Multi-Criteria Decision Making in Industry 4.0: a Systematic Literature Review and Bibliometric Analysis

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Abstract: The application of Multi-Criteria Decision-Making (MCDM) methods in Industry 4.0 is increasingly important as organizations face complex decisions related to digital transformation, automation, and sustainability. This study presents a systematic literature review and bibliometric analysis of 256 peer-reviewed articles published between 2011 and 2024, focusing on how MCDM techniques support decision-making in Industry 4.0 contexts. The analysis reveals that the Analytical Hierarchy Process (AHP), TOPSIS, VIKOR, and PROMETHEE are the most frequently applied methods, often integrated with fuzzy logic to handle uncertainty. Key application areas include production planning, supply chain optimization, energy management, and AI-driven automation. Through co-citation and keyword network analysis using Bibliometrix in R, four main thematic clusters were identified, highlighting trends in sustainability, robotics, and data-driven decision-making. The study also underscores the increasing role of hybrid models that combine MCDM with advanced analytic. These findings provide valuable insights for both researchers and practitioners aiming to leverage MCDM tools in the evolving landscape of Industry 4.0.

Keywords: MCDM, industry 4.0, bibliometric analysys, co-citation networks.

1. INTRODUCTION

Industry 4.0, throught the advanced integration of digital technologies such as big data, Internet of Things (IoT), robotics and automation, artificial intelligence (AI), has transformed production processes. These interconnected and complex systems require sophisticated management and innovative solutions to address decision-making problems characterized by multiple criteria and conflicting objectives. Multi-Criteria Decision-Making (MCDM) methods have proven to be a useful tool to help make decisions in complex situations, that is, situations in which a balance of the different factors at play is required to optimize the results. In our work, we analyze the evolution and application of multi-criteria methods in the context of Industry 4.0, highlighting the main contexts of application of the tools, the prevalent techniques, the advantages and the associated challenges. The review indicates that MCDM methods are applied across numerous complex Industry 4.0 contexts, confirming their widespread relevance; specifically, the areas of greatest application are the optimization of production processes, supply chain management, sustainability. Among the most used MCDM methods, the AHP, TOPSIS, VIKOR and PROMETHEE methods stand out; they allow us to address the complexities and uncertainties that characterize modern industrial situations. The combination of these methods with fuzzy techniques and the analysis of uncertain data (such as Gray Relational Analysis) are fundamental tools for making informed decisions in environments with high technological and dynamic complexity. The most used method is certainly the AHP, known for its ability to structure complex problems hierarchically, assigning weights to the various criteria and comparing the alternatives based on their values; the AHP is mainly used for technology selection problems, supplier performance evaluation and production system design. In the literature, AHP has been used to compare and choose between emerging technologies such as 3D printing (Shahrubudin, N., 2021), collaborative robotics and IoT (Kim, C. & Won, J. S., 2020), based on economic, operational and technological criteria. Again, AHP has been used to support the selection of the most suitable technologies for a smart industrial plant, considering factors such as implementation costs, compatibility with the existing system and the ability to improve operational efficiency (Moghaddam et al., 2022). Another widely used method is the TOPSIS method, its field of application mainly concerns supplier selection, evaluation of automation solutions and energy resource management in smart industrial environments. TOPSIS is based on the idea of identifying the alternative that is closest to the ideal solution and furthest from the worst solution. It is particularly appreciated for its simplicity and ability to provide easily interpretable results. Zhang et al. (2022) applied TOPSIS for the selection of intelligent monitoring systems in automated manufacturing environments, considering variables such as accuracy, cost, and reliability. The TOPSIS method has also been employed to optimize supply chain management in highly variable manufacturing environments, simultaneously considering quality, lead time, and cost (Zhou *et al.*, 2021). VIKOR is used to solve trade-off problems between different optimal solutions in complex industrial scenarios, such as production process selection or

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production planning in contexts with conflicting criteria. The method aims to find a balance between alternatives, considering stakeholder preferences and the priorities of different criteria. The VIKOR method has been used in several applications in Industry 4.0 to manage production performance and select optimal solutions when there are conflicting criteria. In the research of Lee et al. (2023) and Salini et al. (2021), VIKOR has been used for supplier selection, ERP system evaluation, and to optimize automated workflows in flexible manufacturing contexts. The combination of AHP and TOPSIS methods with fuzzy logic is very popular in Industry 4.0, where data and preferences are often uncertain or vague. These methods are used to evaluate emerging technologies, complex production processes, and IoT solutions, where managing uncertainty plays a crucial role. Fuzzy methods allow us to express more realistically the uncertainty and ambiguity typical in these contexts. Tran, N. T. et al. (2024) in their study presents an effective MCDM model that integrates Fuzzy-AHP-TOPSIS to evaluate and choose the best robot. The PROMETHEE method is used to rank alternatives according to different criteria to obtain a hierarchy of preferences. It is widely used for material selection, supply chain optimization and production operations management in Industry 4.0, where the need to balance various often conflicting criteria is a central issue. According to Torbacki, W. (2021), presents how the DANP and PROMETHEE II methods are integrated to overcome the problem of cybersecurity in the information flow process within companies participating in the modern production process in the era of sustainable production. In recent years, advanced applications combining MCDM with evolutionary optimization techniques (such as genetic algorithms) have emerged. These approaches have been used to optimize production planning in highly variable environments and to solve complex scheduling problems in scenarios with multiple conflicting objectives (Tavana et al., 2021). These approaches allow simulating multiple scenarios and analyzing the impact of different choices on the overall performance of the production system (Wang et al., 2023). In our work we try to understand how quantitative methodologies of multi-criteria decision analysis are used in diversified realities. To comprehend and arrange the findings, researchers employ a variety of qualitative and quantitative literature review methodologies. A systematic, transparent, and repeatable evaluation process based on the statistical measurement of science, scientists, or scientific activity is one of the possible benefits of bibliometrics (Broadus, 1987, Diodato, 1994, Pritchard, 1969). Bibliometrics offers more trustworthy and objective assessments than other methods. To understand the current state of the scientific landscape on the topic and the evolution of future research, it is necessary to conduct a systematic review of the literature. This review aims to provide a broad theoretical background on the use of MCDM, taking into account the studies that have already been conducted. The aim of this work is to describe, explore and classify how MCDM methods are used to solve problems in a new and complex field, such as sustainability and therefore industry 4.0. We also intend to verify whether and how decision makers intervene in the construction of an MCDM method. The paper is organized as follows: Section 2 defines the materials and methods; Section 3 reports the main results; Section 4 concludes the paper.

