çifçi, 2012a; Özceylan *et al.*, 2021); business economics (Sipahi and Timor, 2010; Durak et al., 2021); operations

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research and management science (Büyüközkan and Çifçi, 2012b; Ceylan et al., 2021); and environmental sciences and ecology (Önüt and Soner, 2008; Everest et al., 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following 5 universities with the three most cited publications are: Istanbul Technical University (Kahraman, Ruan and Doğan, 2003; Kahraman et al., 2009; Kaya and Kahraman, 2010); Yildiz Technical University (Önüt and Soner, 2008; Önüt et al., 2009; Tuzkaya *et al.*, 2009); Gazi University (Gencer and Gürpinar, 2007; Boran *et al.*, 2009; Dağdeviren et al., 2009); Galatasaray University (Büyüközkan and Çifçi, 2012a, 2012b; Büyüközkan and Güleryüz, 2016); And Karadeniz Technical University (Hamzaçebi and Pekkaya, 2011; Cebi, 2013; Colak et al., 2020). With regards to the top 5 funding sources that have significantly contributed to the development of research on multi-criteria methods, the leading institutes identified in Turkey are as follows: Galatasaray University (3.628%); Turkiye Bilimsel Ve Teknolojik Arastirma Kurumu Tubitak (2.243%); Bagep Award of The Science Academy in Turkey (0.396%); Erciyes University (0.396%); European Commission (0.396%). These five institutions together fund nearly 7.06% of all research related to multi-criteria methods in Turkey.

In terms of the authors, the top five researchers who have vastly contributed in the area of multi-criteria methods in terms of academic production are Cengiz Kahraman, H-index (56), with 123 publications, the most cited work: (Kahraman et al., 2003); Gulcin Buyukozkan, H-index (39), with 60 publications, the most cited work: (Büyüközkan and Çifçi, 2012a); Basa Oztaysi, H-index (20), with 40 publications, the most cited work: (Kahraman, Onar and Oztaysi, 2015); Ihsan Kaya, H-index (28), with 36 publications, the most cited work: (Kahraman et al., 2009); and Metin Dagdeviren, H-index (15), with 36 publications, the most cited work: (Dağdeviren, Yavuz and Kılınç, 2009). The above researchers' top five most researched multicriteria methods in their studies are AHP, TOPSIS; ANP; VIKOR; and PROMETHEE.

3.1.5 A view of scientific production in Taiwan

Following Turkey, Taiwan is the fifth country globally in scientific production on multicriteria decision support methods and applications, accounting for 5.23 percent of global academic output. The research areas where the majority of the recent multicriteria decision-making related studies are done: computer science (Chen, 2000, 2021); engineering, (Chen, Lin and Huang, 2006; Lin, 2021); operations research and management science (Opricovic and Tzeng, 2004; Chiu, Manoharan and Huang, 2020); business economics (Opricovic and Tzeng, 2007; Chen, 2020); and environmental sciences and ecology (Tsaur et al., 2002; Yang *et al.*, 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are National Yang Ming Chiao Tung University (Opricovic and Tzeng, 2004, 2007; Tzeng et al., 2007); Nan Kai University Technology (Wu et al., 2009; Chen et al., 2011; Yang and Tzeng, 2011); National Taipei University (Lu et al., 2013; Liou et al., 2014; Liou *et al.*, 2016); National Taipei University of Technology (Hsu and Hu, 2009; Liou *et al.*, 2016; Lo *et al.*, 2018); And National Kaohsiung University of Science Technology (Chen, 2011; Yang and Chen, 2016; Wang *et al.*, 2018). The top five funding sources that have considerably contributed to the growth of scientific production on the topic of multi-criteria methods are as follows: Ministry of Science and Technology Taiwan (18.635%); Chang Gung Memorial Hospital (1.426%); National Natural Science Foundation of China (1.426%); Taiwan Ministry of Science and Technology (1.120%); and Ministry Of Sciences And Technology In Taiwan (1.018%). These five institutions together fund nearly 23.63% of all research related to multi-criteria methods in Taiwan.

In terms of the authors, the top five researchers who have vastly contributed in the area of multi-criteria methods in terms of academic production in Taiwan are Gwo-Hshiung Tzeng, H-index (66), with 156 publications, the most cited work: (Opricovic and Tzeng, 2004); James J. H. Liou, H-index (30), with 46 publications, the most cited work: (Liou *et al.*, 2016); Chi-Yo Huang, H-index (11), with 27 publications, the most cited work: (Tzeng and Huang, 2012); Ming-Lang Tseng, H-index (42), with 24 publications, the most cited work: (Tseng, 2011); and Ting-Yu Chen, H-index (33), with 23 publications, the most cited work: (Chen, 2012). The top five most researched multicriteria methods in their studies are AHP, DEMATEL; TOPSIS; ANP; and VIKOR.

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3.1.6 A view of scientific production in the United States

The United States occupies sixth place in the ranking, with 3.64% of scientific production on methods and applications related to the multi-criteria method. The research areas where the majority of the recent multicriteria decision-making related studies done in the United States are engineering (Govindan, Khodaverdi and Jafarian, 2013; Delanka-Pedige *et al.*, 2021); computer science (Hong and Choi, 2000; Dymova *et al.*, 2021); operations research and management science (Wallenius *et al.*, 2008; Mousavi and Lin, 2020); business economics (Tam and Tummala, 2001; Kotikot et al., 2020); and environmental sciences and ecology (Gorsevski *et al.*, 2012; Azbari *et al.*, 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are State University System of Florida (Pires et al., 2011; Onat *et al.*, 2016; Rani *et al.*, 2019); Pennsylvania Commonwealth System of Higher Education (Saaty, 2013; Saaty and Ergu, 2015; Saaty and De Paola, 2017); University of California (Afshar *et al.*, 2011; Abdel-Basset et al., 2018; Abdel-Basset, Manogaran, *et al.*, 2019); University of Memphis (Ferreira et al., 2011; Filipe et al., 2015; Oliveira *et al.*, 2017); and La Salle University (Hatami-Marbini and Tavana, 2011; Hashemi et al., 2015; Tavana *et al.*, 2016). With regards to the top 5 funding sources that have significantly contributed to the development of research on multi-criteria methods, the leading institutes identified in the United States are the National Natural Science Foundation of China (9.138%); National Science Foundation (2.464%); China Scholarship Council (1.437%); Fundamental Research Funds for the Central Universities (1.335%); Portuguese Foundation for Science and Technology (1.027). Together, these five institutions fund nearly 15.4% of all research related to multi-criteria methods in the United States.

The top five researchers who have vastly contributed in the area of multi-criteria methods in terms of academic production in the United States are Madjid Tavana, H-index (30), with 36 publications, the most cited work: (Tavana *et al.*, 2016); Florentin Smarandache, H-index (30), with 32 publications, the most cited work: (Abdel-Basset et al., 2019); Surendra M. Gupta, H-index (37), with 14 publications, the most cited work: (Kongar and Gupta, 2006); Joseph Sarkis, H-index (78), with ten publications, the most cited work: (Sarkis, 2000); and Dursun Delen, H-index (34), with eight publications, the most cited work: (Kilic et al., 2015). The top five most researched multicriteria methods in their studies are AHP, TOPSIS; PROMETHEE; ANP; and VIKOR.

3.1.7 A view of scientific production in Brazil

Following the United States, Brazil occupies seventh place in the ranking with 3.50% of scientific production on methods and applications related to the multi-criteria method. The research areas where the majority of the recent multicriteria decision-making related studies done in Brazil are the engineering (Krohling and Campanharo, 2011; Gaviao *et al.*, 2020; Maeda et al., 2021; Drumond et al., 2021); computer science (Lima Junior et al., 2014; de Banos et al., 2021; Costa et al., 2021a); business economics (Bana e Costa *et al.*, 1999; Basilio *et al.*, 2020; Maeda et al., 2021a); operations research and management science (Krohling and de Souza, 2012; Silva *et al.*, 2020; Soares et al., 2021); and environmental sciences and ecology (Bouzon *et al.*, 2016; Nepomuceno et al., 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following 5 universities with the three most cited publications are: Universidade Federal de Pernambuco (de Almeida, 2007; Brito et al., 2010; Morais and de Almeida, 2012); Universidade Federal Fluminense (Barata *et al.*, 2014; Pereira and Costa, 2015; Basilio *et al.*, 2018); Universidade Federal do Rio De Janeiro (Passos *et al.*, 2014; Barros and Wanke, 2015; Wanke et al., 2015); Universidade de São Paulo (Lima Junior et al., 2014; Santos et al., 2017; Serafim *et al.*, 2019); and Universidade Tecnológica Federal do Paraná (Lima-Junior and Carpinetti, 2017; Guarnieri and Trojan, 2019). Concerning the top 5 funding sources that have significantly contributed to the development of research on multi-criteria methods, the leading institutes identified are National Council for Scientific and Technological Development (CNPQ), being responsible for 22.18% of funding for research production; followed by the Coordination for the Improvement of Higher Education Personnel (CAPES), with 15.6%; in third place, we have the Foundation for Research Support of the State of São Paulo (FAPESP), with 2.95%; in fourth place, we have the Foundation for the Support of Science and Technology of the State of Pernambuco (FACEPE), with 1.39%; and in fifth place the Foundation for Research Support of the State of Minas

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Gerais (FAPEMIG), with 1.39%. These five institutions together fund nearly 44% of all research related to multi-criteria methods in Brazil.
Regarding the authors, the top five researchers who stand out in the area of multi-criteria methods in terms of academic production in Brazil are Adiel Texeira de Almeida, H-index (24), with 51 publications, the most cited work: (de Almeida, 2007); Luiz Flavio Autran Monteiro Gomes, H-index (11), with 23 publications, the most cited work: (Gomes and Rangel, 2009); Danielle Costa Morais, H-index (12), with 21 publications, the most cited work: (Morais and de Almeida, 2012); Ana Paula Cabral Seixas Costa, H-index (7), with 18 publications, the most cited work: (de Almeida *et al.*, 2016); and Helder Gomes Costa, H-index (10), with 12 publications, the most cited work: (Pereira and Costa, 2015). The top five most researched multicriteria methods done by the above researchers in their studies are AHP, TOPSIS; PROMETHEE, ELECTRE; and MACBETH.

3.1.8 A view of scientific production in Spain

Spain occupies the eighth place in this study's ranking, with 2.82% of scientific production on methods and applications related to the multi-criteria method. The research areas where majority of the recent multicriteria decision-making related studies done are: computer science (Liu and Rodríguez, 2014; Reig-Mullor and Brotons-Martinez, 2021); engineering (Jato-Espino *et al.*, 2014; Ramirez-Atencia et al., 2020); environmental sciences and ecology (Benítez et al., 2007; Cárdenas-Gómez et al., 2021); operations research and management science (Aguarón and Moreno-Jiménez, 2003; Casas-Rosal et al., 2021); and business economics (Escobar et al., 2004; Luna et al., 2020). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are Polytechnic University of Valencia (Aragonés-Beltrán *et al.*, 2010, 2014; Sierra et al., 2018); Polytechnic University of Madrid (Tamiz et al., 1998; Romero, 2001, 2004); University of Granada (Wei et al., 2015; Sánchez-Lozano et al., 2016; Wu *et al.*, 2018); University of Oviedo (Bilbao-Terol et al., 2012; Bilbao-Terol *et al.*, 2014; Rodríguez et al., 2016); and Polytechnic University of Catalonia (Garfì *et al.*, 2011; Pons and Aguado, 2012; Amin Hosseini et al., 2016). With regards to the top 5 funding sources that have significantly contributed to the development of research on multi-criteria methods, the leading institutes identified are the European Commission (13.422%); Spanish Government (8.555%); National Natural Science Foundation of China (4.425%); Spanish Ministry of Economy and Competitiveness (4.425%); and Junta de Andalucia (2.507%). These five institutions together fund almost 33.33% of all research related to multi-criteria methods in Spain.

The top five researchers who have significantly contributed in the area of multi-criteria methods in terms of academic production in Spain are Morteza Yazdani, H-index (16), with 25 publications, the most cited work: (Yazdani *et al.*, 2017); Juan Miguel Sanchez-Lozano, H-index (10), with 23 publications, the most cited work: (Sánchez-Lozano *et al.*, 2013); Monica Garcia-Melon, H-index (14), with 22 publications, the most cited work: (Aragonés-Beltrán *et al.*, 2009); Maria Carmen Carnero, H-index (11), with 20 publications, the most cited work: (Bana e Costa et al., 2012); and Maria Teresa Lamata, H-index (19), with 19 publications, the most cited work: (Sánchez-Lozano et al., 2016). The top five most researched multicriteria methods in their studies are AHP, TOPSIS; VIKOR; ELECTRE; and ANP.

3.1.9 A view of scientific production in Italy

Italy is ninth in this ranking in scientific production on multicriteria decision support methods and applications, accounting for 2.61 percent of the total academic output globally. The research areas where the majority of the multicriteria decision-making related studies are done are the engineering (Braglia et al., 2003; La Fata *et al.*, 2021); environmental sciences, and ecology (Bottero et al., 2011; Zoghi *et al.*, 2021); computer science (Calabrese et al., 2013; Corrente *et al.*, 2021); science technology other topics (Beccali et al., 2003; Nepomuceno et al., 2021); and operations research and management science (Gamberini et al., 2006; Sangiorgio *et al.*, 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are: University of Catania (Greco et al., 2002; Angilella *et al.*, 2004); University of Naples Federico II (Caterino *et al.*, 2009; Formisano and Mazzolani, 2015; Saaty and De Paola, 2017); University of Palermo (Beccali et al., 2003; Lupo, 2015; Carpitella *et al.*, 2018); Polytechnic University of Turin (Norese, 2006; Bottero, Comino and Riggio, 2011; Ferretti and Pomarico, 2013); And University of Cassino

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(Silvestri et al., 2012; Barrios *et al.*, 2016; Petrillo *et al.*, 2016). The top five funding sources that have considerably contributed to the growth of scientific production on the topic of multi-criteria methods are as follows: European Commission (3.303%); Ministry of Education Universities and Research (2.385%); National Natural Science Foundation of China (0.917%); Ministry of Science and Higher Education Poland (0.734%); and European Commission Joint Research Centre (0.550%). These five institutions together fund almost 7.89% of all research related to multi-criteria methods in Italy.

Regarding the authors, the top five researchers who stand out in the area of multi-criteria methods in terms of academic production in Italy are Salvatore Greco, H-index (47), with 33 publications, the most cited work: (Greco et al., 2002); Antonella Petrillo, H-index (14), with 28 publications, the most cited work: (Petrillo *et al.*, 2016); Fabio De Felice, H-index (14), com 25 publications, the most cited work: (Petrillo *et al.*, 2016); Fausto Cavallaro, H-index (17), with 17 publications, the most cited work: (Cavallaro, 2010); and Silvia Carpitella, H-index (4), with publications, the most cited work: (Carpitella *et al.*, 2018). The top five most researched multicriteria methods done by the above researchers in their studies are AHP, TOPSIS; ELECTRE; PROMETHEE; and ANP.

3.1.10 A view of scientific production in Malaysia

Malaysia ranks tenth in this study's rating, with 2.34% of scientific production on multi-criteria techniques and applications. The research areas where the majority of the recent multicriteria decision-making related studies are done: engineering (Azadnia et al., 2015; Umer *et al.*, 2021); computer science (Mardani et al., 2015; Khoso *et al.*, 2021); science technology other topics (Shahabi and Hashim, 2015; Gohari *et al.*, 2020); environmental sciences and ecology (Rostamzadeh *et al.*, 2015; Akhtar *et al.*, 2021); and operations research and management science field (Abdullah and Najib, 2014; Umer *et al.*, 2021). Regarding the top universities with the highest productivity of research on multi-criteria methods, the following five universities with the three most cited publications are Universiti Teknologi Malaysia (Mardani *et al.*, 2015; Mardani et al., 2015; Rostamzadeh *et al.*, 2015); Universiti Malaya (Zaidan *et al.*, 2015; Aghajani Mir *et al.*, 2016; Fallahpour *et al.*, 2017); University Putra Malaysia (Jahan *et al.*, 2012; Mansor *et al.*, 2014; Bathrellos *et al.*, 2017); University Pendidikan Sultan Idris (Zaidan *et al.*, 2015; Zaidan and Zaidan, 2017; Salih *et al.*, 2019); And University Sains Malaysia (Adiat et al., 2012; Wong et al., 2014; Ignatius *et al.*, 2016). The top five funding sources that have considerably contributed to the growth of scientific production on the topic of multi-criteria methods in Malaysia are as follows: Ministry Of Education Malaysia (4.48%); University Teknologi Malaysia (2.83%); University Sains Malaysia (2.12%); University Kebangsaan Malaysia (1.18%); and University Malaya (0.94%). These five institutions together fund 11.55% of all research related to multi-criteria methods in Malaysia.

In terms of the authors, the top five researchers who have contributed in the area of multi-criteria methods in terms of academic production are Bilal Bahaa Zaidan, H-index (32), with 33 publications, the most cited work: (Zaidan and Zaidan, 2017); Aos Ala Zaidan, H-index (30), with 32 publications, the most cited work: (Zaidan *et al.*, 2015); Lazim Abdullah, H-index (13), with 25 publications, the most cited work: (Abdullah and Najib, 2014); Osamah Shihab Albahri, H-index (21), with 20 publications, the most cited work: (Albahri *et al.*, 2019); and Mardini Abbas, H-index (26), with 17 publications, the most cited work: (Mardani *et al.*, 2015). The top five most researched multicriteria methods done by the above researchers in their studies are AHP, TOPSIS; VIKOR; DEMATEL; and PROMETHEE.

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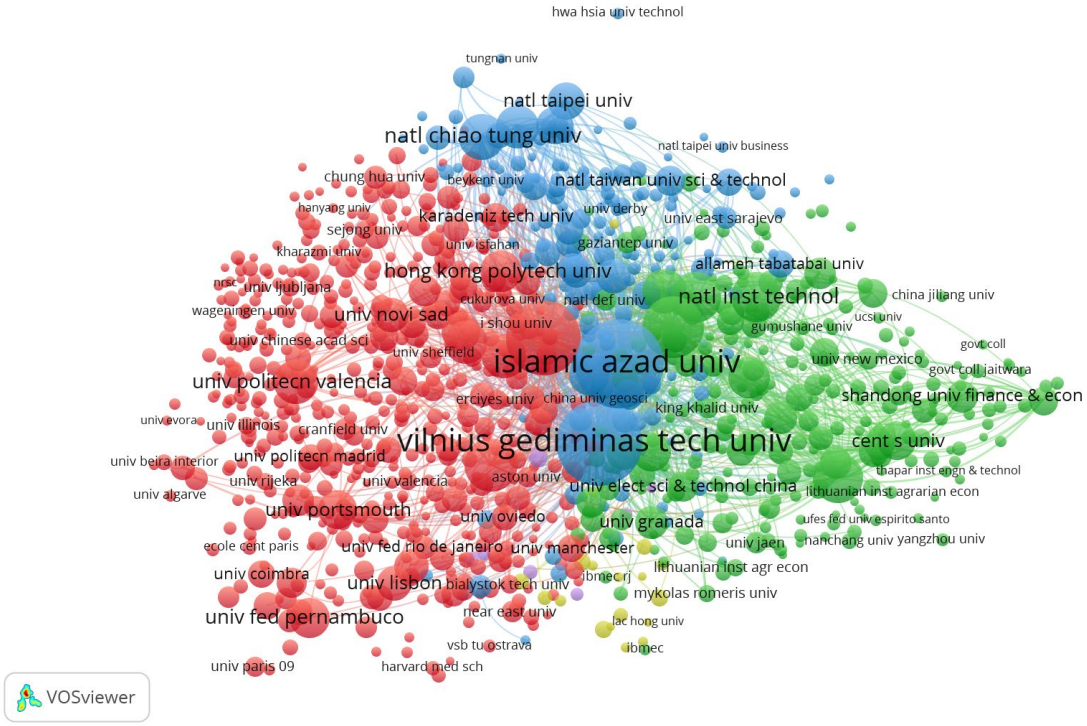

Figure 6 The network map of institutions involved in multicriteria methods of decision support research
Note: The colors of the circles are used to identify the clusters resulting from the analysis of the relations treated with the VOSviewer software.

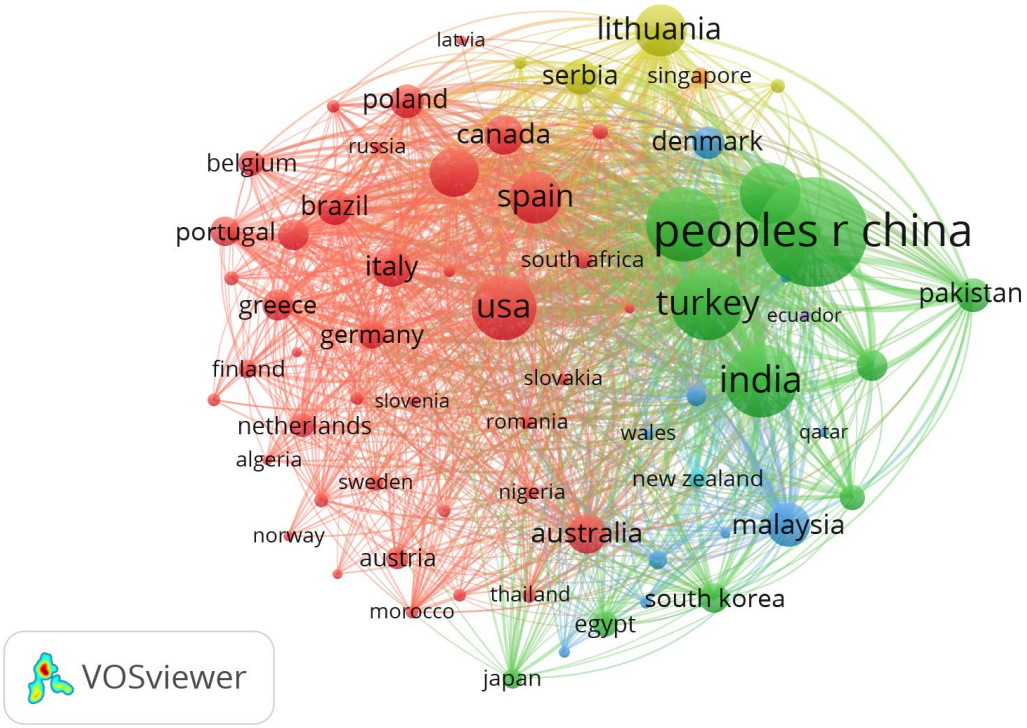

Figure 7 The network map of countries involved in multicriteria methods of decision support research
Note: The colors of the circles are used to identify the clusters resulting from the analysis of the relations treated with the VOSviewer software.

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3.2 Overview of the leading journals and papers that disseminate research on multicriteria methods

In the forty-four years of research, 6,105 sources have published research on the topic of multicriteria methods. The top 10 popular journals published 2,180 of all 20,861 studies on multicriteria methods (10.40%), as seen in Table 2. The top 3 journals are the *Expert Systems With Applications*; *Sustainability; and Journal of Cleaner Production*, which account for more than 4.67% of all indexed literature. The highest impact factor (IF) belongs to *the Journal of Cleaner Production* (7.246), followed by *Applied Soft Computing* (5.472) and *Expert Systems With Applications* (5.452). According to the JCR 2019 standards, five journals are classified as Q1, two as Q2, and three as Q3. In the eighth column of Table 5, we can observe the number of citations of each Journal as an illustration. Figure 8 depicts the inter-relationship between the Journals, which was developed based on the researchers' preferences and referencing publications from sources with a high impact factor. The diameter of the circles is directly related to the number of citations, while the colors represent the identified clusters. In the eleventh column of Table 5, we can observe the five countries that published the most in each source. The maximum number of articles is from China, occupying the first position in eight out of the ten journals. The analysis of the highly cited papers shows that *Renewable and Sustainable Energy Reviews, Expert Systems with Applications,* and *the International Journal of Production Economics* have an incredible scientific impact on all scholars and have articles with more than 800 citations (*Table 3*).

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Table 2 Top 10 most active journals that published research articles on multicriteria methods (sorted by count)

Rank	Journal title	Percentage (N/20,861), %	IF [2019]	Quartile in category [2019]	H-index	Article counts	Total number of citations	Average number of citations	Percentage (TNC/335.028), %	Top 5 countries by source
1	Expert Systems With Applications	1.70	5.452	Q1	91	356	26,410	74.19	7.88	Taiwan; Turkey; China; USA; England
2	Sustainability	1.68	2.576	Q3	25	352	2,978	8.46	0.89	China; Italy; Spain; Taiwan; Lithuania
3	Journal of Cleaner Production	1.29	7.246	Q1	43	270	7,627	28.25	2.28	China; India; Iran; USA; Denmark
4	European Journal of Operational Research	1.26	4.213	Q1	76	264	22,144	83.88	6.61	France; England; USA; Belgium; Greece
5	Journal of Intelligent & Fuzzy Systems	1.07	1.851	Q3	26	225	2,508	11.15	0.75	China; Turkey; Pakistan; Iran; India
6	Applied Soft Computing	0.79	5.472	Q1	48	166	6,557	39.50	1.96	China; Iran; Turkey; Taiwan; India
7	Computers & Industrial Engineering	0.69	4.135	Q1	40	146	5,165	35.38	1.54	China; Iran; Turkey; USA; Taiwan
8	Soft Computing	0.68	3.050	Q2	22	142	1,402	9.87	0.42	China; Turkey; India; Iran; Taiwan
9	Symmetry-Basel	0.66	2.645	Q2	21	138	1,407	10.20	0.42	China; Serbia; Lithuania; Pakistan; Taiwan
10	International Journal of Information Technology & Decision Making	0.58	1.894	Q3	24	121	2,254	18.63	0.67	China; Taiwan; Turkey; USA; Iran
	Total	10.4				2,180	78,452		23.42	

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Table 3 Top 10 manuscripts per citations

Rank	Title	Journal	first author	Publication year	Total citations	TCper Year
1	A fuzzy extension of Saaty's priority theory	Fuzzy Sets and Systems	van Laarhoven, PJM	1983	1950	50.0
2	Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS	European Journal of Operational Research	Opricovic S	2004	1834	101.9
3	Extensions of the TOPSIS for group decision-making under fuzzy environment	Fuzzy Sets and Systems	Chen CT	2000	1815	82.5
4	How to select and how to rank projects: The Promethee method	European Journal of Operational Research	Brans JP	1986	1422	39.5
5	Application of multi-criteria decision making to sustainable energy planning—A review	Renewable and Sustainable Energy Reviews	Pohekar SD	2004	960	53.3
6	Handling multicriteria fuzzy decision-making problems based on vague set theory	Fuzzy Sets and Systems	Chen SM	1994	888	31.8
7	A fuzzy approach for supplier evaluation and selection in supply chain management	International Journal of Production Economics	Chen CT	2006	854	53.4
8	A state-of the-art survey of TOPSIS applications	Expert Systems with Applications	Behzadian M	2012	742	74.2
9	A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method	Expert Systems with Applications	Boran FE	2009	732	56.3
10	Extended VIKOR method in comparison with outranking methods	European Journal of Operational Research	Opricovic S	2007	706	47.1

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3.3 Analysis of the most influential authors who discuss the topic of the multicriteria methods

Zavadskas E, Wang J, Tzeng G, Wang Y, and Kahraman C are among the ten authors who have published the most articles on this subject out of all 29,050 authors (Table 4). Edmundas Kazimieras Zavadskas is the first vice-rector of Vilnius Gediminas Technical University (VGTU). He is also a member of the VGTU Senate, a professor, and the director of the Department of Construction Technology and Management. He has written and co-written over 50 novels in Lithuanian, Russian, German, and English. Various corporations and academic organizations commissioned over 40 research papers. The professor's primary research interests include building life cycles, decision support systems, and multi-criteria optimization methods in construction technology and management. Figure 9 produced by VOSviewer illustrates a sample made using two criteria: number of documents (N>=10) and the minimum number of citations (N>=500), thus resulting in a group of 160 authors divided into six clusters. Cluster 1 (Red) has 37.5% of the sample and is represented by authors Wang Y (Links=112, Total Links Strength (TLS)=540) and Cheng Y (Links=103, TLS=394); Cluster 2 (Green) has 26.9% of the sample and is represented by the authors Wang J (Links=140, TLS=315), Xu Z (Links=141, TLS=2048); Zhang H (Links=144, TLS=1935), and Wang X (Links=121, TLS=658); Cluster 3 (Blue) has 10.6% of the sample and is represented by author Kahraman C (Links=143, TLS=2548); Cluster 4 (Yellow) has 10% of the sample and is represented by the author Zavadskas E (Links=153, TLS=9165), and Turskis Z (Links=138, TLS=4074); Cluster 5 (Purple) has 7.5% of the sample and is represented by author Liu H (Links=122, TLS=1395); and Cluster 6 (Light blue) has 7.5% of the sample and is represented by author Tzeng G (Links=139, TLS=2167).

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Table 4 Ranking of authors with the highest scientific production on multicriteria methods

Rank	Authors	Country	University	h_index	g_index	Article Counts	Total number of citations	Average number of citations	First author counts	First author citations counts	Average first author citations counts
1	ZAVADSKAS E	Lithuania	Vilnius Gediminas Technical University	57	87	240	9955	41.48	50	1806	36.12
2	WANG J	China	Central South University	46	68	211	5785	27.42	65	1946	29.93
3	TZENG G	Taiwan	National Taipei University	44	97	191	9814	51.38	5	1621	324.2
4	WANG Y	China	Qinghai Normal University	28	57	161	3419	21.24	75	2222	29.62
5	KAHRAMAN C	Turkey	Istanbul Technical University	34	68	145	4980	34.34	39	1939	49.71
6	CHEN Y	China	Chongqing University	29	53	124	3036	24.48	42	1173	27.92
7	ZHANG H	China	Central South University	37	59	104	3620	34.81	27	552	20.44
8	XU Z	China	Sichuan University	31	64	95	4178	43.98	12	832	69.33
9	WANG X	China	Central South University	20	33	94	1321	14.05	28	526	18.78
10	TURSKIS Z	Lithuania	Vilnius Gediminas Technical University	34	63	93	4264	45.85	10	273	27.3
Total						1,458	50,372	34.54	353	12,890	36.51

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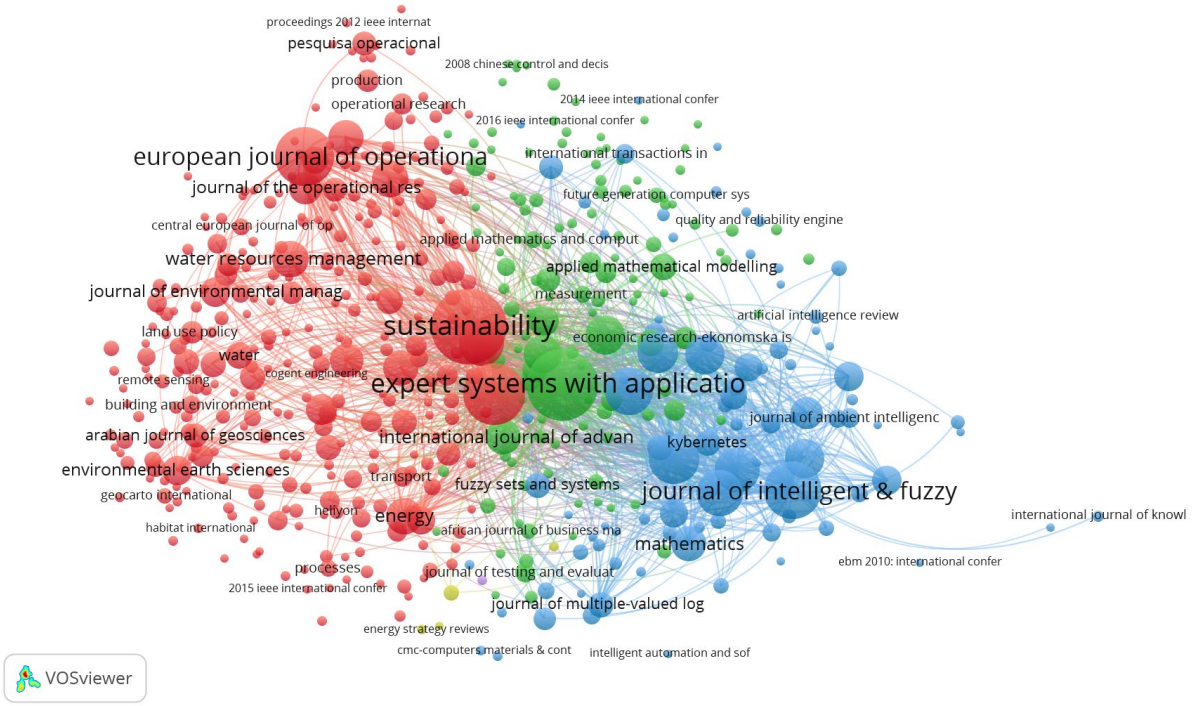

Figure 8 The network map of co-cited journals
Note: The colors of the circles are used to identify the clusters resulting from the analysis of the relations treated with the VOSviewer software

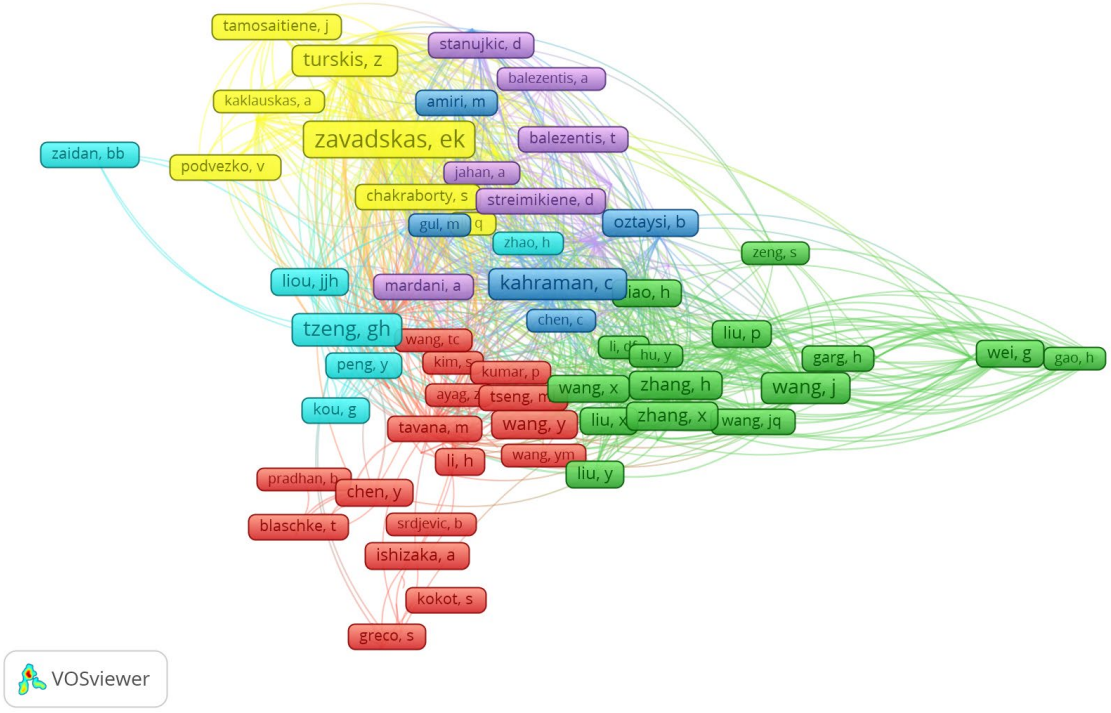

Figure 9 The network map of productive authors
Note: The colors of the circles are used to identify the clusters resulting from the analysis of the relations treated with the VOSviewer software**.**

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3.4 Evolution of the concept map on multicriteria methods

VOSviewer was used to extract and analyze keywords from 33,761 articles. Figure 10 depicts 329 terms that appeared more than 50 times which are grouped into six clusters: cluster 1 (in red); cluster 2 (in green); cluster 3 (in blue); cluster 4 (in yellow); cluster 5 (in purple); and cluster 6 (in light blue). Keywords that appeared frequently are represented by frames with a big size. The following keywords have the highest connection strength inside Cluster 1: AHP (14,621), analytic hierarchy process (8,026). Furthermore, relevant terms in Cluster 2 included: model (14,499), performance (5,679), framework (4,987), supplier selection (3,975), and dematel (2,807). The primary keywords in Cluster 3 were topsis (13,046), multicriteria decision making (4,171), and group decision-making (3,748). Similarly, the main keywords in Cluster 4 were decision-making (8,304), ranking (4,050), optimization (3,658), and promethee (3,084). The main keywords in Cluster 5 were selection (12,276), mcdm (6,947), and vikor (4,054). Relevant keywords in Cluster 6 were fuzzy (2,181), prioritizing (1,023), and fahp (666).