2. MATERIALS AND METHODS

The present study adopts a systematic literature review approach following PRISMA guidelines, combined with bibliometric and co-citation analyses, to investigate the role of Multi-Criteria Decision-Making (MCDM) methods in Industry 4.0. The methodology unfolds in three main stages (see Fig. **1**):

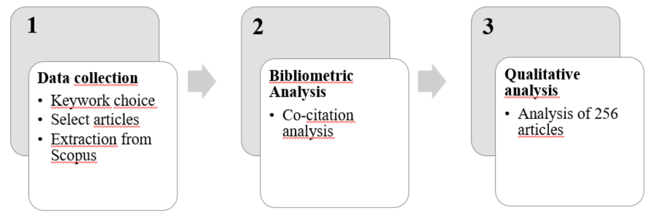

Fig. (1). Main steps of the research.

2.1. Data Collection

The selection process was designed to ensure the inclusion of high-quality, relevant, and methodologically consistent studies. The initial dataset was compiled from the Web of Science database using a comprehensive keyword strategy. Keywords included: “Industry 4.0”, “MCDM”, “sustainability”, “smart manufacturing”, “supply chain optimization”, “IoT decision-making”, and related phrases, searched across titles, abstracts, and full texts. The search covered articles published between 2011 and 2024, aligning with the emergence and evolution of Industry 4.0. To focus on technically and methodologically relevant literature, articles were limited to journals categorized under: (1) Decision Sciences, (2) Engineering, (3) Computer Science, (4) Business, Management and Accounting and (5) Mathematics. From an initial pool of 52,562 documents, filtering by source type and subject area yielded 945 articles. Studies that did not use quantitative MCDM methods (e.g., purely descriptive or theoretical works) were excluded. Titles and abstracts were reviewed manually to ensure alignment with the research scope, resulting in a final selection of 256 peer-reviewed articles.

2.2. Bibliometric Analysis and Data Analysis

Bibliometric analysis was conducted using R's Bibliometrix package to assess publication trends, citation patterns, and author productivity (Aria et al., 2017). Co-citation analysis was then employed to uncover thematic relationships among studies. Two documents are considered co-cited when they appear together in the references of a third article. The frequency of such pairings reflects thematic or conceptual proximity. About Cluster detection, the Louvain community detection algorithm was applied to the co-citation network to identify clusters-groups of closely interconnected authors or articles. These clusters reveal major research areas and schools of thought within the field. A co-word analysis was also conducted to identify frequently associated terms, enabling the mapping of thematic clusters based on terminology. Through the integration of co-citation patterns and qualitative analysis of article content, four main thematic clusters were identified. Each cluster represents a coherent research focus within the broader topic of MCDM in Industry 4.0:

I. Production Planning and Optimization: this cluster groups studies that apply MCDM to improve production efficiency, reduce waste, and balance competing objectives like cost, quality, and time. These methods help optimize decision-making in environments with dynamic production demands.

II. Supply Chain Management and Logistics: MCDM supports real-time and strategic decision-making in complex supply networks. Integration with IoT and sensor data enables responsive and sustainable supply chain systems. Studies often aim to achieve agility, resilience, and environmental performance.

III. Automation, Robotics, and Artificial Intelligence: this cluster reflects the integration of intelligent technologies into manufacturing environments. MCDM aids in selecting optimal technologies under conditions of uncertainty, particularly where trade-offs between cost, performance, and compatibility exist.

IV. Energy Management and Sustainability: focuses on the application of MCDM to environmental objectives, including evaluating renewable energy options, reducing carbon emissions, and optimizing energy consumption. This cluster reflects the alignment of Industry 4.0 with sustainability goals.

Each cluster was validated both through network metrics (e.g., modularity, centrality, node degree) and through the qualitative review of representative studies within each theme. The clustering structure provides a conceptual map of the research landscape, helping to identify both well-established areas and potential gaps for future research.