Figure 11 depicts a map of the conceptual framework constructed from the authors' keywords. The map, created using the MCA method (Multiple Correspondence Analysis), is divided into three periods: the first spans the years 1982-2001, highlighting the following methods: AHP, PROMETHEE. There are two clusters in the second phase between 2002 and 2011. The blue cluster represents the ANP method, whereas the red cluster reflects the AHP, PROMETHEE, TOPSIS, VIKOR, and GIS methods. Finally, in the third period of 2012-2021, four clusters can be observed, with the red cluster being the most prominent one. Furthermore, a wide range of methods and applications is observed demonstrating a significant rise in scientific output throughout this time of multicriteria methods. Figure 12 shows the outcome of using the Bibliometrix package's thematicMap function. The illustration is split into four quadrants. The first portrays the motor themes, the second the highly developed and isolated themes, the third the developing or decreasing themes, and the fourth the basic and transversal themes. This thematic map was split into three phases to illustrate how the themes revolving around using multicriteria methods evolved between 1982 and 2021.

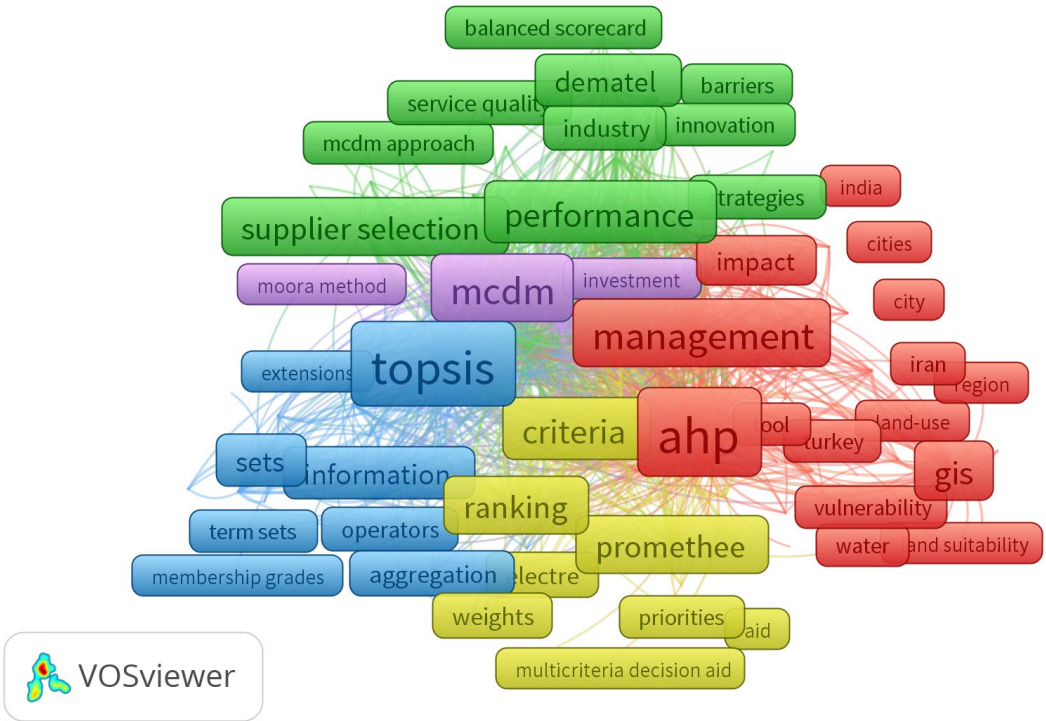

Figure 10 The analysis of keywords in publications of the multicriteria methods of decision support research
Note: The colors of the frames are used to identify the clusters resulting from the analysis of the relations treated with the VOSviewer software.

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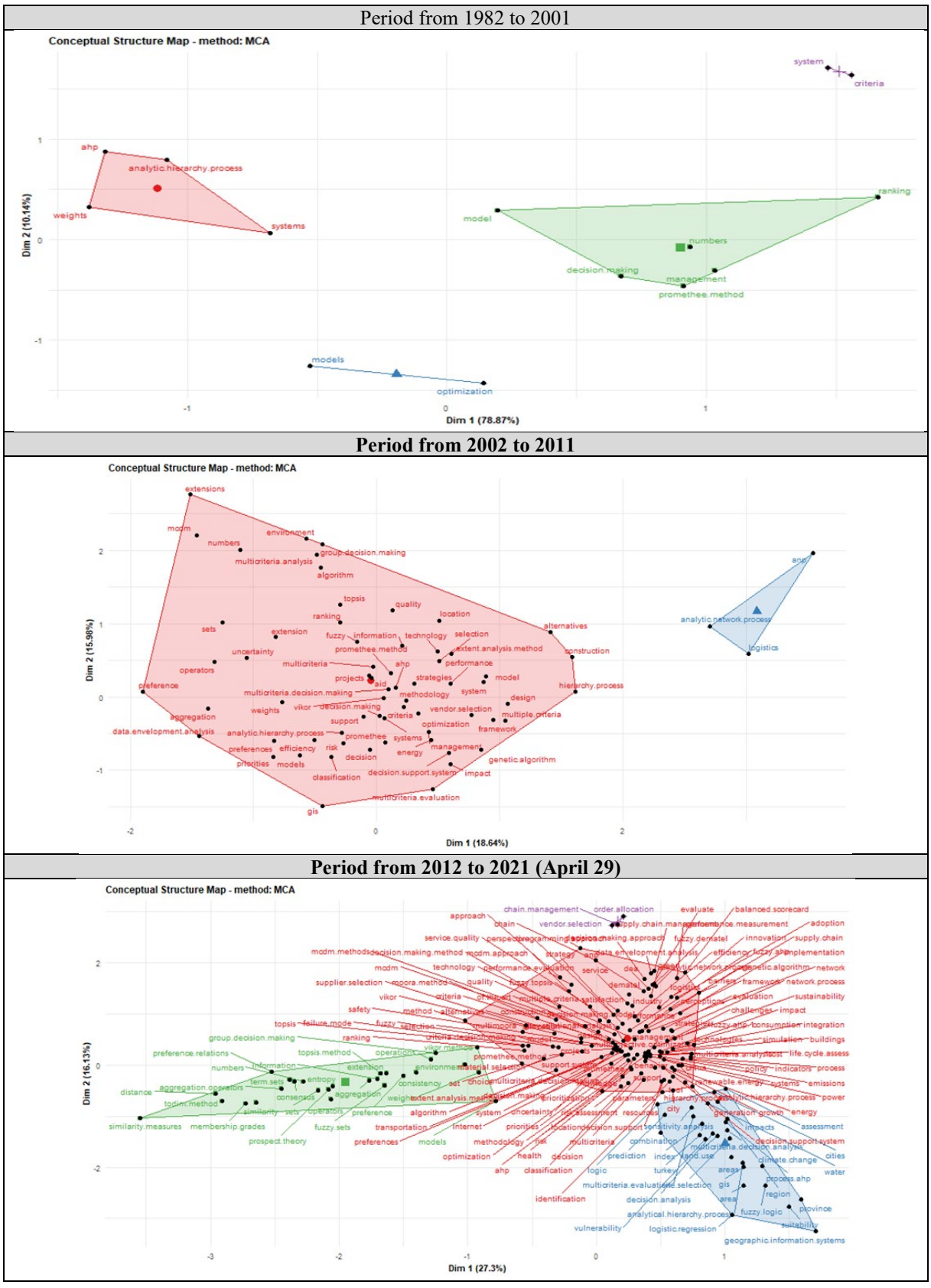

Figure 11 Conceptual map built with the authors' keywords

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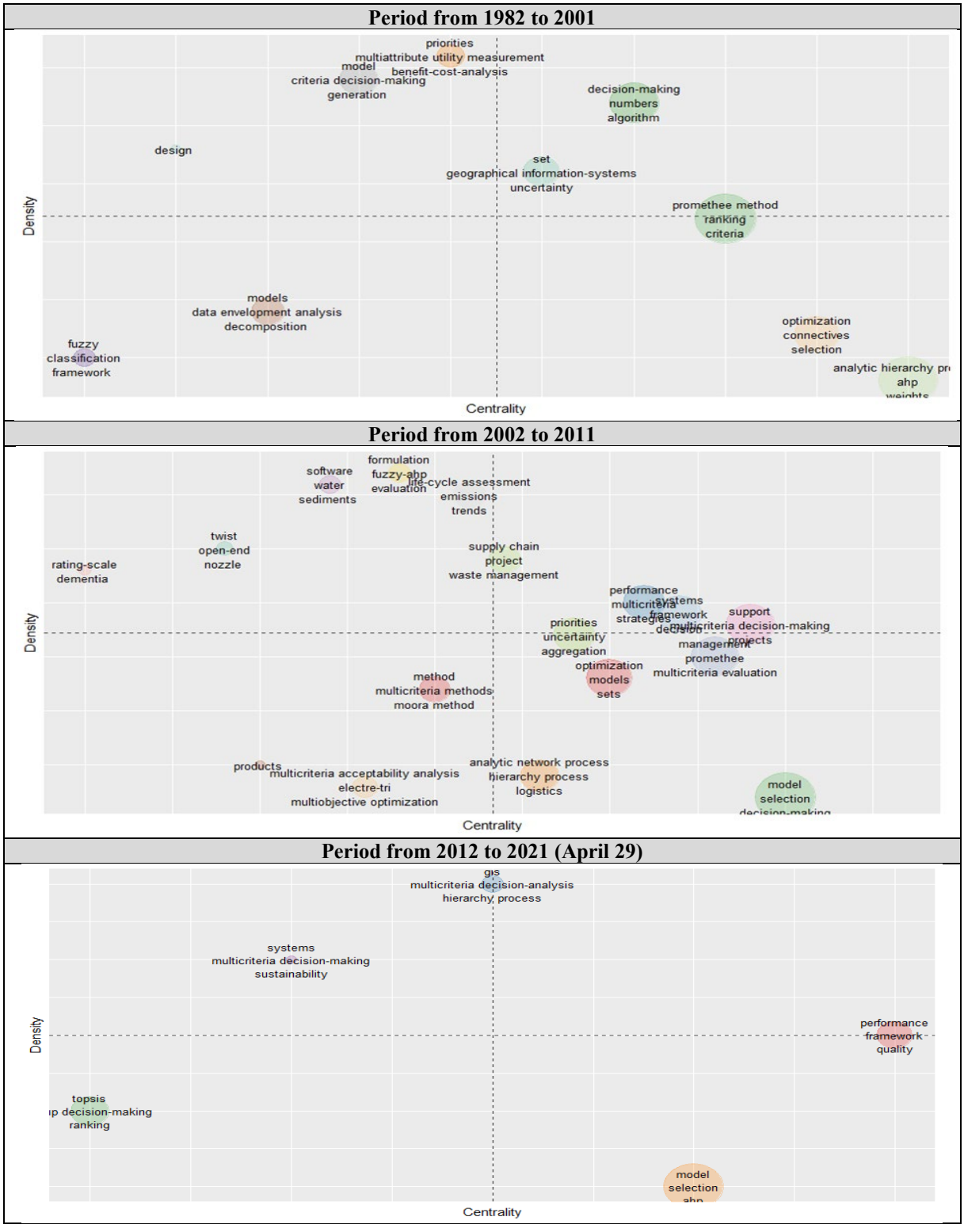

Figure 12 Thematic map on research in multicriteria methods of decision support

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4. Conclusion

This research article presents a bibliometric analysis of the multicriteria methods from 1977 to April 29, 2021. The bibliographic data was obtained from the Scopus and Web of Science (WoS) databases. The bibliometric analysis was conducted using the Bibliometrix R tool and the VOSviewer software to investigate the essential characteristics of the studies done so far, including publications; citations, citation structure; influential authors; co-citation contributors, and burst detection analysis; author-keywords; co-occurrence analyses; and timeline view analysis.

The ability to make decisions is a trait that distinguishes a person. Man makes judgments spontaneously and intuitively based on the information processing capabilities of our brain. We make decisions ranging from the color of our tie at a business meeting to whether or not to spend millions on a particular project. We recognize that we are dealing with two different sorts of decisions: easy and difficult. We can make easy judgments with few variables without much difficulty. However, when the problem involves a matrix (n x m) variable, we need methods and computer capability to systematize, organize, and rank the best possibilities to help us make decisions. In this view, the purpose of this study was to comprehend the global progress of research on the development and application of multicriteria decision methods.

With a 13.88 percent yearly growth rate in scientific production, it is evident that the academic community is interested in researching and publishing articles on multicriteria decision-making methods. Furthermore, 60.93 percent of all publications were concentrated in only ten countries, with China leading the way with 14.14 percent, India with 10.76 percent, and Iran with 8.09 percent. It is also found that the remaining 39 percent of publications have a production rate of less than 1% on average, indicating a potential for multicriteria method research dissemination in such nations and investment to increase academic output. The leading ten countries follow the same pattern in terms of citations, accounting for 62.48% of all citations made during the research period. In terms of multi-country collaboration in publications, it is observed that among the top ten countries, Turkey has the lowest MCP ratio with 0.0519, suggesting limited collaboration with researchers from other countries, followed by India (0.0641) and Brazil (0.0861). Malaysia, having an MCP ratio of 0.2331, takes the lead in multi-country collaboration, followed by the United States (0.2234) and Spain (0.2169).

In terms of universities, about 80% of the publications come from China, India, Iran, and Turkey respectively, which are the top four countries having the most publications on the topic of multicriteria methods. The academic production of these universities amounts to 11.79 percent, with the Islamic Azad University of Iran accounting for 2.14 percent and Vilnius Gediminas Technical University of Lithuania accounting for 2.18 percent. Interestingly, Lithuania is not among the top ten countries in terms of scientific production. However, Prof. Edmundas Kazimieras Zavadskas of Lithuania is placed first among the other authors in this study, with 240 publications published on the subject of multicriteria methods. Regarding sources that publish articles related to multicriteria methods, the analysis reveals the top ten journals having published about 10.4 percent of the total publications about the topic.

'*Expert Systems With Applications'* leads the ranking with 1.70 percent of articles published thus far, followed by '*Sustainability'* with 1.68 percent, and '*Journal of Cleaner Production*' with 1.29 percent. In terms of citations, the leading journals are: '*Expert Systems With Applications'* with an average citation of 7.88, followed by '*European Journal of Operational Research'* with an average citation score of 6.61 per article. With respect to the country of origin of publications, it is observed that eight among the top 10 countries publish most of their articles in the ten best-ranked journals. However, in the case of the '*European Journal of Operational Research,'* the ratio is 2 out of 10.

In terms of the most influential authors in this subject area, it can be seen that around 0.034 percent of the total of 29,050 authors are responsible for 6.98 percent of publications in the past forty-four years, with ZAVADSKAS E having the most publications with 240 articles; followed by WANG J with 211 articles; and TZENG G with 191

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articles. Through this bibliometric analysis, it is also observed that six of the top ten authors are Chinese, with Central South University being the standout for author affiliation. Furthermore, in addition to identifying authors with higher academic productivity, this study also provides a detailed overview of the countries, funding sources, and the five most explored multicriteria methods, i.e., AHP, TOPSIS, VIKOR PROMETHEE, and ANP, by the authors in their respective studies. In summary, this paper provides a comprehensive overview of multicriteria methods through a bibliometric analysis, which would aid the researchers in understanding the current state, future development trends, and research scope of the multicriteria decision-making methods. As an indication for future research, we can highlight the need to understand the emergence and regionalization of some methods and their variants; expand research within the ranked countries to deepen knowledge about their scientific production in relation to the topic explored; Apply topic modelling to identify latent themes in the studied database; and systematize the variants of the methods and their interfaces with other areas of operational research.

Abbreviations

The following abbreviations are used in this manuscript:

- AHP Analytic Hierarchy Process
- ANP Analytical Network Process
- COMET Characteristic Objects Method
- COPRAS Complex Proportional Assessment
- DRSA Dominance-based Rough Set Approach
- ELECTRE ÉLimination et Choix Traduisant la REalité (French)
- MACBETH Measuring Attractiveness by a Categorical Based Evaluation Technique
- MCDA Multi Criteria Decision Analysis
- MCDM Multi Criteria Decision Making
- MODM MultiObjective Decision Making
- MOORA Multi-Objective Optimization by Ratio Analysis
- MULTIMOORA MOORA plus the full Multiplicative Form
- NAIADE Novel Approach to Imprecise Assessment and Decision Environment
- PCCA Pairwise Criterion Comparison Approach
- PROMETHEE Preference Ranking Organization Method for Enrichment of Evaluation
- WASPAS Weighted Aggregated Sum Product Assessment
- TODIM Tomada de Decisão Interativa Multicritério (Portuguese)
- TOPSIS Technique for Order of Preference by Similarity to Ideal Solution
- VIKOR VlseKriterijumska Optimizacija I Kompromisno Resenje (Serbian)

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References

Aalami, H.A., Moghaddam, M.P. and Yousefi, G.R. (2010), "Modeling and prioritizing demand response programs in power markets", *Electric Power Systems Research*, Vol. 80 No. 4, pp. 426-435.

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

https://doi.org/10.1016/j.epsr.2009.10.007.

Abdel-Basset, M., Manogaran, G., Gamal, A., and Smarandach, F. (2019), "A Group Decision Making Framework Based on Neutrosophic TOPSIS Approach for Smart Medical Device Selection", *Journal of Medical Systems*, Vol. 43 No. 38. https://doi.org/10.1007/s10916-019-1156-1.