3. RESULTS

3.1. Quantitative Results

The 256 articles analyzed were collected from 79 journals. Detailed information on the dataset is provided in Table **1**. The reference period of the research goes from 2011 to 2024; over the years there have been several peaks of interest in the topic, Fig. (**2**) highlights how 2022 was the year in which the most articles were produced, 63 documents, on the topic of the research.

As for the average citation rate per year, Fig. (**3**) records an average citation rate of 11.2 in 2015; 2017 was the year with the highest rate of 13.4%; followed by 2019 which recorded 6.2%; and finally, in 2021 an average rate of 4.8% was highlighted.

From the analysis of the articles, it emerged that the journals that have dealt with the topic of Industry 4.0 using a multi-criteria approach are Sustainability and Mathematics (see Table **3**), while Table **4** represents the authors' production over time taking into account the year, the frequency (freq), the total number of citations (TC) and the TC per year (TCpY).

Of the 256 articles mentioned above, 241 were empirical studies and 15 literature reviews. Additionally, the analysis involved 932 authors and only 26 single-authored documents. On average, each document was cited 18.94, and the total of references reported by all documents in the dataset equals 13607. The most cited article was written by Kubler, S., (2016), followed by Kahraman, C., (2017) and Mardani, A., (2015) (see Table **2**).

Table 1. Main informations of the dataset.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2011:2024
Sources (Journals, Books, etc)	79
Documents	256
Annual Growth Rate %	30,55
Document Average Age	2,71
Average citations per doc	18,94
References	13607
DOCUMENT CONTENTS	
Keywords Plus (ID)	687
Author's Keywords (DE)	1008
AUTHORS	
Authors	932
Authors of single-authored docs	26
AUTHORS COLLABORATION	
Single-authored docs	26
Co-Authors per Doc	4,04
International co-authorships %	38,67
DOCUMENT TYPES	
article	241
review	15

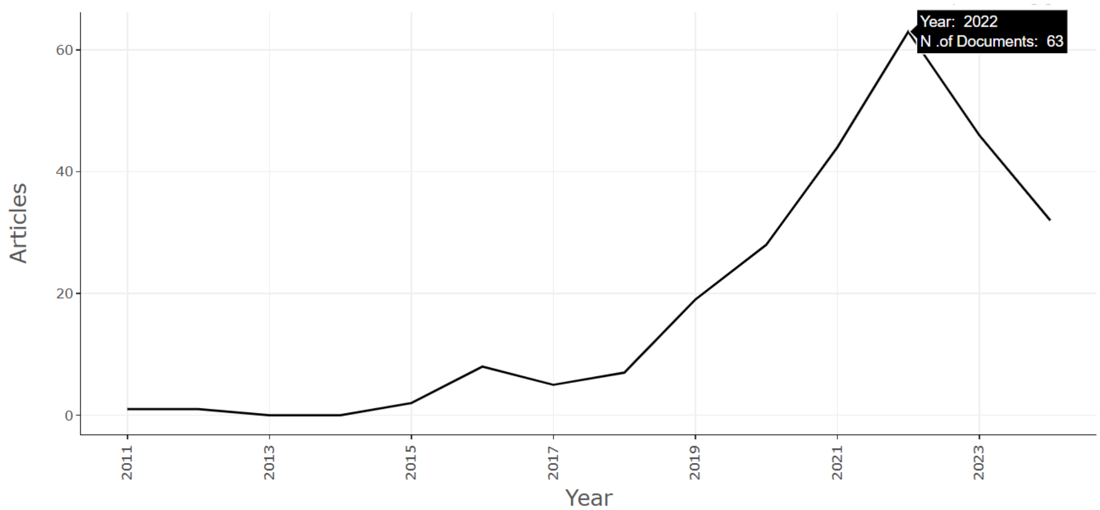

Fig. (2). Annual Scientific Production.

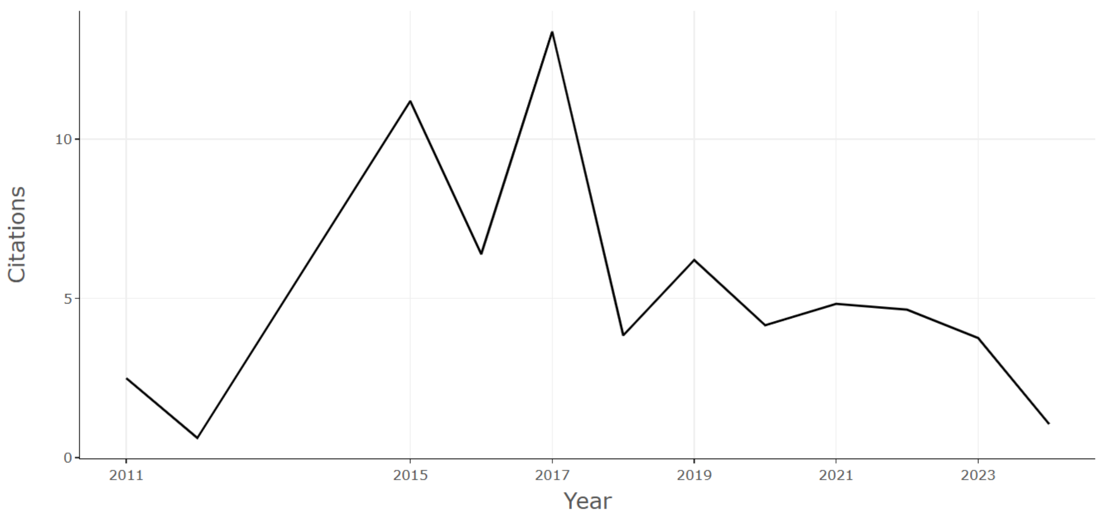

Fig. (3). Average citations per year.