Abdel-Basset, M., Saleh, M., *Gamal, A., and Smarandach, F.* (2019), "An approach of TOPSIS technique for developing supplier selection with group decision making under type-2 neutrosophic number", *Applied Soft Computing*, Vol. 77, pp. 438-452. https://doi.org/10.1016/j.asoc.2019.01.035.

Abdel-Basset, M., Manogaran, G. and Mohamed, M. (2018), "Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems", *Future Generation Computer Systems*, Vol. 86, pp. 614-628. https://doi.org/10.1016/j.future.2018.04.051.

Abdullah, L. and Najib, L. (2014), "A new type-2 fuzzy set of linguistic variables for the fuzzy analytic hierarchy process", *Expert Systems with Applications*, Vol. 41 No. 7, pp. 3297-3305. https://doi.org/10.1016/j.eswa.2013.11.028.

Adiat, K.A.N., Nawawi, M.N.M. and Abdullah, K. (2012), "Assessing the accuracy of GIS-based elementary multi criteria decision analysis as a spatial prediction tool – A case of predicting potential zones of sustainable groundwater resources", *Journal of Hydrology*, Vol. 440–441, pp. 75-89. https://doi.org/10.1016/j.jhydrol.2012.03.028.

Afshar, A., Mariño, M.A., Saadatpour, M., and *Afsha, A.* (2011), "Fuzzy TOPSIS Multi-Criteria Decision Analysis Applied to Karun Reservoirs System", *Water Resources Management*, Vol. 25, pp. 545–563. https://doi.org/10.1007/s11269-010-9713-x.

Mir, M.A., Ghazvinei, P.T., Sulaiman, N.M.N., Basri, N.E.A., Saheri, S., Mahmood, N.Z., Jahan, A., Begum, R.A., and *A*ghamohammadi, N. (2016), "Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model", *Journal of Environmental Management*, Vol. 166, pp. 109-115. https://doi.org/10.1016/j.jenvman.2015.09.028.

Aguarón, J. and Moreno-Jiménez, J.M. (2003), "The geometric consistency index: Approximated thresholds", *European Journal of Operational Research*, Vol. 147No 1, pp. 137-145. https://doi.org/10.1016/S0377-2217(02)00255-2.

Akhtar, N., Ishak, M.I.S., Ahmad, M.I., Umar, K., Md Yusuff, M.S., Anees, M.T., Qadir, A., and Ali Almanasir, Y.K. (2021) "Modification of the Water Quality Index (WQI) Process for Simple Calculation Using the Multi-Criteria Decision-Making (MCDM) Method: A Review", *Water*, Vol. 13 No. 7, pp 905-939. https://doi.org/10.3390/w13070905.

Akram, M., Waseem, N. and Liu, P. (2019), "Novel Approach in Decision Making with m–Polar Fuzzy ELECTRE-I", *International Journal of Fuzzy Systems*, Vol. 21 No. 4, pp. 1117–1129. https://doi.org/10.1007/s40815-019-00608-y.

Albahri, O.S., Albahri, A.S., Zaidan, A.A., Zaidan, B.B., Alsalem, M.A., Mohsin, A.H., Mohammed, K.I., Alamoodi, A.H., Nidhal, S., Enaizan, O., Chyad, M.A., Abdulkareem, K.H., Almahdi, E.M., Shafeey, G.A.A., Baqer, M.J., Jasim, A.N., Jalood, N.S., and Shareef, A.H. (2019), "Fault-Tolerant mHealth Framework in the Context of IoT-Based Real-Time Wearable Health Data Sensors", *IEEE Access*, Vol. 7, pp. 50052-50080. https://doi.org/10.1109/ACCESS.2019.2910411

de Almeida, A.T., de Almeida, J.A., Costa, A.P.C.S., de Almeida-Filho, A.T. (2016), "A new method for elicitation of criteria weights in additive models: Flexible and interactive tradeoff", *European Journal*

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

of Operational Research, Vol. 250 No. 1, pp. 179-191. https://doi.org/10.1016/j.ejor.2015.08.058

Amin Hosseini, S. M., de la Fuente, A. and Pons, O. (2016), "Multi-criteria decision-making method for assessing the sustainability of post-disaster temporary housing units technologies: A case study in Bam, 2003", *Sustainable Cities and Society*, Vol. 20 38-51, pp. . https://doi.org/10.1016/j.scs.2015.09.012.

Angilella, S., Greco, S., Lamantia, F., and Matarazzo, B. (2004), "Assessing non-additive utility for multicriteria decision aid", *European Journal of Operational Research*, Vol. 158 No. 3, pp. 734-744. https://doi.org/10.1016/S0377-2217(03)00388-6

Aragonés-Beltrán, P., Mendoza-Roca, J.A., Bes-Pía, A., García-Melón, M., and Parra-Ruiz, E. (2009), "Application of multicriteria decision analysis to jar-test results for chemicals selection in the physical–chemical treatment of textile wastewater", *Journal of Hazardous Materials*, Vol. 164 No. 1, pp. 288-295. https://doi.org/10.1016/j.jhazmat.2008.08.046

Aragonés-Beltrán, P., Pastor-Ferrando, J.P., García-García, F., and Pascual-Agulló, A. (2010), "An Analytic Network Process approach for siting a municipal solid waste plant in the Metropolitan Area of Valencia (Spain)", *Journal of Environmental Management*, Vol. 91 No. 5, pp. 1071-1086. https://doi.org/10.1016/j.jenvman.2009.12.007

Aragonés-Beltrán, P., Chaparro-González, F., Pastor-Ferrando, J.P., and Pla-Rubio, A. (2014) "An AHP (Analytic Hierarchy Process)/ANP (Analytic Network Process)-based multi-criteria decision approach for the selection of solar-thermal power plant investment projects", *Energy*, Vol. 66, pp. 222-238. https://doi.org/10.1016/j.energy.2013.12.016

Ashtiani, B., Haghighirad, F., Makui, A., and Montazer, G.A. (2009), "Extension of fuzzy TOPSIS method based on interval-valued fuzzy sets", *Applied Soft Computing*, Vol. 9 No. 2, PP. 457-461. https://doi.org/10.1016/j.asoc.2008.05.005

Gomes, L.F.A.M., and Rangel, L.A.D. (2009), "An application of the TODIM method to the multicriteria rental evaluation of residential properties", *European Journal of Operational Research*, Vol. 193 No. 1, pp. 204-211. https://doi.org/10.1016/j.ejor.2007.10.046.

Azadnia, A.H., Saman, M.Z.M. and Wong, K.Y. (2015), "Sustainable supplier selection and order lot-sizing: an integrated multi-objective decision-making process", *International Journal of Production Research*, Vol. 53 No. 2, pp. 383-408. https://doi.org/10.1080/00207543.2014.935827.

Azbari, K.E., Ashofteh, P.S., Golfam, P., andLoáiciga, H.A. (2021), "Ranking of wastewater reuse allocation alternatives using a variance-based weighted aggregated sum product assessment method", *Environment Development and Sustainability*. https://doi.org/10.1007/s10668-021-01543-5

Bana e Costa, C.A., Ensslin, L., Cornêa, E.C., and Vansnick, J.C. (1999), "Decision Support Systems in action: Integrated application in a multicriteria decision aid process", *European Journal of Operational Research*, Vol. 113 No. 2, pp. 315-335. https://doi.org/10.1016/S0377-2217(98)00219-7

Bana e Costa, C.A., Carnero, M.C. and Oliveira, M.D. (2012), "A multi-criteria model for auditing a Predictive Maintenance Programme", *European Journal of Operational Research*, Vol. 217 No. 2, pp. 381-393. https://doi.org/10.1016/j.ejor.2011.09.019.

Banaeian, N., Mobli, H., Fahimnia, B., Nielsen, I.E., and Omid, M. (2018), "Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry", *Computers & Operations Research*, Vol. 89, pp. 337-347. https://doi.org/10.1016/j.cor.2016.02.015

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Montenegro de Barros, G.M., Pereira, V. and Roboredo, M.C. (2021), "ELECTRE tree: a machine learning approach to infer ELECTRE Tri-B parameters", Data Technologies and Applications, Vol. 55 No. 4, pp. 586-608. https://doi.org/10.1108/DTA-10-2020-0256

Barata, J., Quelhas, O., Costa, H., Gutierrez, R., de Jesus Lameira, V., and Meiriño, M. (2014), "Multi-Criteria Indicator for Sustainability Rating in Suppliers of the Oil and Gas Industries in Brazil", *Sustainability*, Vol. 6 No. 3, pp. 1107-1128. https://doi.org/10.3390/su6031107

Barrios, M.A.O., De Felice, F., Negrete, K.P., Romero, B.A., Arenas, A.Y., and Petrillo, A. (2016), "An AHP-Topsis Integrated Model for Selecting the Most Appropriate Tomography Equipment", *International Journal of Information Technology & Decision Making*, Vol. 15 No. 04, pp. 861-885. https://doi.org/10.1142/S021962201640006X

Barros, C.P. and Wanke, P. (2015), "An analysis of African airlines efficiency with two-stage TOPSIS and neural networks", *Journal of Air Transport Management*, Vol. 44–45, pp. 90-102. https://doi.org/10.1016/j.jairtraman.2015.03.002.

Basilio, M.P., Brum, G.S. and Pereira, V. (2020), "A model of policing strategy choice: The integration of the Latent Dirichlet Allocation (LDA) method with ELECTRE I", Journal of Modelling in Management, Vol. 15 No. 3, pp. 849-891. https://doi.org/10.1108/JM2-10-2018-0166

Basilio, M.P., de Freitas, J.G., Kämpffe, M.G.F. and Bordeaux Rego, R. (2018), "Investment portfolio formation via multicriteria decision aid: a Brazilian stock market study", Journal of Modelling in Management, Vol. 13 No. 2, pp. 394-417. https://doi.org/10.1108/JM2-02-2017-0021

Basilio, M.P., Pereira, V., Oliveira, M.W.C.d. and Costa Neto, A.F.d. (2020), "Ranking policing strategies as a function of criminal complaints: application of the PROMETHEE II method in the Brazilian context", Journal of Modelling in Management, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JM2-05-2020-0122

Basilio, M.P., Pereira, V., de Oliveira, M.W.C.M., da Costa Neto, A.F., Moraes, O.C.R.d. and Siqueira, S.C.B. (2021), "Knowledge discovery in research on domestic violence: an overview of the last fifty years", Data Technologies and Applications, Vol. 55 No. 4, pp. 480-510. https://doi.org/10.1108/DTA-08-2020-0179

Basilio, M.P., Pereira, V. and Oliveira, M.W.C.M.d. (2021a), "Knowledge discovery in research on policing strategies: an overview of the past fifty years", Journal of Modelling in Management. https://doi.org/10.1108/JM2-10-2020-0268

Basilio, M.P. and Pereira, V. (2020), "Operational research applied in the field of public security: The ordering of policing strategies such as the ELECTRE IV", Journal of Modelling in Management, Vol. 15 No. 3, pp. 1227-1276. https://doi.org/10.1108/JM2-02-2019-0034

Basilio, M. P., and Pereira, V. (2020a), "Estudo sobre a premiação das áreas de segurança pública no Rio de Janeiro via método multicritério: uma aplicação do método Electre III", Exacta, Vol. 18 No 1, pp. 130-164. https://doi.org/10.5585/Exacta.v18n1.8725

Basilio, M.P., Pereira, V. and Costa, H.G. (2017), "Review of the Literature on Multicriteria Methods Applied in the Field of Public Security", Universal Journal of Management, Vol. 5 No. 12, pp. 549–562. https://doi.org/10.13189/ujm.2017.051202

Basilio, M.P., Pereira, V. and Costa, H.G. (2019), "Método de apoio decisão multicritério: um estudo empírico aplicado na classificação das áreas integradas de segurança pública no estado do rio de janeiro", ENGEVISTA, Vol. 21 No. 1, pp. 47–63. https://doi.org/10.22409/engevista.v21i1.10129

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Basilio, M.P., Pereira, V. and Costa, H.G. (2019), "Classifying the integrated public safety areas (IPSAs): a multi-criteria based approach", Journal of Modelling in Management, Vol. 14 No. 1, pp. 106-133. https://doi.org/10.1108/JM2-01-2018-0001

Bathrellos, G.D., Skilodimou, H.D., Chousianitis, K., Youssef, A.M., and Pradhan, B. (2017), "Suitability estimation for urban development using multi-hazard assessment map", *Science of The Total Environment*, Vol. 575, pp. 119-134. https://doi.org/10.1016/j.scitotenv.2016.10.025

Beccali, M., Cellura, M. and Mistretta, M. (2003), "Decision-making in energy planning. Application of the Electre method at regional level for the diffusion of renewable energy technology", *Renewable Energy*, Vol. 28 No. 13, pp. 2063-2087. https://doi.org/10.1016/S0960-1481(03)00102-2

Behzadian, M., Kazemzadeh, R.B., Albadvi, A., and Aghdasi, M. (2010), "PROMETHEE: A comprehensive literature review on methodologies and applications", *European Journal of Operational Research*, Vol. 200 No. 1, pp. 198-215. https://doi.org/10.1016/j.ejor.2009.01.021

Behzadian, M., Otaghsara, S.K., Yazdani, M., and Ignatius, J. (2012), "A state-of the-art survey of TOPSIS applications", *Expert Systems with Applications*, Vol. 39 No. 17, pp. 13051-13069. https://doi.org/10.1016/j.eswa.2012.05.056

Benítez, J.M., Martín, J.C. and Román, C. (2007), "Using fuzzy number for measuring quality of service in the hotel industry", *Tourism Management*, Vol. 28 No. 2, pp. 544-555. https://doi.org/10.1016/j.tourman.2006.04.018

Bilbao-Terol, A., Arenas-Parra, M., Cañal-Fernández, V., and Antomil-Ibias, J. (2014), "Using TOPSIS for assessing the sustainability of government bond funds", *Omega*, Vol. 49, pp. 1-17. https://doi.org/10.1016/j.omega.2014.04.005

Bilbao-Terol, A., Arenas-Parra, M. and Cañal-Fernández, V. (2012), "Selection of Socially Responsible Portfolios using Goal Programming and fuzzy technology", *Information Sciences*, Vol. 189, pp. 110-125. https://doi.org/10.1016/j.ins.2011.12.001

Boloorani, A.D., Shorabeh, S.N., Samany, N.N., Mousivand, A., Kazemi, Y., Jaafarzadeh, N., Zahedi, A., and Rabiei, J. (2021), "Vulnerability mapping and risk analysis of sand and dust storms in Ahvaz, IRAN", *Environmental Pollution*, Vol. 279. https://doi.org/10.1016/j.envpol.2021.116859

Boran, F.E., Genç, S., Kurt, M., and Akay, D. (2009), "A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method", *Expert Systems with Applications*, Vol. 36 No. 8, pp. 11363-11368. https://doi.org/10.1016/j.eswa.2009.03.039

Bottero, M., Comino, E. and Riggio, V. (2011), "Application of the Analytic Hierarchy Process and the Analytic Network Process for the assessment of different wastewater treatment systems", *Environmental Modelling & Software*, Vol. 26 No. 10, pp. 1211-1224. https://doi.org/10.1016/j.envsoft.2011.04.002

Bouzon, M., Govindan, K., Rodriguez, C.M.T., and Campos, L.M.S. (2016), "Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP", *Resources, Conservation and Recycling*, Vol. 108, pp. 182-197. https://doi.org/10.1016/j.resconrec.2015.05.021

Braglia, M., Frosolini, M. and Montanari, R. (2003), "Fuzzy TOPSIS approach for failure mode, effects and criticality analysis", *Quality and Reliability Engineering International*, Vol. 19 No. 5, pp. 425-443. https://doi.org/10.1002/qre.528

Brito, A.J., de Almeida, A.T. and Mota, C.M.M. (2010), "A multicriteria model for risk sorting of natural gas pipelines based on ELECTRE TRI integrating Utility Theory", *European Journal of*

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Operational Research, Vol. 200 No. 3, pp. 812-821. https://doi.org/10.1016/j.ejor.2009.01.016

Büyüközkan, G. and Çifçi, G. (2012a), "A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry", *Expert Systems with Applications*, Vol. 39 No. 3, pp. 2341-2354. https://doi.org/10.1016/j.eswa.2011.08.061

Büyüközkan, G. and Çifçi, G. (2012b), "A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers", *Expert Systems with Applications*, Vol. 39 No. 3, pp. 3000-3011. https://doi.org/10.1016/j.eswa.2011.08.162

Büyüközkan, G. and Güleryüz, S. (2016), "An integrated DEMATEL-ANP approach for renewable energy resources selection in Turkey", *International Journal of Production Economics*, Vol. 182, pp. 435-448. https://doi.org/10.1016/j.ijpe.2016.09.015

Calabrese, A., Costa, R. and Menichini, T. (2013), "Using Fuzzy AHP to manage Intellectual Capital assets: An application to the ICT service industry", *Expert Systems with Applications*, Vol. 40 No. 9, pp. 3747-3755. https://doi.org/10.1016/j.eswa.2012.12.081

Cárdenas-Gómez, J.C., Bosch Gonzales, M. and Damiani Lazo, C.A. (2021), "Evaluation of Reinforced Adobe Techniques for Sustainable Reconstruction in Andean Seismic Zones", *Sustainability*, Vol. 13 No. 9, pp. 4955-4978. https://doi.org/10.3390/su13094955

Carpitella, S., Certa, A., Izquierdo, J., and La Fata, C.M. (2018), "A combined multi-criteria approach to support FMECA analyses: A real-world case", *Reliability Engineering & System Safety*, Vol. 169, pp. 394-402. https://doi.org/10.1016/j.ress.2017.09.017

Casas-Rosal, J.C., Segura, M. and Maroto, C. (2021), "Food market segmentation based on consumer preferences using outranking multicriteria approaches", *International Transactions in Operational Research*. https://doi.org/10.1111/itor.12956

Caterino, N., Iervolino, I., Manfredi, G., and Cosenza, E. (2009), "Comparative Analysis of Multi-Criteria Decision-Making Methods for Seismic Structural Retrofitting", *Computer-Aided Civil and Infrastructure Engineering*, Vol. 24 No. 6, pp. 432-445. https://doi.org/10.1111/j.1467-8667.2009.00599.x