Table 2. Most Global Cited Documents.

Paper	DOI	TC	TCpY	Normalized TC
KUBLER S, 2016, EXPERT SYST APPL	10.1016/j.eswa.2016.08.064	297	33,00	5,17
KAHRAMAN C, 2017, J ENVIRON ENG LANDSC MANAG	10.3846/16486897.2017.1281139	201	25,13	1,88
MARDANI A, 2015, SUSTAINABILITY	10.3390/su71013947	183	18,30	1,63
PAMUCAR D, 2017, EXPERT SYST APPL	10.1016/j.eswa.2017.06.037	168	21,00	1,57
ARABAMERI A, 2019, SCI TOTAL ENVIRON	10.1016/j.scitotenv.2018.12.115	151	25,17	4,05
SITORUS F, 2019, EXPERT SYST APPL	10.1016/j.eswa.2018.12.001	123	20,50	3,30
TSCHEIKNER-GRATL F, 2017, WATER	10.3390/w9020068	103	12,88	0,96
NABEEH NA, 2019, IEEE ACCESS	10.1109/ACCESS.2019.2899841	101	16,83	2,71
MINA H, 2021, J CLEAN PROD	10.1016/j.jclepro.2020.125273	92	23,00	4,76
BASILIO MP, 2022, ELECTRONICS	10.3390/electronics11111720	85	28,33	6,09
WANG H, 2019, J CLEAN PROD	10.1016/j.jclepro.2018.10.131	82	13,67	2,20
SOTOUDEH-ANVARI A, 2022, APPL SOFT COMPUT	10.1016/j.asoc.2022.109238	79	26,33	5,66
YOUSSEF AE, 2020, IEEE ACCESS	10.1109/ACCESS.2020.2987111	71	14,20	3,42
WANG L, 2020, IEEE ACCESS	10.1109/ACCESS.2020.3017221	62	12,40	2,98
CHEN HMW, 2016, MATH PROBL ENG	10.1155/2016/8097386	56	6,22	0,97
SANCHEZ-GARRIDO AJ, 2022, J CLEAN PROD	10.1016/j.jclepro.2021.129724	54	18,00	3,87
TAYLAN O, 2020, SUSTAINABILITY	10.3390/su12072745	52	10,40	2,50
ALI SA, 2021, ENVIRON SCI POLLUT RES	10.1007/s11356-020-11004-7	50	12,50	2,59
AFRASIABI A, 2022, ENVIRON SCI POLLUT RES	10.1007/s11356-021-17851-2	50	16,67	3,58
TIRKOLAEE EB, 2021, MATHEMATICS	10.3390/math9111304	48	12,00	2,48

Table 3. Most Relevant Sources.

Sources	Articles
SUSTAINABILITY	49
MATHEMATICS	22
IEEE ACCESS	19
APPLIED SCIENCES-BASEL	12
CMC-COMPUTERS MATERIALS \& CONTINUA	12
MATHEMATICAL PROBLEMS IN ENGINEERING	9
EXPERT SYSTEMS WITH APPLICATIONS	8
AXIOMS	7
COMPLEX \& INTELLIGENT SYSTEMS	4
ELECTRONICS	4

Table 4. Authors' Production over Time.

Author	year	freq	TC	TCpY
AGRAWAL ALKA	2024	1	0	0
ALHARBI ABDULLAH	2024	1	0	0
ALOSAIMI WAEL	2024	1	0	0
ALYAMI HASHEM	2024	1	0	0
EREN TAMER	2024	1	0	0
KUMAR RAJEEV	2024	1	0	0
AGRAWAL ALKA	2023	1	5	2,5
DANG THANH-TUAN	2023	1	2	1
KHAN RAEES AHMAD	2023	1	5	2,5
WANG CHIA-NAN	2023	1	2	1
ABUSHARK YOOSEF B	2022	2	9	3
AGRAWAL ALKA	2022	3	16	5,333
ALHARBI ABDULLAH	2022	1	14	4,667
ALMALAWI ABDULMOHSEN	2022	2	9	3
ALOSAIMI WAEL	2022	1	14	4,667
ALYAMI HASHEM	2022	1	14	4,667
DANG THANH-TUAN	2022	1	15	5
EREN TAMER	2022	1	10	3,333
KHAN RAEES AHMAD	2022	5	42	14
KUMAR RAJEEV	2022	3	28	9,333
WANG CHIA-NAN	2022	3	28	9,333
ABDEL-BASSET MOHAMED	2021	2	18	4,5
ABUSHARK YOOSEF B	2021	1	11	2,75
AGRAWAL ALKA	2021	4	37	9,25
ALHARBI ABDULLAH	2021	3	26	6,5
ALMALAWI ABDULMOHSEN	2021	1	11	2,75
ALOSAIMI WAEL	2021	3	26	6,5
ALYAMI HASHEM	2021	1	6	1,5
DANG THANH-TUAN	2021	2	60	15
KHAN RAEES AHMAD	2021	3	31	7,75
KUMAR RAJEEV	2021	3	26	6,5
WANG CHIA-NAN	2021	2	59	14,75
ABDEL-BASSET MOHAMED	2020	1	32	6,4
EREN TAMER	2020	2	66	13,2
ABDEL-BASSET MOHAMED	2019	1	101	16,833

The most cited countries are China with 680 citations and 160 documents, followed by Turkey with 589 citations and 67 documents, and India with 311 citations and 131 documents (Table **5**).