Cavallaro, F. (2010), "Fuzzy TOPSIS approach for assessing thermal-energy storage in concentrated solar power (CSP) systems", *Applied Energy*, Vol. 87 No. 2, pp. 496-503. https://doi.org/10.1016/j.apenergy.2009.07.009

Cebi, S. (2013), "Determining importance degrees of website design parameters based on interactions and types of websites", *Decision Support Systems*, Vol. 54, No. 2,pp. 1030-1043. https://doi.org/10.1016/j.dss.2012.10.036

Ceylan, Z., Tozan, H. and Bulkan, S. (2021), "A coordinated scheduling problem for the supply chain in a flexible job shop machine environment", *Operational Research*, Vol. 21 No. 2, pp. 875–900. https://doi.org/10.1007/s12351-020-00615-0

Chai, J., Liu, J. N.K. and Ngai, E.W.T. (2013), "Application of decision-making techniques in supplier selection: A systematic review of literature", *Expert Systems with Applications*, Vol. 40 No. 10, pp. 3872-3885. https://doi.org/10.1016/j.eswa.2012.12.040

Chakraborty, S. and Zavadskas, E.K. (2014), "Applications of WASPAS Method in Manufacturing Decision Making", *Informatica*, Vol. 25 No. 1, pp. 1–20. https://doi.org/10.15388/Informatica.2014.01

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Chan, F.T.S., Kumar, N., Tiwari, M.K., Lau, H.C.W., and Choy, K.L. (2008), “Global supplier selection: a fuzzy-AHP approach”, *International Journal of Production Research*, Vol. 46 No. 14, pp. 3825-3857. https://doi.org/10.1080/00207540600787200

Chatterjee, K. and kar, S. (2018), “A multi-criteria decision making for renewable energy selection using Z-numbers in uncertain environment”, *Technological and Economic Development of Economy*, Vol. 24 No. 2, pp. 739-764. https://doi.org/10.3846/20294913.2016.1261375

Chatterjee, P., Athawale, V.M. and Chakraborty, S. (2011), “Materials selection using complex proportional assessment and evaluation of mixed data methods”, *Materials & Design*, Vol. 32 No. 2, pp. 851-860. https://doi.org/10.1016/j.matdes.2010.07.010

Chatterjee, P. and Chakraborty, S. (2012), “Material selection using preferential ranking methods”, *Materials & Design*, Vol.35, pp. 384-393. https://doi.org/10.1016/j.matdes.2011.09.027

Chen, C.-T. (2000), “Extensions of the TOPSIS for group decision-making under fuzzy environment”, *Fuzzy Sets and Systems*, Vol. 114 No. 1, pp. 1-9. https://doi.org/10.1016/S0165-0114(97)00377-1

Chen, C.-T., Lin, C.-T. and Huang, S.-F. (2006), “A fuzzy approach for supplier evaluation and selection in supply chain management”, *International Journal of Production Economics*, Vol. 102 No. 2, pp. 289-301. https://doi.org/10.1016/j.ijpe.2005.03.009

Chen, F.-H., Hsu, T.-S. and Tzeng, G.-H. (2011), “A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP”, *International Journal of Hospitality Management*, Vol. 30 No. 4, pp. 908-932. https://doi.org/10.1016/j.ijhm.2011.02.001

Chen, T.-Y. (2012), “Comparative analysis of SAW and TOPSIS based on interval-valued fuzzy sets: Discussions on score functions and weight constraints”, *Expert Systems with Applications*, Vol. 39 No. 2, pp. 1848-1861. https://doi.org/10.1016/j.eswa.2011.08.065

Chen, T.-Y. (2021), “A likelihood-based preference ranking organization method using dual point operators for multiple criteria decision analysis in Pythagorean fuzzy uncertain contexts”, *Expert Systems with Applications*, Vol. 176. https://doi.org/10.1016/j.eswa.2021.114881

Chen, T. (2020), “Enhancing the efficiency and accuracy of existing FAHP decision-making methods”, *EURO Journal on Decision Processes*, Vol. 8 No. 3–4, pp. 177-204. https://doi.org/10.1007/s40070-020-00115-8

Chen, Y.-J. (2011), “Structured methodology for supplier selection and evaluation in a supply chain”, *Information Sciences*, Vol. 181 No. 9, pp. 1651-1670. https://doi.org/10.1016/j.ins.2010.07.026

Chiu, W.-Y., Manoharan, S.H. and Huang, T.-Y. (2020), “Weight Induced Norm Approach to Group Decision Making for Multiobjective Optimization Problems in Systems Engineering”, *IEEE Systems Journal*, Vol. 14 No. 2, pp. 1580-1591. https://doi.org/10.1109/JSYST.2019.2939824

Choudhary, D. and Shankar, R. (2012), “An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India”, *Energy*, Vol. 42 No. 1, pp. 510-521. https://doi.org/10.1016/j.energy.2012.03.010

Cicioğlu, M. (2021), “Multi-criteria handover management using entropy-based SAW method for SDN-based 5G small cells”, *Wireless Networks*, Vol. 27 No. 4, pp. 2947–2959. https://doi.org/10.1007/s11276-021-02625-y

Cinelli, M., Kadzinski, M., Gonzalez, M., and Słowinski, R. (2020), "How to Support the Application of

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Multiple Criteria Decision Analysis? Let Us Start with a Comprehensive Taxonomy", Omega, Vol. 96, Article Number 102261. https://doi.org/10.1016/j.omega.2020.102261

Colak, H.E., Memisoglu, T. and Gercek, Y. (2020), “Optimal site selection for solar photovoltaic (PV) power plants using GIS and AHP: A case study of Malatya Province, Turkey”, *Renewable Energy*, Vol. 149, pp. 565-576. https://doi.org/10.1016/j.renene.2019.12.078

Corrente, S., Greco, S., Leonardi, F., and Słowiński, R. (2021), “The hierarchical SMAA-PROMETHEE method applied to assess the sustainability of European cities”, *Applied Intelligence, Vol. 51, pp. pages6430–6448*. https://doi.org/10.1007/s10489-021-02384-5

Costa, I.P.A., Basilio, M.P., Maeda, S.M.N., Rodrigues, M.V.G., Moreira, M.A.L., Gomes, C.F.S., and Santos, M. (2021), “Bibliometric Studies on Multi-Criteria Decision Analysis (MCDA) Applied in Personnel Selection”, Tallón-Ballesteros, A.J. (Ed.), Modern Management based on Big Data II and Machine Learning and Intelligent Systems III - Proceedings of MMBD 2021 and MLIS 2021, IOS Press BV, Amsterdam, Vol. 341, pp. 119-125. https://doi.org/10.3233/FAIA210239

Costa, I.P.A., Basílio,M.P., Maeda, S.M.N., Rodrigues, M.V.G., Moreira, M.A.L., Gomes, C.F.S., and Santos, M. (2021a), “Algorithm Selection for Machine Learning Classification: An Application of the MELCHIOR Multicriteria Method”, Tallón-Ballesteros, A.J. (Ed.), Modern Management based on Big Data II and Machine Learning and Intelligent Systems III - Proceedings of MMBD 2021 and MLIS 2021, IOS Press BV, Amsterdam, Vol. 341, pp. 154-161. https://doi.org/10.3233/FAIA210243

Cunha, V.H.C., Caiado, R.G.G., Corseuil, E.T., Neves, H. F., and Bacoccoli, L. (2021), “Automated compliance checking in the context of Industry 4.0: from a systematic review to an empirical fuzzy multi-criteria approach”, *Soft Computing*, Vol. 25 No. 8, pp. 6055–6074. https://doi.org/10.1007/s00500-021-05599-3

Dağdeviren, M., Yavuz, S. and Kılınç, N. (2009), “Weapon selection using the AHP and TOPSIS methods under fuzzy environment”, *Expert Systems with Applications*, Vol. 36 No. 4, pp. 8143-8151. https://doi.org/10.1016/j.eswa.2008.10.016

Dai, F. ., Lee, C. . and Zhang, X. . (2001), “GIS-based geo-environmental evaluation for urban land-use planning: a case study”, *Engineering Geology*, Vol. 61 No. 4, pp. 257-271. https://doi.org/10.1016/S0013-7952(01)00028-X

Deng, X., Hu, Y., Deng, Y., and Mahadevan, S. (2014), “Supplier selection using AHP methodology extended by D numbers”, *Expert Systems with Applications*, Vol. 41 No. 1, pp. 156-167. https://doi.org/10.1016/j.eswa.2013.07.018

Deng, Y. and Chan, F.T.S. (2011), “A new fuzzy dempster MCDM method and its application in supplier selection”, *Expert Systems with Applications*, Vol. 38 No. 8, pp. 9854-9861. https://doi.org/10.1016/j.eswa.2011.02.017

Drumond, P., Basilio, M.P., Costa, I.P.A., Pereira, D.A.M., Gomes, C.F.S., and Santos, M. (2021), “Multicriteria Analysis in Additive Manufacturing: An ELECTRE-MOr Based Approach”, Tallón-Ballesteros, A.J. (Ed.), Modern Management based on Big Data II and Machine Learning and Intelligent Systems III - Proceedings of MMBD 2021 and MLIS 2021, IOS Press BV, Amsterdam, Vol. 341, pp. 126-132. https://doi.org/10.3233/FAIA210240

Du, Y., Wang, W., Lu, Q., and Li, Z. (2020), “A DPSIR-TODIM Model Security Evaluation of China”s Rare Earth Resources”, *International Journal of Environmental Research and Public Health*, Vol. 17 No. 19. https://doi.org/10.3390/ijerph17197179

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Durak, İ., Arslan, H.M. and Özdemir, Y. (2021), “Application of AHP–TOPSIS methods in technopark selection of technology companies: Turkish case”, *Technology Analysis & Strategic Management*. https://doi.org/10.1080/09537325.2021.1925242

Dymova, L., Kaczmarek, K., Sevastjanov, P., Sułkowski, Ł. and Przybyszewski, K. (2021), “An Approach to Generalization of the Intuitionistic Fuzzy Topsis Method in the Framework of Evidence Theory”, *Journal of Artificial Intelligence and Soft Computing Research*, Vol. 11 No. 2, pp. 157-175. https://doi.org/10.2478/jaiscr-2021-0010

Escobar, M.T., Aguarón, J. and Moreno-Jiménez, J.M. (2004), “A note on AHP group consistency for the row geometric mean priorization procedure”, *European Journal of Operational Research*, Vol. 153 No. 2, pp. 318-322. https://doi.org/10.1016/S0377-2217(03)00154-1

Everest, T., Sungur, A. and Özcan, H. (2021), “Applying the Best–Worst Method for land evaluation: a case study for paddy cultivation in northwest Turkey”, *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-021-03373-4

Fallahpour, A., Olugu, E.U., Musa, S.N., Wong, K.Y., and Noori, S. (2017), “A decision support model for sustainable supplier selection in sustainable supply chain management”, *Computers & Industrial Engineering*, Vol. 105, pp. 391-410. https://doi.org/10.1016/j.cie.2017.01.005

Farahani, R.Z., SteadieSeifi, M. and Asgari, N. (2010), “Multiple criteria facility location problems: A survey”, *Applied Mathematical Modelling*, Vol. 34 No. 7, pp. 1689-1709. https://doi.org/10.1016/j.apm.2009.10.005

La Fata, C.M., Giallanza, A., Micale, R., and La Scalia, G. (2021), “Ranking of occupational health and safety risks by a multi-criteria perspective: Inclusion of human factors and application of VIKOR”, *Safety Science*, Vol. 138. https://doi.org/10.1016/j.ssci.2021.105234

Fei, L., Deng, Y. and Hu, Y. (2019), “DS-VIKOR: A New Multi-criteria Decision-Making Method for Supplier Selection”, *International Journal of Fuzzy Systems*, Vol. 21 No. 1, pp. 157–175. https://doi.org/10.1007/s40815-018-0543-y

Ferreira, F.A.F., Santos, S.P. and Rodrigues, P. M. M. (2011), “Adding value to bank branch performance evaluation using cognitive maps and MCDA: a case study”, *Journal of the Operational Research Society*, Vol. 62 No. 7, pp. 1320-1333. https://doi.org/10.1057/jors.2010.111

Ferretti, V. and Pomarico, S. (2013), “Ecological land suitability analysis through spatial indicators: An application of the Analytic Network Process technique and Ordered Weighted Average approach”, *Ecological Indicators*, Vol. 34, pp. 507-519. https://doi.org/10.1016/j.ecolind.2013.06.005

Filipe, M.N.M., Ferreira, F.A.F. and Santos, S.P. (2015), “A multiple criteria information system for pedagogical evaluation and professional development of teachers”, *Journal of the Operational Research Society*, Vol. 66 No. 11, pp. 1769-1782. https://doi.org/10.1057/jors.2014.129

Formisano, A. and Mazzolani, F.M. (2015), “On the selection by MCDM methods of the optimal system for seismic retrofitting and vertical addition of existing buildings”, *Computers & Structures*, Vol. 159, pp. 1-13. https://doi.org/10.1016/j.compstruc.2015.06.016

Fossile, D.K., Frej, E.A., da Costa, S.E.G., de Lima, E.P., and de Almeida, A.T. (2020), “Selecting the most viable renewable energy source for Brazilian ports using the FITradeoff method”, *Journal of Cleaner Production*, Vol. 260. https://doi.org/10.1016/j.jclepro.2020.121107

Fouladgar, M.M., Yazdani-Chamzini, A., Lashgari, A., Zavadskas, E.K., andTurskis, Z. (2012), "Maintenance strategy selection using AHP and COPRAS under fuzzy environment / Priežiūros

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

strategijos parinkimas taikant AHP ir COPRAS metodus neapibrėžtose situacijose", International Journal of Strategic Property Management, Vol. 16 No. 1, pp. 85-104. https://doi.org/10.3846/1648715X.2012.666657

Gamberini, R., Grassi, A. and Rimini, B. (2006), “A new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem”, *International Journal of Production Economics*, Vol. 102 No. 2, pp. 226-243. https://doi.org/10.1016/j.ijpe.2005.02.013

Garfì, M., Ferrer-Martí , L., Bonoli, A., and Tondelli, S. (2011), “Multi-criteria analysis for improving strategic environmental assessment of water programmes. A case study in semi-arid region of Brazil”, *Journal of Environmental Management*, Vol. 92 No. 3, pp. 665-675. https://doi.org/10.1016/j.jenvman.2010.10.007

Garg, H. (2017), “Novel intuitionistic fuzzy decision making method based on an improved operation laws and its application”, *Engineering Applications of Artificial Intelligence*, Vol. 60, pp. 164-174. https://doi.org/10.1016/j.engappai.2017.02.008

Gaviao, L.O., Sant'Anna, A.P., Lima, G.B.A., de Almada Garcia, P.A., Kostin, S., and Asrilhant, (2020), “Selecting a Cargo Aircraft for Humanitarian and Disaster Relief Operations by Multicriteria Decision Aid Methods”, *IEEE Transactions on Engineering Management*, Vol. 67 No. 3, pp. 631-640. https://doi.org/10.1109/TEM.2019.2956356

Gencer, C. and Gürpinar, D. (2007), “Analytic network process in supplier selection: A case study in an electronic firm”, *Applied Mathematical Modelling*, Vol. 31 No. 11, pp. 2475-2486. https://doi.org/10.1016/j.apm.2006.10.002

Gershon, M. (1984), "The role of weights and scales in the application of multiobjective decision making", European Journal of Operational Research, Vol. 15 No. 2 , pp. 244–250. https://doi.org/10.1016/0377-2217(84)90214-5

Ghasemi, P., Mehdiabadi, A., Spulbar, C., and Birau, R. (2021), “Ranking of Sustainable Medical Tourism Destinations in Iran: An Integrated Approach Using Fuzzy SWARA-PROMETHEE”, *Sustainability*, Vol. 13 No. 2. https://doi.org/10.3390/su13020683

Ghodsypour, S.H. and O”Brien, C. (1998), “A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming”, *International Journal of Production Economics*, Vol. 56–57, pp. 199-212. https://doi.org/10.1016/S0925-5273(97)00009-1

Ghosh, A. and Prasad, V.K.S. (2021), "Off-grid Solar energy systems adoption or usage - A Bibliometric Study using the Bibliometrix R tool", Library Philosophy and Practice (e-journal), Num Article 5673. https://digitalcommons.unl.edu/libphilprac/5673

Gohari, A., Tighnavard Balasbaneh, A., Yusof, K.W., Toloue, I., Taofeeq Sholagberu, A., and Hasan, R. (2020), “Comparative analysis of single- and multi-criteria container transport modes in Peninsular Malaysia”, *International Journal of Sustainable Engineering, Vol 14 No 5, pp. 1239-1250*. https://doi.org/10.1080/19397038.2020.1774819

Gorsevski, P.V., Donevska, K.R., Mitrovski, C.D., and Frizado, J.P.(2012), “Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average”, *Waste Management*, Vol. 32 No. 2, pp. 287-296. https://doi.org/10.1016/j.wasman.2011.09.023

Govindan, K. and Jepsen, M.B. (2016), “ELECTRE: A comprehensive literature review on methodologies and applications”, *European Journal of Operational Research*, Vol. 250 No. 1, pp. 1-29.

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

https://doi.org/10.1016/j.ejor.2015.07.019

Govindan, K., Khodaverdi, R. and Jafarian, A. (2013), “A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach”, *Journal of Cleaner Production*, Vol. 47, pp. 345-354. https://doi.org/10.1016/j.jclepro.2012.04.014

Greco, S., Figueira, J., and Ehrgott, M. (2016), Multiple Criteria Decision Analysis, Springer, Berlin/Heidelberg, Germany.

Greco, S., Matarazzo, B. and Slowinski, R. (2002), “Rough approximation by dominance relations”, *International Journal of Intelligent Systems*, Vol. 17 No. 2, pp. 153-171. https://doi.org/10.1002/int.10014

Guarnieri, P. and Trojan, F. (2019), “Decision making on supplier selection based on social, ethical, and environmental criteria: A study in the textile industry”, *Resources, Conservation and Recycling*, Vol. 141, pp. 347-361. https://doi.org/10.1016/j.resconrec.2018.10.023

Guitouni, A. and Martel, J.M. (1998), "Tentative guidelines to help choosing an appropriate MCDA method", European Journal of Operational Research, Vol. 109 No. 2, pp. 501–521. https://doi.org/10.1016/S0377-2217(98)00073-3

Guo, S. and Zhao, H. (2015), “Optimal site selection of electric vehicle charging station by using fuzzy TOPSIS based on sustainability perspective”, *Applied Energy*, Vol. 158, pp. 390–402. https://doi.org/10.1016/j.apenergy.2015.08.082

Guo, S. and Zhao, H. (2017), “Fuzzy best-worst multi-criteria decision-making method and its applications”, *Knowledge-Based Systems*, Vol. 121, pp. 23-31. https://doi.org/10.1016/j.knosys.2017.01.010

Hamzaçebi, C. and Pekkaya, M. (2011), “Determining of stock investments with grey relational analysis”, *Expert Systems with Applications*, Vol. 38 No. 8, pp. 9186-9195. https://doi.org/10.1016/j.eswa.2011.01.070

Hashemi, H., Mousavi, S., Zavadskas, E., Chalekaee, A., and Turskis, Z. (2018), “A New Group Decision Model Based on Grey-Intuitionistic Fuzzy-ELECTRE and VIKOR for Contractor Assessment Problem”, *Sustainability*, Vol. 10 No. 5. https://doi.org/10.3390/su10051635

Hashemi, S.H., Karimi, A. and Tavana, M. (2015), “An integrated green supplier selection approach with analytic network process and improved Grey relational analysis”, *International Journal of Production Economics*, Vol. 159, pp. 178-191. https://doi.org/10.1016/j.ijpe.2014.09.027

Hatami-Marbini, A. and Tavana, M. (2011), “An extension of the Electre I method for group decision-making under a fuzzy environment”, *Omega*, Vol. 39 No. 4, pp. 373-386. https://doi.org/10.1016/j.omega.2010.09.001

Hatefi, M.A. (2021), “BRAW: Block-wise Rating the Attribute Weights in MADM”, *Computers & Industrial Engineering*, Vol. 156. https://doi.org/10.1016/j.cie.2021.107274

He, L., Shao, F. and Ren, L. (2020), “Identifying optimal groundwater remediation strategies through a simulation-based PROMETHEE-TOPSIS approach: An application to a naphthalene-contaminated site”, *Human and Ecological Risk Assessment: An International Journal*, Vol. 26 No. 6, pp. 1550-1568. https://doi.org/10.1080/10807039.2019.1591267

Heidari, M.D., Gandasasmita, S., Li, E., and Pelletier, N. (2021), “Proposing a framework for sustainable feed formulation for laying hens: A systematic review of recent developments and future

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

directions", *Journal of Cleaner Production*, Vol. 288. https://doi.org/10.1016/j.jclepro.2020.125585

Hong, D.H. and Choi, C.-H. (2000), "Multicriteria fuzzy decision-making problems based on vague set theory", *Fuzzy Sets and Systems*, Vol. 114 No. 1, pp. 103-113. https://doi.org/10.1016/S0165-0114(98)00271-1

Hong, X., Bai, X. and Song, Y. (2021), "Selection of product recycling channels based on extended TODIM method", *Expert Systems with Applications*, Vol. 168. https://doi.org/10.1016/j.eswa.2020.114295

Hsu, C.-W. and Hu, A. H. (2009), "Applying hazardous substance management to supplier selection using analytic network process", *Journal of Cleaner Production*, Vol. 17 No. 2, pp. 255-264. https://doi.org/10.1016/j.jclepro.2008.05.004

Hua, Z., Gong, B. and Xu, X. (2008), "A DS–AHP approach for multi-attribute decision making problem with incomplete information", *Expert Systems with Applications*, Vol. 34 No. 3, pp. 2221-2227. https://doi.org/10.1016/j.eswa.2007.02.021

Ignatius, J., Rahman, A., Yazdani, M., Šaparauskas, J., and Haron, S. H. (2016), "An integrated fuzzy anp–qfd approach for green building assessment", *Journal Of Civil Engineering And Management*, Vol. 22 No. 4, pp. 551-563. https://doi.org/10.3846/13923730.2015.1120772

Jahan, A., Mustapha, F., Sapuan, S.M., Ismail, Md. Y., and Bahraminasab, M. (2012), "A framework for weighting of criteria in ranking stage of material selection process", *The International Journal of Advanced Manufacturing Technology*, Vol. 58 No. 1–4, pp. 411–420. https://doi.org/10.1007/s00170-011-3366-7

Jahanshahloo, G.R., Lotfi, F H. and Izadikhah, M. (2006), "An algorithmic method to extend TOPSIS for decision-making problems with interval data", *Applied Mathematics and Computation*, Vol. 175 No. 2, pp. 1375-1384. https://doi.org/10.1016/j.amc.2005.08.048

Jaiswal, P., Singh, A., Misra, S.C. and Kumar, A. (2021), "Barriers in implementing lean manufacturing in Indian SMEs: a multi-criteria decision-making approach", Journal of Modelling in Management, Vol. 16 No. 1, pp. 339-356. https://doi.org/10.1108/JM2-12-2019-0276

Jato-Espino, D., Castillo-Lopez, E., Rodriguez-Hernandez, J., and Canteras-Jordana, J. C. (2014), "A review of application of multi-criteria decision making methods in construction", *Automation in Construction*, Vol. 45, pp. 151-162. https://doi.org/10.1016/j.autcon.2014.05.013

Jeya Girubha, R. and Vinodh, S. (2012), "Application of fuzzy VIKOR and environmental impact analysis for material selection of an automotive component", *Materials & Design*, Vol. 37, pp. 478-486. https://doi.org/10.1016/j.matdes.2012.01.022

Joshi, D. and Kumar, S. (2016), "Interval-valued intuitionistic hesitant fuzzy Choquet integral based TOPSIS method for multi-criteria group decision making", *European Journal of Operational Research*, Vol. 248 No. 1, pp. 183-191. https://doi.org/10.1016/j.ejor.2015.06.047

Kadhim, M.H. and Mardukhi, F. (2021), "A Novel IoT Application Recommendation System Using Metaheuristic Multi-Criteria Analysis", *Computer Systems Science and Engineering*, Vol. 37 No. 2, pp. 149–158. https://doi.org/10.32604/csse.2021.014608

Kahraman, C., Kaya, İ. and Cebi, S. (2009), "A comparative analysis for multiattribute selection among renewable energy alternatives using fuzzy axiomatic design and fuzzy analytic hierarchy process", *Energy*, Vol. 34 No. 10, pp. 1603-1616. https://doi.org/10.1016/j.energy.2009.07.008

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Kahraman, C., Onar, S.C. and Oztaysi, B. (2015), “Fuzzy Multicriteria Decision-Making: A Literature Review”, *International Journal of Computational Intelligence Systems*, Vol. 8 No. 4, pp. 637-666. https://doi.org/10.1080/18756891.2015.1046325

Kahraman, C., Ruan, D. and Doğan, I. (2003), “Fuzzy group decision-making for facility location selection”, *Information Sciences*, Vol. 157, pp. 135-153. https://doi.org/10.1016/S0020-0255(03)00183-X

Kanchanamala Delanka-Pedige, H.M., Munasinghe-Arachchige, S.P., Abeysiriwardana-Arachchige, I.S. A., and Nirmalakhandan, N. (2021), “Evaluating wastewater treatment infrastructure systems based on UN Sustainable Development Goals and targets”, *Journal of Cleaner Production*, Vol. 298. https://doi.org/10.1016/j.jclepro.2021.126795

Kannan, D., Khodaverdi, R., Olfat, L., Jafarian, A., and Diabat, A. (2013), “Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain”, *Journal of Cleaner Production*, Vol. 47, pp. 355-367. https://doi.org/10.1016/j.jclepro.2013.02.010

Kaya, T. and Kahraman, C. (2010), “Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul”, *Energy*, Vol. 35 No. 6, pp. 2517-2527. https://doi.org/10.1016/j.energy.2010.02.051

Ghorabaee, M.K., Zavadskas, E.K., Amiri, M., and Esmaeili, A. (2016), “Multi-criteria evaluation of green suppliers using an extended WASPAS method with interval type-2 fuzzy sets”, *Journal of Cleaner Production*, Vol. 137, pp. 213-229. https://doi.org/10.1016/j.jclepro.2016.07.031

Khalilzadeh, M., Ghasemi, P., Afrasiabi, A. and Shakeri, H. (2021), "Hybrid fuzzy MCDM and FMEA integrating with linear programming approach for the health and safety executive risks: a case study", Journal of Modelling in Management. https://doi.org/10.1108/JM2-12-2019-0285

Khoso, A.R., Yusof, A.M., Khahro, S.H, Abidin, N.I.A.B., and Memon, N.A. (2021), “Automated two-stage continuous decision support model using exploratory factor analysis-MACBETH-SMART: an application of contractor selection in public sector construction”, *Journal of Ambient Intelligence and Humanized Computing*. https://doi.org/10.1007/s12652-021-03186-w

Kilic, H.S., Zaim, S. and Delen, D. (2015), “Selecting “The Best” ERP system for SMEs using a combination of ANP and PROMETHEE methods”, *Expert Systems with Applications*, Vol. 42 No. 5, pp. 2343-2352. https://doi.org/10.1016/j.eswa.2014.10.034

Kongar, E. and Gupta, S. M. (2006), “Disassembly to order system under uncertainty”, *Omega*, Vol. 34 No. 6, pp. 550-561. https://doi.org/10.1016/j.omega.2005.01.006

Kotikot, S.M., Kar, B. and Omitaomu, O.A. (2020), “A Geospatial Framework Using Multicriteria Decision Analysis for Strategic Placement of Reserve Generators in Puerto Rico”, *IEEE Transactions on Engineering Management, Vol. 67 No. 3, pp. 659-669*. https://doi.org/10.1109/TEM.2020.2964606

Kou, G., Lu, Y., Peng, Y., and Shi, Y. (2012), “EVALUATION OF CLASSIFICATION ALGORITHMS USING MCDM AND RANK CORRELATION”, *International Journal of Information Technology & Decision Making*, Vol. 11 No. 01, pp. 197-225. https://doi.org/10.1142/S0219622012500095

Krohling, R.A. and Campanharo, V.C. (2011), “Fuzzy TOPSIS for group decision making: A case study for accidents with oil spill in the sea”, *Expert Systems with Applications*, Vol. 38 No. 4, pp. 4190-4197. https://doi.org/10.1016/j.eswa.2010.09.081

Krohling, R.A. and de Souza, T.T.M. (2012), “Combining prospect theory and fuzzy numbers to multi-

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

criteria decision making", *Expert Systems with Applications*, Vol. 39 No. 13, pp. 11487-11493. https://doi.org/10.1016/j.eswa.2012.04.006

Kumar, A., Sah, B., Singh, A.R., Deng, Y., He, X., Kumar, P., and Bansal, R.C. (2017), "A review of multi criteria decision making (MCDM) towards sustainable renewable energy development", *Renewable and Sustainable Energy Reviews*, Vol. 69, pp. 596-609. https://doi.org/10.1016/j.rser.2016.11.191

Kumar, A. (2021), "Transition management theory-based policy framework for analyzing environmentally responsible freight transport practices", *Journal of Cleaner Production*, Vol. 294. https://doi.org/10.1016/j.jclepro.2021.126209

Kumar, A. and Dixit, G. (2018), "Evaluating critical barriers to implementation of WEEE management using DEMATEL approach", *Resources, Conservation and Recycling*, Vol. 131, pp. 101-121. https://doi.org/10.1016/j.resconrec.2017.12.024

Nayagam, V.L.G., Muralikrishnan, S. and Sivaraman, G. (2011) "Multi-criteria decision-making method based on interval-valued intuitionistic fuzzy sets", *Expert Systems with Applications*, Vol. 38 No. 3, pp. 1464-1467. https://doi.org/10.1016/j.eswa.2010.07.055

Leung, K.H., Lau, H.C.W., Nakandalab, D., Kong, X.T.R., and Ho, G.T.S. (2021), "Standardising fresh produce selection and grading process for improving quality assurance in perishable food supply chains: an integrated Fuzzy AHP-TOPSIS framework", *Enterprise Information Systems*, Vol. 15 No. 5, pp. 651-675. https://doi.org/10.1080/17517575.2020.1790041

Liang, D. and Xu, Z. (2017), "The new extension of TOPSIS method for multiple criteria decision making with hesitant Pythagorean fuzzy sets", *Applied Soft Computing*, Vol. 60, pp. 167-179. https://doi.org/10.1016/j.asoc.2017.06.034

Liang, X., Chen, T., Ye, M., Lin, H., and Li, Z. (2021), "A hybrid fuzzy BWM-VIKOR MCDM to evaluate the service level of bike-sharing companies: A case study from Chengdu, China", *Journal of Cleaner Production*, Vol. 298. https://doi.org/10.1016/j.jclepro.2021.126759

Liao, H., Xu, Z. and Zeng, X.-J. (2015), "Hesitant Fuzzy Linguistic VIKOR Method and Its Application in Qualitative Multiple Criteria Decision Making", *IEEE Transactions on Fuzzy Systems*, Vol. 23 No. 5, pp. 1343-1355. https://doi.org/10.1109/TFUZZ.2014.2360556

Lima-Junior, F.R. and Carpinetti, L.C.R. (2017), "Quantitative models for supply chain performance evaluation: A literature review", *Computers & Industrial Engineering*, Vol. 113, pp. 333-346. https://doi.org/10.1016/j.cie.2017.09.022

Lima Junior, F.R., Osiro, L. and Carpinetti, L.C.R. (2014), "A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection", *Applied Soft Computing*, Vol. 21, pp. 194-209. https://doi.org/10.1016/j.asoc.2014.03.014

Lin, Y.-F. (2021), "Construction of Consistent Comparison Matrix by Macharis" Method Revisit", *Mathematical Problems in Engineering*, Vol. 2021, Article ID 5585662, pages 7. https://doi.org/10.1155/2021/5585662

Liou, J.J.H., Tamošaitienė, J., Zavadskas, E.K., and Tzeng, G.-H. (2016), "New hybrid COPRAS-G MADM Model for improving and selecting suppliers in green supply chain management", *International Journal of Production Research*, Vol. 54 No. 1, pp. 114-134. https://doi.org/10.1080/00207543.2015.1010747

Liou, J.J.H., Chuang, Y.-C. and Tzeng, G.-H. (2014), "A fuzzy integral-based model for supplier evaluation and improvement", *Information Sciences*, Vol. 266, pp. 199-217.

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

https://doi.org/10.1016/j.ins.2013.09.025

Liu, H.-C., Yang, M., Zhou, M., and Tian, G. (2019), "An Integrated Multi-Criteria Decision Making Approach to Location Planning of Electric Vehicle Charging Stations", *IEEE Transactions on Intelligent Transportation Systems*, Vol. 20 No. 1, pp. 362-373. https://doi.org/10.1109/TITS.2018.2815680

Liu, H. and Rodríguez, R.M. (2014), "A fuzzy envelope for hesitant fuzzy linguistic term set and its application to multicriteria decision making", *Information Sciences*, Vol. 258, pp. 220-238. https://doi.org/10.1016/j.ins.2013.07.027

Liu, J.-C. and Li, D.-F. (2018), "Corrections to "TOPSIS-Based Nonlinear-Programming Methodology for Multi-attribute Decision Making With Interval-Valued Intuitionistic Fuzzy Sets" [Apr 10 299-311]", *IEEE Transactions on Fuzzy Systems*, Vol. 26 No. 1, pp. 391-391. https://doi.org/10.1109/TFUZZ.2016.2637375

Liu, P. and Wang, P. (2018), "Some q-Rung Orthopair Fuzzy Aggregation Operators and their Applications to Multiple-Attribute Decision Making", *International Journal of Intelligent Systems*, Vol. 33 No. 2, pp. 259-280. https://doi.org/10.1002/int.21927

Liu, X. and Ma, Y. (2021), "A method to analyze the rank reversal problem in the ELECTRE II method", *Omega*, Vol. 102. https://doi.org/10.1016/j.omega.2020.102317

Lo, H.-W., Liou, J.J.H., Wang, H.-S., and Tsai, Y.-S. (2018), "An integrated model for solving problems in green supplier selection and order allocation", *Journal of Cleaner Production*, Vol. 190, pp. 339-352. https://doi.org/10.1016/j.jclepro.2018.04.105

Lu, M.-T., Lin, S.-W. and Tzeng, G.-H. (2013), "Improving RFID adoption in Taiwan"s healthcare industry based on a DEMATEL technique with a hybrid MCDM model", *Decision Support Systems*, Vol. 56, pp. 259-269. https://doi.org/10.1016/j.dss.2013.06.006

Luna, M., Llorente, I. and Cobo, A. (2020), "A fuzzy approach to decision-making in sea-cage aquaculture production", *International Transactions in Operational Research*, Vol. 29 No. 2, pp. 1025-1047.https://doi.org/10.1111/itor.12866

Lupo, T. (2015), "Fuzzy ServPerf model combined with ELECTRE III to comparatively evaluate service quality of international airports in Sicily", *Journal of Air Transport Management*, Vol. 42, pp. 249-259. https://doi.org/10.1016/j.jairtraman.2014.11.006

Luthra, S., Govindan, K., Kannan, D., Mangla, S.K., and Garg, C.P. (2017), "An integrated framework for sustainable supplier selection and evaluation in supply chains", *Journal of Cleaner Production*, Vol. 140, pp. 1686-1698. https://doi.org/10.1016/j.jclepro.2016.09.078

Maeda, S.M.N., Basilio, M.P., Costa, I.P.A., Moreira, M.A.L., Santos, M., Gomes, C.F.S., Almeida, I.D.P., and Costa, A.P.A. (2021), "Investments in Times of Pandemics: An Approach by the SAPEVO-M-NC Method", Tallón-Ballesteros, A.J. (Ed.), Modern Management based on Big Data II and Machine Learning and Intelligent Systems III - Proceedings of MMBD 2021 and MLIS 2021, IOS Press BV, Amsterdam, Vol. 341, pp. 162-168. https://doi.org/10.3233/FAIA210244

Maeda, S.M.N., Basílio, M.P., Costa, I.P.A., Moreira, M.A.L., Santos, M., and Gomes, C.F.S. (2021a), "The SAPEVO-M-NC Method", Tallón-Ballesteros, A.J. (Ed.), Modern Management based on Big Data II and Machine Learning and Intelligent Systems III - Proceedings of MMBD 2021 and MLIS 2021, IOS Press BV, Amsterdam, Vol. 341, pp. 89-95. https://doi.org/10.3233/FAIA210235

Majumdar, A., Biswas, A., Majumder, A., Sood, S.K., and Baishnab, K.L. (2021), "A novel DNA-inspired encryption strategy for concealing cloud storage", *Frontiers of Computer Science*, Vol. 15 No. 3, pp. .