Table 5. Top 20 most cited countries and number of documents.

Country	TC	Freq
CHINA	680	160
TURKEY	589	67
INDIA	311	131
MALAYSIA	301	27
LUXEMBOURG	297	2
IRAN	252	34
SAUDI ARABIA	241	69
SERBIA	228	23
EGYPT	197	23
VIETNAM	181	34
UNITED KINGDOM	178	18
SPAIN	134	32
DENMARK	113	6
BRAZIL	107	12
AUSTRIA	103	5
GREECE	101	17
ITALY	98	15
PAKISTAN	95	28
USA	87	24
LITHUANIA	82	30

Keywords are necessary elements to analyze the contents and issues of documents. According to Callon *et al.*, the study of the co-occurrence of these keywords is defined as co-word analysis; it is performed to calculate the degree of co-occurrence of keywords and concepts of the research domain (Khanra *et al*., 2020). In our study, we use Biblioshiny (see Fig. **4**); we consider 50 plus keywords to build this word cloud, these are obtained from the titles of cited references and are assumed to reflect the theoretical essence of the articles. The keyword AHP shows the highest frequency of 98, followed by Topsis (85), model (59), selection (49), decision making (42), criteria (31) and so on.

3.2. Qualitative Results and co-Citation Analysis

After the descriptive analysis, we focused on a more qualitative analysis that covered the most significant application areas of MCDM in the context of Industry 4.0. First, we noticed that, in literature, different methodologies have been adopted in empirical studies. From our analysis, it emerged that the most used methodologies are AHP, Topsis, fuzzy AHP, Vikor and only recently, some authors have experimented with the adoption of more advanced big data analysis techniques and the use of predictive models able to effectively combine data with multi-criteria decision-making methods. Regarding the application fields, Fig. (**5**), shows the main application areas of MCDM methods in the context of Industry 4.0.

In particular, it is possible to observe in Fig. (**5**) that the areas with a greater number of studies are: *Environmental Sciences* (36%), *e.g.*, Çalık, A. (2021) present a paper aims to develop a new group decision-making approach based on Industry 4.0 components for selecting the best green supplier by integrating AHP and TOPSIS methods under the Pythagorean fuzzy environment; *Green Sustainable Science Technology* (17%), *e.g*., Akila, D. et al. (2023) considered a Sustainable City using Multi-Criteria Decision Making (SC-MCDM) system is designed in this research to test and achieve sustainable developmental goals; *Mathematics* (14%), e.g., Abdullah, F. M. *et al*. (2023) their study aims to build a powerful hybrid MCDM method to classify the influence of I4.0 technologies on MSOs by adopting a combination of AHP and fuzzy TOPSIS; *Computer Science Artificial Intelligence* (13%), *e.g*., Alshahrani, R. *et al.* (2024) defined and applied a hybrid Multi-Criteria Decision Making (MCDM) integrated fuzzy model to identify the important barriers to the development of a long-term cloud Artificial Intelligence (AI) system in an Information Technology (IT) business; and so on.

From the qualitative analysis performed, we identified 4 main thematic clusters where MCDM methods are applied in Industry 4.0 (see Fig. **6**). These clusters reflect the main application areas, emerging technologies and specific challenges that Industry 4.0 is facing.

Custer 1 (blue): Production planning and optimization. This cluster is about the use of MCDM methods to optimize decisions related to production planning, resource management and improvement of production flows in an intelligent