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

https://doi.org/10.1007/s11704-019-9015-2

Mansor, M.R., Sapuan, S.M., Zainudin, E.S., Nuraini, A.A., and Hambali, A. (2014), "Conceptual design of kenaf fiber polymer composite automotive parking brake lever using integrated TRIZ–Morphological Chart–Analytic Hierarchy Process method", *Materials & Design (1980-2015)*, Vol. 54, pp. 473-482. https://doi.org/10.1016/j.matdes.2013.08.064

Mardani, A., Jusoh, A., MD Nor, K., Khalifah, Z., Zakwan, N., and Valipour, A. (2015), "Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014", *Economic Research-Ekonomska Istraživanja*, Vol. 28 No. 1, pp. 516-571. https://doi.org/10.1080/1331677X.2015.1075139

Mardani, A., Jusoh, A. and Zavadskas, E.K. (2015), "Fuzzy multiple criteria decision-making techniques and applications – Two decades review from 1994 to 2014", *Expert Systems with Applications*, Vol. 42 No. 8, pp. 4126-4148. https://doi.org/10.1016/j.eswa.2015.01.003

Morais, D.C. and de Almeida, A.T. (2012), "Group decision making on water resources based on analysis of individual rankings", *Omega*, Vol. 40 No. 1, pp. 42-52. https://doi.org/10.1016/j.omega.2011.03.005

Moreira, M.A.L., Gomes, C.F.S., dos Santos, M., Basilio, M.P., Costa, I.P.A., Rocha Jumior,C.S., Jardim, R.R.-A. J. (2022), "Evaluation of drones for public security: a multicriteria approach by the PROMETHEE-SAPEVO-M1 systematic", Procedia Computer Science, Vol. 199, pp. 125-133. https://doi.org/10.1016/j.procs.2022.01.016.

Moreno-Calderón, A., Tong, T. S. and Thokala, P. (2020), "Multi-criteria Decision Analysis Software in Healthcare Priority Setting: A Systematic Review", *PharmacoEconomics*, Vol. 38 No. 3, pp. 269–283. https://doi.org/10.1007/s40273-019-00863-9

Mousavi, M.M. and Lin, J. (2020), "The application of PROMETHEE multi-criteria decision aid in financial decision making: Case of distress prediction models evaluation", *Expert Systems with Applications*, Vol. 159. https://doi.org/10.1016/j.eswa.2020.113438

Nepomuceno, T.C.C., Daraio, C. and Costa, A.P.C.S. (2021), "Multicriteria Ranking for the Efficient and Effective Assessment of Police Departments", *Sustainability*, Vol. 13 No. 8, pp. 4251-4266. https://doi.org/10.3390/su13084251

Ngai, E.W.T. and Chan, E.W.C. (2005), "Evaluation of knowledge management tools using AHP", *Expert Systems with Applications*, Vol. 29 No. 4, pp. 889-899. https://doi.org/10.1016/j.eswa.2005.06.025

Nie, R., Tian, Z.-P., Wang, J.-Q., Zhang, H.-Y., and Wang, T.-L. (2018), "Water security sustainability evaluation: Applying a multistage decision support framework in industrial region", *Journal of Cleaner Production*, Vol. 196, pp. 1681-1704. https://doi.org/10.1016/j.jclepro.2018.06.144

Norese, M.F. (2006), "ELECTRE III as a support for participatory decision-making on the localisation of waste-treatment plants", *Land Use Policy*, Vol. 23 No. 1, pp. 76-85. https://doi.org/10.1016/j.landusepol.2004.08.009

Oliveira, M.D.N.T., Ferreira, F.A.F., Ilander, G.O.P.B., and Jalali, M.S. (2017), "Integrating cognitive mapping and MCDA for bankruptcy prediction in small- and medium-sized enterprises", *Journal of the Operational Research Society*, Vol. 68 No. 9, pp. 985-997. https://doi.org/10.1057/s41274-016-0166-3

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Onat, N.C., Gumus, S., Kucukvar, M., and atari, O. (2016), “Application of the TOPSIS and intuitionistic fuzzy set approaches for ranking the life cycle sustainability performance of alternative vehicle technologies”, *Sustainable Production and Consumption*, Vol. 6, pp. 12-25. https://doi.org/10.1016/j.spc.2015.12.003

Önüt, S., Kara, S.S. and Işik, E. (2009), “Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company”, *Expert Systems with Applications*, Vol. 36 No. 2, pp. 3887-3895. https://doi.org/10.1016/j.eswa.2008.02.045

Önüt, S. and Soner, S. (2008), “Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment”, *Waste Management*, Vol. 28 No. 9, pp. 1552-1559. https://doi.org/10.1016/j.wasman.2007.05.019

Opricovic, S. and Tzeng, G.-H. (2004), “Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS”, *European Journal of Operational Research*, Vol. 156 No. 2, pp. 445-455. https://doi.org/10.1016/S0377-2217(03)00020-1

Opricovic, S. and Tzeng, G.-H. (2007), “Extended VIKOR method in comparison with outranking methods”, *European Journal of Operational Research*, Vol. 178 No. 2, pp. 514-529. https://doi.org/10.1016/j.ejor.2006.01.020

Özceylan, E., Erbaş, M., Çetinkaya, C., and Kabak, M. (2021), “Analysis of Potential High-Speed Rail Routes: A Case of GIS-Based Multicriteria Evaluation in Turkey”, *Journal of Urban Planning and Development*, Vol. 147 No. 2. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000674

Passos, A.C., Teixeira, M.G., Garcia, K.C., Cardoso, A.M., and Gomes, L.F.A.. (2014), “Using the TODIM-FSE method as a decision-making support methodology for oil spill response”, *Computers & Operations Research*, Vol. 42, pp. 40-48. https://doi.org/10.1016/j.cor.2013.04.010

Pati, R., Vrat, P. and Kumar, P. (2008), “A goal programming model for paper recycling system☆”, *Omega*, Vol. 36 No. 3, pp. 405-417. https://doi.org/10.1016/j.omega.2006.04.014

Pelissari, R., Oliveira, M.C., Abackerli, A.J., Ben-Amor, S., and Assumpção, M.R.P. (2021), “Techniques to model uncertain input data of multi-criteria decision-making problems: a literature review”, *International Transactions in Operational Research*, Vol. 28 No. 2, pp. 523-559. https://doi.org/10.1111/itor.12598

Peng, J., Wang, J.-Q., Zhang, H.-Y., and Chen, X.-H. (2014), “An outranking approach for multi-criteria decision-making problems with simplified neutrosophic sets”, *Applied Soft Computing*, Vol. 25, pp. 336-346. https://doi.org/10.1016/j.asoc.2014.08.070

Pereira, V. and Costa, H.G. (2015), “Nonlinear programming applied to the reduction of inconsistency in the AHP method”, *Annals of Operations Research*, Vol. 229 No. 1, pp. 635–655. https://doi.org/10.1007/s10479-014-1750-z

Petrillo, A., De Felice, F., Jannelli, E., Autorino, C., Minutillo, M., and Lavadera, A.L. (2016), “Life cycle assessment (LCA) and life cycle cost (LCC) analysis model for a stand-alone hybrid renewable energy system”, *Renewable Energy*, Vol. 95, pp. 337-355. https://doi.org/10.1016/j.renene.2016.04.027

Pires, A., Chang, N.-B. and Martinho, G. (2011), “An AHP-based fuzzy interval TOPSIS assessment for sustainable expansion of the solid waste management system in Setúbal Peninsula, Portugal”, *Resources, Conservation and Recycling*, Vol. 56 No. 1, pp. 7-21. https://doi.org/10.1016/j.resconrec.2011.08.004

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Pohekar, S.D. and Ramachandran, M. (2004), “Application of multi-criteria decision making to sustainable energy planning—A review”, *Renewable and Sustainable Energy Reviews*, Vol. 8 No. 4, pp. 365-381. https://doi.org/10.1016/j.rser.2003.12.007

Pons, O. and Aguado, A. (2012), “Integrated value model for sustainable assessment applied to technologies used to build schools in Catalonia, Spain”, *Building and Environment*, Vol. 53, pp. 49-58. https://doi.org/10.1016/j.buildenv.2012.01.007

Qin, J., Liu, X. and Pedrycz, W. (2017), “An extended TODIM multi-criteria group decision making method for green supplier selection in interval type-2 fuzzy environment”, *European Journal of Operational Research*, Vol. 258 No. 2, pp. 626-638. https://doi.org/10.1016/j.ejor.2016.09.059

Rafi, S., Yu, W., Akbar, M.A., Alsanad, A., and Gumaei, A.(2020), “Prioritization Based Taxonomy of DevOps Security Challenges Using PROMETHEE”, *IEEE Access*, Vol. 8, pp. 105426-105446. https://doi.org/10.1109/ACCESS.2020.2998819

Rahmati, O., Samani, A.N., Mahdavi, M., Pourghasemi, H.R., and Zeinivand, H. (2015), “Groundwater potential mapping at Kurdistan region of Iran using analytic hierarchy process and GIS”, *Arabian Journal of Geosciences*, Vol. 8 No. 9, pp. 7059–7071. https://doi.org/10.1007/s12517-014-1668-4

Raju, K.S. and Kumar, D.N. (2006), “Ranking Irrigation Planning Alternatives Using Data Envelopment Analysis”, *Water Resources Management*, Vol. 20 No. 4, pp. 553–566. https://doi.org/10.1007/s11269-006-3090-5

Ramanathan, R. (2001), “A note on the use of the analytic hierarchy process for environmental impact assessment”, *Journal of Environmental Management*, Vol. 63 No. 1, pp. 27-35. https://doi.org/10.1006/jema.2001.0455

Ramirez-Atencia, C., Rodriguez-Fernandez, V. and Camacho, D. (2020), “A revision on multi-criteria decision making methods for multi-UAV mission planning support”, *Expert Systems with Applications*, Vol. 160. https://doi.org/10.1016/j.eswa.2020.113708

Rani, P., Mishra, A.R., Pardasani, K.R., Mardani, A., Liao, H., and Streimikiene, D. (2019), “A novel VIKOR approach based on entropy and divergence measures of Pythagorean fuzzy sets to evaluate renewable energy technologies in India”, *Journal of Cleaner Production*, Vol. 238. https://doi.org/10.1016/j.jclepro.2019.117936

Ravi, V., Shankar, R. and Tiwari, M.K. (2005), “Analyzing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach”, *Computers & Industrial Engineering*, Vol. 48 No. 2, pp. 327-356. https://doi.org/10.1016/j.cie.2005.01.017

Reig-Mullor, J. and Brotons-Martinez, J.M. (2021), “The evaluation performance for commercial banks by intuitionistic fuzzy numbers: the case of Spain”, *Soft Computing*, Vol. 25, pp. 9061–9075. https://doi.org/10.1007/s00500-021-05847-6

Ren, P., Xu, Z. and Gou, X. (2016), “Pythagorean fuzzy TODIM approach to multi-criteria decision making”, *Applied Soft Computing*, Vol. 42, pp. 246-259. https://doi.org/10.1016/j.asoc.2015.12.020

Rezaeisaray, M., Ebrahimnejad, S. and Khalili-Damghani, K. (2016), “A novel hybrid MCDM approach for outsourcing supplier selection”, *Journal of Modelling in Management*, Vol. 11 No. 2, pp. 536-559. https://doi.org/10.1108/JM2-06-2014-0045

Rodríguez, A., Ortega, F. and Concepción, R. (2016), “A method for the evaluation of risk in IT projects”, *Expert Systems with Applications*, Vol. 45, pp. 273-285. https://doi.org/10.1016/j.eswa.2015.09.056

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Romero, C. (2001), “Extended lexicographic goal programming: a unifying approach”, *Omega*, Vol. 29 No. 1, pp. 63-71. https://doi.org/10.1016/S0305-0483(00)00026-8

Romero, C. (2004), “A general structure of achievement function for a goal programming model”, *European Journal of Operational Research*, Vol. 153 No. 3, pp. 675-686. https://doi.org/10.1016/S0377-2217(02)00793-2

Rostamzadeh, R., Govindan, K., Esmaeili, A., and Sabaghi, M. (2015), “Application of fuzzy VIKOR for evaluation of green supply chain management practices”, *Ecological Indicators*, Vol. 49, pp. 188-203. https://doi.org/10.1016/j.ecolind.2014.09.045

Roy, S., Bose, A. and Mandal, G. (2021), “Modeling and mapping geospatial distribution of groundwater potential zones in Darjeeling Himalayan region of India using analytical hierarchy process and GIS technique”, *Modeling Earth Systems and Environment*. https://doi.org/10.1007/s40808-021-01174-9

Saaty, T.L. (2013), “The Modern Science of Multicriteria Decision Making and Its Practical Applications: The AHP/ANP Approach”, *Operations Research*, Vol. 61 No. 5, pp. 1101-1118. https://doi.org/10.1287/opre.2013.1197

Saaty, T.L. and Ergu, D. (2015), “When is a Decision-Making Method Trustworthy? Criteria for Evaluating Multi-Criteria Decision-Making Methods”, *International Journal of Information Technology & Decision Making*, Vol. 14 No. 06, pp. 1171-1187. https://doi.org/10.1142/S021962201550025X

Saaty, T. and De Paola, P. (2017), “Rethinking Design and Urban Planning for the Cities of the Future”, *Buildings*, Vol. 7 No. 4, pp. 76-98. https://doi.org/10.3390/buildings7030076

Sałabun, W., Wątróbski, J., and Shekhovtsov, A. (2020), "Are MCDA Methods Benchmarkable? A Comparative Study of TOPSIS, VIKOR, COPRAS, and PROMETHEE II Methods", Symmetry, Vol. 12 No. 9, Article Number 1549. http://dx.doi.org/10.3390/sym12091549

Salih, M.M., Zaidan, B.B., Zaidan, A.A., and Ahmed, M.A. (2019), “Survey on fuzzy TOPSIS state-of-the-art between 2007 and 2017”, *Computers & Operations Research*, Vol. 104, pp. 207-227. https://doi.org/10.1016/j.cor.2018.12.019

Sanayei, A., Farid Mousavi, S. and Yazdankhah, A. (2010), “Group decision making process for supplier selection with VIKOR under fuzzy environment”, *Expert Systems with Applications*, Vol. 37 No. 1, pp. 24-30. https://doi.org/10.1016/j.eswa.2009.04.063

Sánchez-Lozano, J.M., Teruel-Solano, J., oto-Elvira, P.L., and García-Cascales, M.S. (2013), “Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) methods for the evaluation of solar farms locations: Case study in south-eastern Spain”, *Renewable and Sustainable Energy Reviews*, Vol. 24, pp. 544-556. https://doi.org/10.1016/j.rser.2013.03.019

Sánchez-Lozano, J.M., García-Cascales, M.S. and Lamata, M.T. (2016), “GIS-based onshore wind farm site selection using Fuzzy Multi-Criteria Decision Making methods. Evaluating the case of Southeastern Spain”, *Applied Energy*, Vol. 171, pp. 86-102. https://doi.org/10.1016/j.apenergy.2016.03.030

Sangaiah, A.K., Samuel, O.W., Li, X., Abdel-Basset, M., and Wang, H. (2018), “Towards an efficient risk assessment in software projects–Fuzzy reinforcement paradigm”, *Computers & Electrical Engineering*, Vol. 71, pp. 833-846. https://doi.org/10.1016/j.compeleceng.2017.07.022

Sangiorgio, V., Di Pierro, B., Roccotelli, M., and Silvestri, B. (2021), “Card game analysis for fast multi-criteria decision making”, *RAIRO - Operations Research*, Vol. 55 No. 3, pp. 1213 - 1229.

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

https://doi.org/10.1051/ro/2021059

Santos, L.F. de O.M., Osiro, L. and Lima, R.H.P. (2017), "A model based on 2-tuple fuzzy linguistic representation and Analytic Hierarchy Process for supplier segmentation using qualitative and quantitative criteria", *Expert Systems with Applications*, Vol. 79, pp. 53-64. https://doi.org/10.1016/j.eswa.2017.02.032

Saraswat, S.K. and Digalwar, A.K. (2021), "Evaluation of energy alternatives for sustainable development of energy sector in India: An integrated Shannon"s entropy fuzzy multi-criteria decision approach", *Renewable Energy*, Vol. 171, pp. 58-74. https://doi.org/10.1016/j.renene.2021.02.068

Sarkis, J. (2000), "A comparative analysis of DEA as a discrete alternative multiple criteria decision tool", *European Journal of Operational Research*, Vol. 123 No. 3, pp. 543-557. https://doi.org/10.1016/S0377-2217(99)00099-5

Sarwar, M., Akram, M. and Liu, P. (2021), "An integrated rough ELECTRE II approach for risk evaluation and effects analysis in automatic manufacturing process", *Artificial Intelligence Review,* Vol. 54, pp. 4449–4481. https://doi.org/10.1007/s10462-021-10003-5

Sayadi, M.K., Heydari, M. and Shahanaghi, K. (2009), "Extension of VIKOR method for decision making problem with interval numbers", *Applied Mathematical Modelling*, Vol. 33 No. 5, pp. 2257-2262. https://doi.org/10.1016/j.apm.2008.06.002

Serafim, M.B., Siegle, E., Corsi, A.C., and Bonetti, J. (2019), "Coastal vulnerability to wave impacts using a multi-criteria index: Santa Catarina (Brazil)", *Journal of Environmental Management*, Vol. 230, pp. 21-32. https://doi.org/10.1016/j.jenvman.2018.09.052

Serugga, J., Kagioglou, M. and Tzortzopolous, P. (2020), "A Utilitarian Decision—Making Approach for Front End Design—A Systematic Literature Review", *Buildings*, Vol. 10 No. 2, pp. 34-63. https://doi.org/10.3390/buildings10020034

Shahabi, H. and Hashim, M. (2015), "Landslide susceptibility mapping using GIS-based statistical models and Remote sensing data in tropical environment", *Scientific Reports*, Vol. 5 No. 1. https://doi.org/10.1038/srep09899

Shemshadi, A., Shirazi, H., Toreihi, M. and Tarokh, M.J. (2011), "A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting", *Expert Systems with Applications*, Vol. 38 No. 10, pp. 12160-12167. https://doi.org/10.1016/j.eswa.2011.03.027

Sierra, L.A., Yepes, V. and Pellicer, E. (2018), "A review of multi-criteria assessment of the social sustainability of infrastructures", *Journal of Cleaner Production*, Vol. 187, pp. 496-513. https://doi.org/10.1016/j.jclepro.2018.03.022

Sievert, C. and Shirley, K. (2014), *LDAvis: A Method for Visualizing and Interpreting Topics*, *ACL Workshop on Interactive Language Learning, Visualization, and Interfaces*. Available at: http://nlp.stanford.edu/events/illvi2014/papers/sievert-illvi2014.pdf.