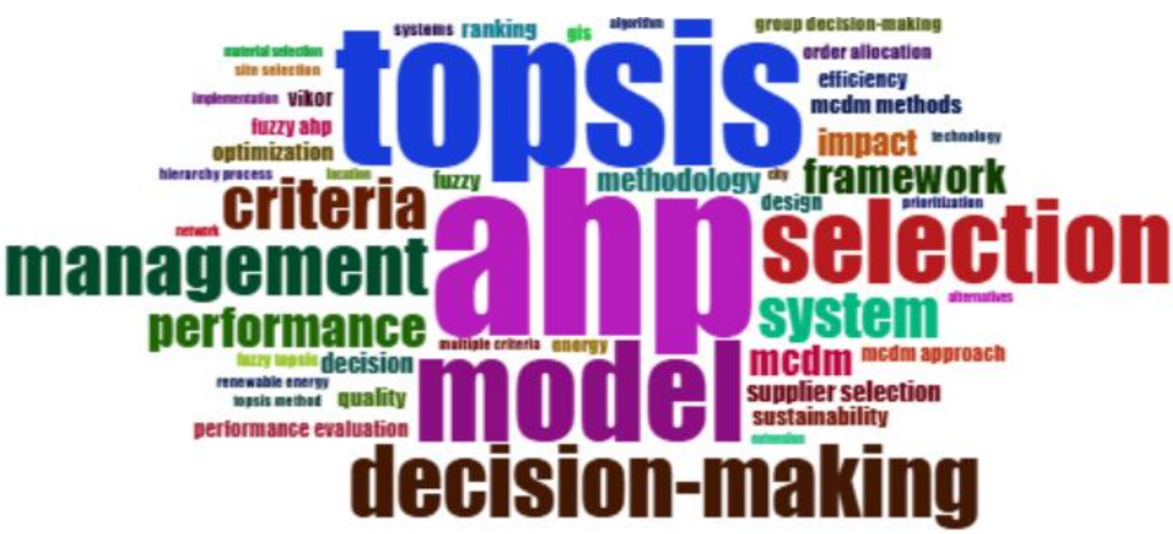

Fig. (4). WordCloud.

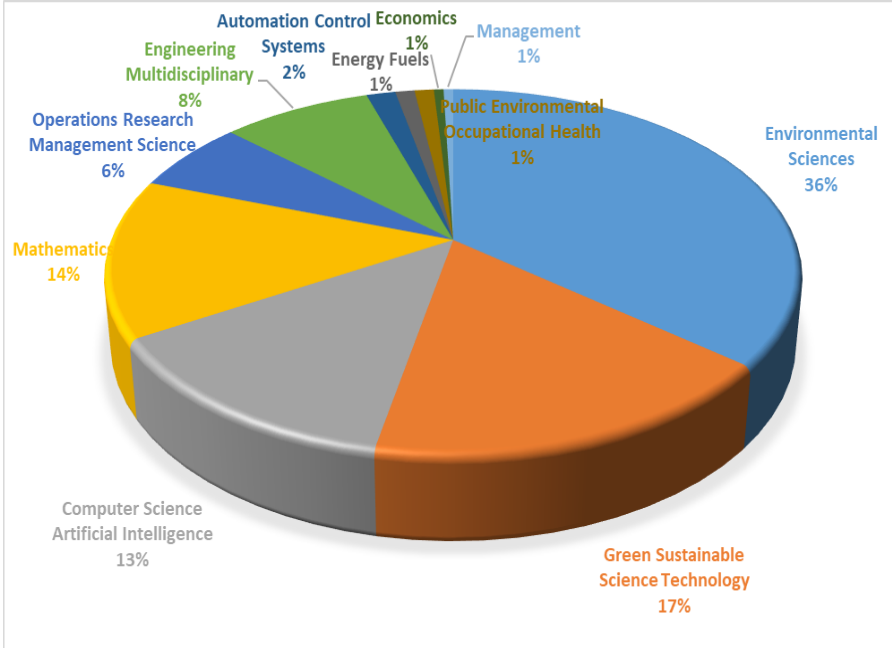

Fig. (5). Main application areas of MCDM in Industry 4.0.

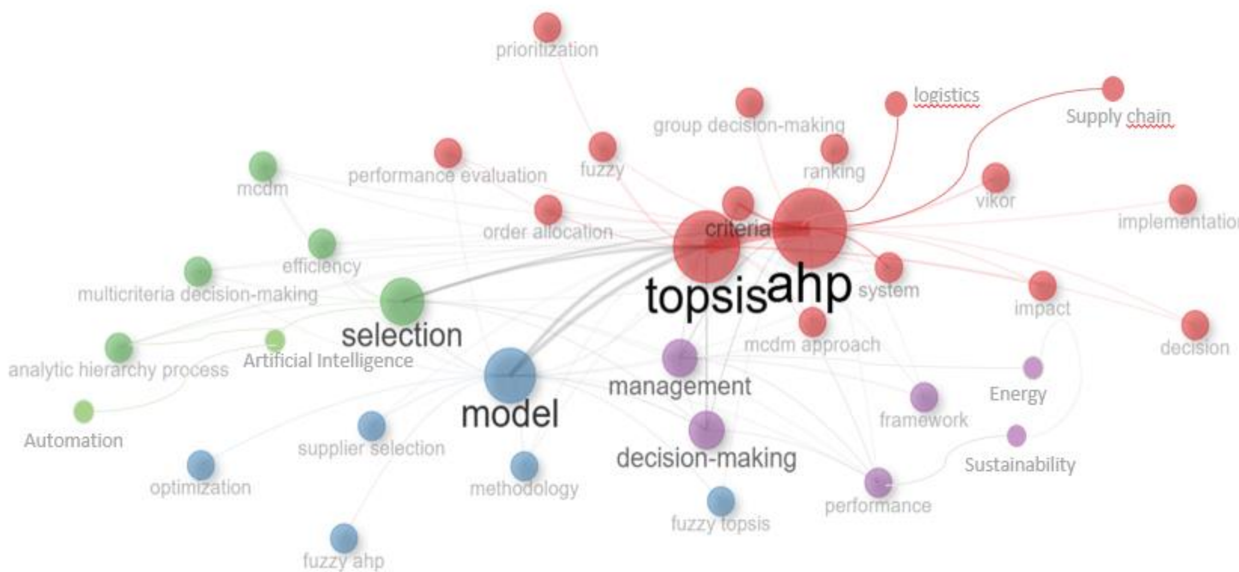

Fig. (6). Main thematic clusters.

environment. Process automation and production line management are key aspects in Industry 4.0 and MCDM methods are used to make optimal decisions when there are several factors to balance, such as cost, quality and production time. Among the most used MCDM methods we highlight AHP, TOPSIS, ANP, MOORA. Kumar, V. et al. (2021) in his work tries to identify the barriers of Industry 4.0 and prioritize strategies to overcome them for successful implementation of Industry 4.0, using a hybrid model of MCDM.