Siksnelyte-Butkiene, I., Zavadskas, E.K. and Streimikiene, D. (2020), "Multi-Criteria Decision-Making (MCDM) for the Assessment of Renewable Energy Technologies in a Household: A Review", *Energies*, Vol. 13 No. 5, pp. 1164-1186. https://doi.org/10.3390/en13051164

Silva, M. do C., Gavião, L.O., Gomes, C.F.S. and Lima, G.B.A. (2020), "Global Innovation Indicators analysed by multicriteria decision", *Brazilian Journal of Operations & Production Management*, Vol. 17 No. 4, pp. 1–17. https://doi.org/10.14488/BJOPM.2020.040

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Silvestri, A., De Felice, F. and Petrillo, A. (2012), "Multi-criteria risk analysis to improve safety in manufacturing systems", *International Journal of Production Research*, Vol. 50 No. 17, pp. . 4806-4821. https://doi.org/10.1080/00207543.2012.657968

Simon, H.A. (1955), A behavioral model of rational choice, *The Quarterly Journal of Economics*, Vol. 69 No. 1, pp. 99–118.

Sipahi, S. and Timor, M. (2010), "The analytic hierarchy process and analytic network process: an overview of applications", *Management Decision*, Vol. 48 No. 5, pp. 775-808. https://doi.org/10.1108/00251741011043920

Soares, L.M.B., Moreira, M.A.L., Basílio, M.P., Gomes, C.F.S., Santos, M., and Costa, I.P.A. (2021), "Strategic Analysis for the Installation of Field Hospitals for COVID-19 Control: An Approach Based on P-Median Model", Tallón-Ballesteros, A.J. (Ed.), Modern Management based on Big Data II and Machine Learning and Intelligent Systems III - Proceedings of MMBD 2021 and MLIS 2021, IOS Press BV, Amsterdam, Vol. 341, pp. 112-118. https://doi.org/10.3233/FAIA210238

Syan, C.S. and Ramsoobag, G. (2019), "Maintenance applications of multi-criteria optimization: A review", *Reliability Engineering & System Safety*, Vol. 190. https://doi.org/10.1016/j.ress.2019.106520

Tam, M.C.Y. and Tummala, V.M.R. (2001), "An application of the AHP in vendor selection of a telecommunications system", *Omega*, Vol. 29 No. 2, pp. 171-182. https://doi.org/10.1016/S0305-0483(00)00039-6

Tamiz, M., Jones, D. and Romero, C. (1998), "Goal programming for decision making: An overview of the current state-of-the-art", *European Journal of Operational Research*, Vol. 111 No. 3, pp. 569-581. https://doi.org/10.1016/S0377-2217(97)00317-2

Tan, C. (2011), "A multi-criteria interval-valued intuitionistic fuzzy group decision making with Choquet integral-based TOPSIS", *Expert Systems with Applications*, Vol. 38 No. 4, pp. 3023-3033. https://doi.org/10.1016/j.eswa.2010.08.092

Tavana, M., Li, Z., Mobin, M., Komaki, M., and Teymourian, E. (2016), "Multi-objective control chart design optimization using NSGA-III and MOPSO enhanced with DEA and TOPSIS", *Expert Systems with Applications*, Vol. 50, pp. 17-39. https://doi.org/10.1016/j.eswa.2015.11.007

Teixeira de Almeida, A. (2007), "Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method", *Computers & Operations Research*, Vol. 34 No. 12, pp. 3569-3574. https://doi.org/10.1016/j.cor.2006.01.003

Tian, Z., Wang, J., Wang, J.Q., and Zhang, H.-Y. (2017), "Simplified Neutrosophic Linguistic Multi-criteria Group Decision-Making Approach to Green Product Development", *Group Decision and Negotiation*, Vol. 26 No. 3, pp. 597–627. https://doi.org/10.1007/s10726-016-9479-5

Tien Bui, D., Khosravi, K., Li, S., Shahabi, H., Panahi, M., Singh, V., Chapi, K., Shirzadi, A., Panahi, S., Chen, W., and Bin Ahmad, B. (2018), "New Hybrids of ANFIS with Several Optimization Algorithms for Flood Susceptibility Modeling", *Water*, Vol. 10 No. 9, pp. 1210-1238. https://doi.org/10.3390/w10091210

Torfi, F., Farahani, R.Z. and Rezapour, S. (2010), "Fuzzy AHP to determine the relative weights of evaluation criteria and Fuzzy TOPSIS to rank the alternatives", *Applied Soft Computing*, Vol. 10 No. 2, pp. 520-528. https://doi.org/10.1016/j.asoc.2009.08.021

Tsaur, S.-H., Chang, T.-Y. and Yen, C.-H. (2002), "The evaluation of airline service quality by fuzzy

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

MCDM", *Tourism Management*, Vol. 23 No. 2, pp. 107-115. https://doi.org/10.1016/S0261-5177(01)00050-4

Tseng, M.-L. (2011), "Using a hybrid MCDM model to evaluate firm environmental knowledge management in uncertainty", *Applied Soft Computing*, Vol. 11 No. 1, pp. 1340-1352. https://doi.org/10.1016/j.asoc.2010.04.006

Tuzkaya, G., Ozgen, A., Ozgen, D., and Tuzkaya, U.R. (2009), "Environmental performance evaluation of suppliers: A hybrid fuzzy multi-criteria decision approach", *International Journal of Environmental Science & Technology*, Vol. 6 No. 3, pp. 477–490. https://doi.org/10.1007/BF03326087

Tzeng, G.-H. and Huang, C.-Y. (2012), "Combined DEMATEL technique with hybrid MCDM methods for creating the aspired intelligent global manufacturing & logistics systems", *Annals of Operations Research*, Vol. 197 No. 1, pp. 159–190. https://doi.org/10.1007/s10479-010-0829-4

Tzeng, G., Chiang, C. and LI, C. (2007), "Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL", *Expert Systems with Applications*, Vol. 32 No. 4, pp. 1028-1044. https://doi.org/10.1016/j.eswa.2006.02.004

Umer, R., Touqeer, M., Omar, A.H., Ahmadian, A., Salahshour, S., and Ferrara, M. (2021), "Selection of solar tracking system using extended TOPSIS technique with interval type-2 pythagorean fuzzy numbers", *Optimization and Engineering, Vol. 22, pp. 2205–2231*. https://doi.org/10.1007/s11081-021-09623-1

Vahdani, B., Mousavi, S.M., Tavakkoli-Moghaddam, R., and Hashemi, H. (2013), "A new design of the elimination and choice translating reality method for multi-criteria group decision-making in an intuitionistic fuzzy environment", *Applied Mathematical Modelling*, Vol. 37 No. 4, pp. 1781-1799. https://doi.org/10.1016/j.apm.2012.04.033

Vahdani, B., Mousavi, S.M. and Tavakkoli-Moghaddam, R. (2011), "Group decision making based on novel fuzzy modified TOPSIS method", *Applied Mathematical Modelling*, Vol. 35 No. 9, pp. 4257-4269. https://doi.org/10.1016/j.apm.2011.02.040

Vashishtha, S. and Ramachandran, M. (2006), "Multicriteria evaluation of demand side management (DSM) implementation strategies in the Indian power sector", *Energy*, Vol. 31 No. 12, pp. 2210-2225. https://doi.org/10.1016/j.energy.2005.10.005

Vinodh, S., Prasanna, M. and Hari Prakash, N. (2014), "Integrated Fuzzy AHP–TOPSIS for selecting the best plastic recycling method: A case study", *Applied Mathematical Modelling*, Vol. 38 No. 19–20, pp. 4662-4672. https://doi.org/10.1016/j.apm.2014.03.007

Wallenius, J., Dyer, J.S., Fishburn, P.C., Steuer, R.E., Zionts, S., and Deb, K. (2008), "Multiple Criteria Decision Making, Multiattribute Utility Theory: Recent Accomplishments and What Lies Ahead", *Management Science*, Vol. 54 No. 7, pp. 1336-1349. https://doi.org/10.1287/mnsc.1070.0838

Wang, C.-N., Nguyen, V.T., Thai, H.T.N., and Duong, D.H. (2018), "Multi-Criteria Decision Making (MCDM) Approaches for Solar Power Plant Location Selection in Viet Nam", *Energies*, Vol. 11 No. 6, pp. 1504-1531. https://doi.org/10.3390/en11061504

Wang, J.-J., Jing, Y.-Y., Zhang, C.-F., Shi, G.-H., and Zhang, X.-T. (2008), "A fuzzy multi-criteria decision-making model for trigeneration system", *Energy Policy*, Vol. 36 No. 10, pp. 3823–3832. https://doi.org/10.1016/j.enpol.2008.07.002

Wang, J.-Q., Wu, J.T., Wang, J., Zhang, H.-Y., and Chen, X.-H. (2016), "Multi-criteria decision-making methods based on the Hausdorff distance of hesitant fuzzy linguistic numbers", *Soft Computing*, Vol.

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

20 No. 4, pp. 1621–1633. https://doi.org/10.1007/s00500-015-1609-5

Wang, J., Wang, Jian-qiang and Zhang, H. (2016), “A likelihood-based TODIM approach based on multi-hesitant fuzzy linguistic information for evaluation in logistics outsourcing”, *Computers & Industrial Engineering*, Vol. 99, pp. 287-299. https://doi.org/10.1016/j.cie.2016.07.023

Wang, P., Zhu, Z. and Wang, Y. (2016), “A novel hybrid MCDM model combining the SAW, TOPSIS and GRA methods based on experimental design”, *Information Sciences*, Vol. 345, pp. 27-45. https://doi.org/10.1016/j.ins.2016.01.076

Wanke, P., Pestana Barros, C. and Chen, Z. (2015), “An analysis of Asian airlines efficiency with two-stage TOPSIS and MCMC generalized linear mixed models”, *International Journal of Production Economics*, Vol. 169, pp. 110-126. https://doi.org/10.1016/j.ijpe.2015.07.028

Watróbski, J., Jankowski, J., Ziemba, P., Karczmarczyk, A., and Zioło, M. (2019), "Generalised framework for multi-criteria method selection", Omega, Vol 86, pp. 107–124. https://doi.org/10.1016/j.omega.2018.07.004

Wei, C., Ren, Z. and Rodríguez, R.M. (2015), “A Hesitant Fuzzy Linguistic TODIM Method Based on a Score Function”, *International Journal of Computational Intelligence Systems*, Vol. 8 No. 4, pp. 701-712. https://doi.org/10.1080/18756891.2015.1046329

Wen, F., Gong, X. and Cai, S. (2016), “Forecasting the volatility of crude oil futures using HAR-type models with structural breaks”, *Energy Economics*, Vol. 59, pp. 400-413. https://doi.org/10.1016/j.eneco.2016.07.014

Wong, J.K.W. and Li, H. (2008), “Application of the analytic hierarchy process (AHP) in multi-criteria analysis of the selection of intelligent building systems”, *Building and Environment*, Vol. 43 No. 1, pp. 108-125. https://doi.org/10.1016/j.buildenv.2006.11.019

Wong, W.P., Ignatius, J. and Soh, K.L. (2014), “What is the leanness level of your organisation in lean transformation implementation? An integrated lean index using ANP approach”, *Production Planning & Control*, Vol. 25 No. 4, pp. 273-287. https://doi.org/10.1080/09537287.2012.674308

Wu, H.-Y., Tzeng, G.-H. and Chen, Y.-H. (2009), “A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard”, *Expert Systems with Applications*, Vol. 36 No. 6, pp. 10135-10147. https://doi.org/10.1016/j.eswa.2009.01.005

Wu, X., Liao, H., Xu, Z., Hafezalkotob, A., and Herrera, F. (2018), “Probabilistic Linguistic MULTIMOORA: A Multicriteria Decision Making Method Based on the Probabilistic Linguistic Expectation Function and the Improved Borda Rule”, *IEEE Transactions on Fuzzy Systems*, Vol. 26 No. 6, pp. 3688-3702. https://doi.org/10.1109/TFUZZ.2018.2843330

Wu, Y., Zhang, J., Yuan, J., Geng, S., and Zhang, H. (2016), “Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: A case of China”, *Energy Conversion and Management*, Vol. 113, pp. 66–81. https://doi.org/10.1016/j.enconman.2016.01.020

Wu, Y., Xu, C. and Zhang, T. (2018), “Evaluation of renewable power sources using a fuzzy MCDM based on cumulative prospect theory: A case in China”, *Energy*, Vol. 147, pp. 1227-1239. https://doi.org/10.1016/j.energy.2018.01.115

Xu, Z. and Zhang, X. (2013), “Hesitant fuzzy multi-attribute decision making based on TOPSIS with incomplete weight information”, *Knowledge-Based Systems*, Vol. 52, pp. 53-64. https://doi.org/10.1016/j.knosys.2013.05.011

SciELO Preprints - This document is a preprint and its current status is available at: https://doi.org/10.1590/SciELOPreprints.3576

Yang, C.-C., Shen, C.-C., Lin, Y.-S., Lo, H.-W., Wu, and J.-Z. (2021), “Sustainable Sports Tourism Performance Assessment Using Grey-Based Hybrid Model”, *Sustainability*, Vol. 13 No. 8, pp. 4214-4235. https://doi.org/10.3390/su13084214

Yang, J.L. and Tzeng, G.-H. (2011), “An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method”, *Expert Systems with Applications*, Vol. 38 No. 3, pp. 1417-1424. https://doi.org/10.1016/j.eswa.2010.07.048

Yang, Y.-C. and Chen, S.-L. (2016), “Determinants of global logistics hub ports: Comparison of the port development policies of Taiwan, Korea, and Japan”, *Transport Policy*, Vol. 45, pp. 179-189. https://doi.org/10.1016/j.tranpol.2015.10.005

Yazdani, M. Chatterjee, P., Zavadskas, E.K., and Zolfani, S.H. (2017), “Integrated QFD-MCDM framework for green supplier selection”, *Journal of Cleaner Production*, Vol. 142, pp. 3728-3740. https://doi.org/10.1016/j.jclepro.2016.10.095

Yu, S., Wang, Jing and Wang, Jian-qiang (2018), “An extended TODIM approach with intuitionistic linguistic numbers”, *International Transactions in Operational Research*, Vol. 25 No. 3, pp. 781-805. https://doi.org/10.1111/itor.12363

Yuan, Y., Xu, Z. and Zhang, Y. (2021), “The DEMATEL–COPRAS hybrid method under probabilistic linguistic environment and its application in Third Party Logistics provider selection”, *Fuzzy Optimization and Decision Making*. https://doi.org/10.1007/s10700-021-09358-9

Zaidan, A. A., Zaidan, B. B., Al-Haiqi, A., Kiah, M.L. M., Hussain, M., and Abdulnabi, M. (2015), “Evaluation and selection of open-source EMR software packages based on integrated AHP and TOPSIS”, *Journal of Biomedical Informatics*, Vol. 53, pp. 390-404. https://doi.org/10.1016/j.jbi.2014.11.012

Zaidan, A.A., Zaidan, B.B., Hussain, M., Kiah, M.L.M., and Abdulnabi, M. (2015), “Multi-criteria analysis for OS-EMR software selection problem: A comparative study”, *Decision Support Systems*, Vol. 78, pp. 15-27. https://doi.org/10.1016/j.dss.2015.07.002

Zaidan, B.B. and Zaidan, A.A. (2017), “Software and Hardware FPGA-Based Digital Watermarking and Steganography Approaches: Toward New Methodology for Evaluation and Benchmarking Using Multi-Criteria Decision-Making Techniques”, *Journal of Circuits, Systems and Computers*, Vol. 26 No. 7. https://doi.org/10.1142/S021812661750116X

Zanakis, S.H., Solomon, A., Wishart, N., Dublish, S. (1998), "Multi-attribute decision making: A simulation comparison of select methods", European Journal of Operational Research, Vol. 107 No. 3 , pp. 507–529. https://doi.org/10.1016/S0377-2217(97)00147-1

Zhang, X. and Xu, Z. (2014a) “Extension of TOPSIS to Multiple Criteria Decision Making with Pythagorean Fuzzy Sets”, *International Journal of Intelligent Systems*, Vol. 29 No. 12, pp. 1061-1078. https://doi.org/10.1002/int.21676

Zhang, X. and Xu, Z. (2014b), “The TODIM analysis approach based on novel measured functions under hesitant fuzzy environment”, *Knowledge-Based Systems*, Vol. 61, pp. 48-58. https://doi.org/10.1016/j.knosys.2014.02.006

Zhou, H., Wang, J. and Zhang, H. (2019), “Stochastic multicriteria decision-making approach based on SMAA-ELECTRE with extended gray numbers”, *International Transactions in Operational Research*, Vol. 26 No. 5, pp. 2032-2052. https://doi.org/10.1111/itor.12380

Zoghi, M., Rostami, G., Khoshand, A., and Motalleb, F. (2021), "Material selection in design for

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deconstruction using Kano model, fuzzy-AHP and TOPSIS methodology", Waste Management & Research. https://doi.org/10.1177/0734242X211013904

Zyoud, S.H. and Fuchs-Hanusch, D. (2017), “A bibliometric-based survey on AHP and TOPSIS techniques”, *Expert Systems with Applications*, Vol. 78, pp. 158-181. https://doi.org/10.1016/j.eswa.2017.02.016

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