Cluster 2 (red): Supply Chain Management and Logistics. In Industry 4.0, advanced supply chain management is a crucial aspect. MCDM methods are applied to optimize logistics, supplier management, and material purchasing and distribution decisions. The ability to monitor material flows in real time via sensors and IoT enables companies to make better decisions about routes, inventory, and suppliers. The MCDM methods used are VIKOR, AHP, PROMETHEE. Krstić, M., et al. (2022) with their research propose to select the most promising intelligent reverse logistics system development scenario that would serve as a guideline for decision making in the process of building sustainable circular economy systems and closed supply chains. To solve the defined problem, they used a new multi-criteria decision-making model, which combines Delphi, Analytical Network Process (ANP) and COmprehensive distance Based RAnking (COBRA) methods in the fuzzy environment.

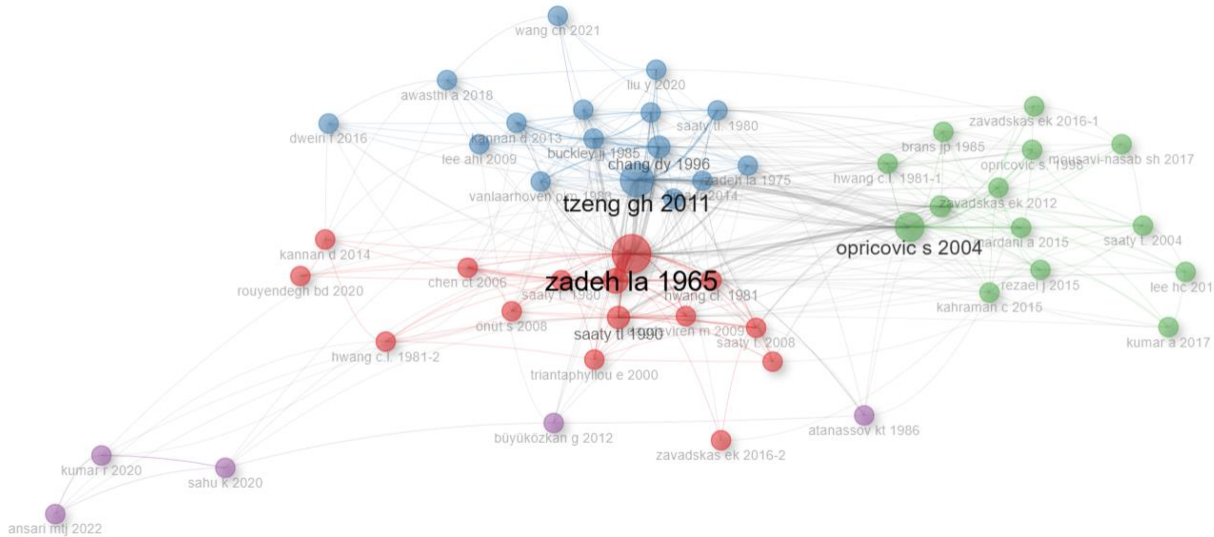

Fig. (7). Co-citation conceptual map. Own elaboration through Bibliometrix.

Cluster 3 (green): Automation, Robotics and Artificial Intelligence. Advanced robotics and automation are continuously evolving in the context of Industry 4.0. MCDM methods are used to make strategic decisions on industrial robot selection, automated system integration and operation optimization. Wang, K., *et al*. (2023) in their study try to investigate the function of AI tools in the construction industry using a hybrid multi-criteria decision making (MCDM) framework based on Delphi method, analytic network process (ANP) and technique for preference ordering by similarity to ideal solution (TOPSIS) in a fuzzy scenario.

Cluster 4 (purple): Energy Management and Sustainability. Energy efficiency and sustainability are central issues in Industry 4.0. MCDM methods are used to balance decisions related to energy consumption, green technologies, resource management and sustainable policies. Favi, C. et al. (2022) present a work based on the combination of EMFA, LCA and MCDM tools in a research model that concerns plant metabolism.

3.3. Co-citation Analysis

Then, we performed a co-citation analysis in the considered period (2011-2024), to highlight whether there are relevant associations between the articles and authors; a total of 4 co-citation networks appeared.

We then performed a co-citation analysis in the considered period (2011-2024), to highlight whether there are relevant associations between articles and authors; a total of 4 co-citation networks appeared. Fig. (**6**) represents a co-citation network (Small, 1973), that is, it highlights the connections between the main articles and authors using MCDMs in the context of Industry 4.0, tracking the articles that have been cited together. This analysis allows us to obtain a complete view of research trends, emerging applications and developments in the field. We speak of co-citation of two documents when both are cited in a third document. Regarding co-citing authors, according to Aria and Cuccurullo [47], proximity measures how many steps are needed to access all the other vertices from a given vertex; page rank approximates the probability that a message reaches a particular vertex. In Fig. (**7**) the lines represent a citation between authors, while the size of the nodes is related to the sum of the frequencies. The concept map allows us to identify 4 working groups or clusters by color. The central group of authors corresponds to experienced researchers, who have taken part in the development of the methodology and several publications in different fields. These authors, strongly correlated by multiple connections, reveal more working connections. In the first group there are 17 authors (red cluster). Zadeh is the most important author (with a betweenness centrality value of 388,498, page rank of 0.062 and closeness of 0.014). The second group is composed of 16 authors (blue cluster). Tzeng gh stands out in it (with a betweenness centrality value of 259,605, page rank of 0.049 and closeness of 0.013). The third group is composed of 14 authors (green cluster). The main author of this group is Opricovic (with a betweenness centrality value of 163,390, a page rank of 0.044, and a closeness value of 0.013). The last group (the purple one) is considerably less significant in size, being characterized by only 3 authors; among these, Kumar stands out, who presents the following characteristics: betweenness centrality value of 11.030, page rank of 0.016 and closeness of 0.008 (see Table **6**).

Table 6. Co-citation Network.

Node	Cluster	Betweenness	Closeness	PageRank
zadeh la 1965	1	388,498	0,014	0,062
chen ct 2000	1	78,142	0,011	0,043
saaty tl 1990	1	81,859	0,011	0,032
hwang cl. 1981	1	22,772	0,01	0,027
saaty t. 1980	1	2,627	0,01	0,022
saaty t. 2008	1	0,855	0,01	0,022
dagdeviren m 2009	1	15,042	0,01	0,024

büyüközkan g 2012	1	2,276	0,009	0,009
hwang c.l. 1981-2	1	1,357	0,007	0,013
saaty rw 1987	1	0,988	0,009	0,013
chen ct 2006	1	1,64	0,008	0,017
önüt s 2008	1	1,561	0,01	0,016
rouyendegh bd 2020	1	0,25	0,007	0,009
triantaphyllou e 2000	1	0	0,008	0,016
atanassov kt 1986	1	0,194	0,009	0,01
kannan d 2014	1	2,8	0,007	0,009
zavadskas ek 2016-2	1	0,218	0,008	0,006
tzeng gh 2011	2	259,605	0,013	0,049
chang dy 1996	2	44,596	0,011	0,036
buckley jj 1985	2	20,986	0,011	0,035
saaty tl. 1980	2	12,572	0,01	0,023
lima fr 2014	2	37,247	0,011	0,022
behzadian m 2012	2	13,255	0,011	0,022
sun cc 2010	2	1,361	0,01	0,025
lee ahi 2009	2	13,832	0,009	0,017
zadeh la 1975	2	16,625	0,011	0,019
liu y 2020	2	2,638	0,009	0,015
shih hs 2007	2	35,628	0,01	0,016
wang cn 2021	2	0	0,008	0,009
awasthi a 2018	2	34,416	0,01	0,014
dweiri f 2016	2	9,278	0,009	0,01
kannan d 2013	2	3,5	0,009	0,022
vanlaarhoven pjm 1983	2	5,686	0,01	0,017
opricovic s 2004	3	163,39	0,013	0,044
saaty tl 1977	3	47,198	0,012	0,027
mardani a 2015	3	2,856	0,01	0,022
hwang c.l. 1981-1	3	21,516	0,011	0,019
rezaei j 2015	3	1,837	0,01	0,013
zavadskas ek 2016-1	3	1,529	0,009	0,012
mousavi-nasab sh 2017	3	0,377	0,009	0,012
zavadskas ek 2012	3	36,274	0,009	0,021
kumar a 2017	3	0,079	0,008	0,01
brans jp 1985	3	2,038	0,01	0,014
saaty t. 2004	3	0,105	0,008	0,017
kahraman c 2015	3	15,511	0,01	0,017
lee hc 2018	3	0,27	0,009	0,009
opricovic s. 1998	3	1,214	0,009	0,018
kumar r 2020	4	11,03	0,008	0,016
sahu k 2020	4	1,151	0,01	0,015
ansari mtj 2022	4	1,322	0,007	0,014

4. CONCLUSION

In our work, it emerged that the use of MCDMs offers several advantages in the context of the Industry 4.0 project, representing a key resource for the management and optimization of processes. In fact, the methods can be adapted to different decision-making contexts, allowing companies to keep up with changing market conditions; they are useful for balancing economic and environmental objectives, to promote sustainable production; furthermore, the combination of MCDMs with advanced technologies, such as Artificial Intelligence, allows us to obtain optimized solutions in real time, based on large volumes of data from sensors and IoT devices. Despite their strengths, the application of MCDMs faces challenges related to data uncertainty and the dynamic nature of industrial environments. Addressing these challenges calls for further refinement of hybrid models, particularly those incorporating predictive analytic and machine learning. Future research should prioritize the integration of MCDMs into digital infrastructures, explore real-time data fusion techniques, and develop frameworks adaptable to various industrial contexts. This will ensure that MCDM methods remain relevant and impactful in the evolving landscape of Industry 4.0.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DECLARATIONS OF INTEREST

None.

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