



Application of MADM methods in Industry 4.0: A literature review

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ABSTRACT

Industry 4.0 has received inordinate attention from the business as well as research communities. Along with the development of Industry 4.0 applications and the diversity of potential alternatives, Multi-Attribute Decision Making (MADM) techniques have been employed by researchers as systematic approaches to support the decision-making processes. However, as the adoption of Industry 4.0 technologies requires considerable capital, and as it is relatively difficult to identify the suitable MADM method for the decision-making process in certain conditions, it becomes necessary to determine which components of Industry 4.0 are most commonly in demand of MADM applications of decision making, and which MADM techniques are mostly preferred by researchers and businesses for varied directions of Industry 4.0. Therefore, this study aims to provide a comprehensive review of MADM methods and their applications for different components of Industry 4.0. A methodology, including a review framework, is provided for the related analyses. The proposed framework includes analyses concerning methods, subtopics, and bibliometry along with the related exploratory tables and figures. Finally, the trends and research gaps are clearly stated to shed light on the further research areas taking into consideration different challenges that can be encountered by researchers, along with a set of propositions to potentially overcome them.

1. Introduction

As a result of industrialization and globalization, technological developments have led to paradigm shifts widely known as industrial revolutions (Lasi et al., 2014). Industry 4.0 is a term that was initially introduced in 2011 at the Hannover Fair and the concept has spread in various fields year by year (Vogel-Heuser and Hess, 2016). After the introduction section, the term has been used mostly in high-tech projects by the German state (Steiner, 2019). Industry 4.0 presents a technique for developing a transition from machine-dominant production to digital production (Oztemel & Gursev, 2020). The 4.0 label implies that this is the fourth industrial revolution in the world, the heir to three previous industrial revolutions that created massive changes in productivity and improved people's lives all around the world (Davies, 2015). The key principle of industry 4.0 is the development of "smart factories," which is mainly related to the cyber-physical systems (CPS) of the manufacturing plants (Steiner, 2019). A smart factory is described as the

use of advanced digital technology innovations including "advanced robotics and artificial intelligence; sophisticated sensors; cloud computing; the Internet of Things (IoT); data capture and analytics; digital fabrication (including 3D printing); software-as-a-service and other new marketing models; smartphones and other mobile devices; platforms that use algorithms to direct motor vehicles (including navigation tools, ride-sharing apps, delivery and ride services, and autonomous vehicles); and the embedding of all these elements in an interoperable global value chain, shared by many companies from many countries" and these elements may be a connection between machine and human (Geissbauer et al., 2016).

The rapid evolution of Industry 4.0 technologies resulted in more alternatives for businesses. The decision-making process for different components of Industry 4.0 is a non-trivial problem and requires complex control subsystems. As most of the real-life problems having various and frequently conflicting criteria, objectives, and goals, Multi-Criteria Decision Making (MCDM) methods play an important role in dealing

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with these problems in a systematic approach. There are two main parts of MCDM. These are Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM) methods. The main difference between them is the number of alternatives. There is a countable number of alternatives within MADM methods. On the other hand, the number of alternatives is infinite in MODM methods. There are more than fifty methods under MADM (Watrobski et al., 2019) but not every method can be used for solving every decision-making problem. MADM models are used in different roles in the concept of Industry 4.0. For instance, the AHP method, which is one of the remarkable MCDM models, has been used by various researchers in the cloud computing environment. Patiniotakis et al. (2013) and Kumar and Kumar (2016) presented assessment systems for cloud service providers by employing fuzzy AHP. Ramachandran et al. (2014) utilized the AHP method to select a suitable cloud computing technology deployment model for an academic institution. Moreover, using Fuzzy TOPSIS, Sohaib and Naderpour (2017) evaluated the technological, organizational, and environmental factors of public cloud computing service models in the context of e-commerce. In the article of Yadav and Goraya (2018), AHP was used to rank both cloud service providers and service requesting customers. Saidi et al. (2019) proposed a deep supervised learning-MCDM model using the ELECTRE III and ELECTRE TRI approaches for energy consumption awareness in cloud computing. For the selection of production simulation software in the Industry 4.0 environment, Cafasso et al. (2020) employed an MCDM approach called Best Worst Method (BWM). To effectually evaluate alternative technologies that combine microelectromechanical systems with integrated circuits, Lee et al. (2021) proposed an integrated approach using Fuzzy AHP and Fuzzy VIKOR. Finally, in the paper of Sadreddini et al. (2021), a smart reservation system is proposed that considers the behavior of electric vehicle (EV) utilizers, the availability of parking spaces, and the state of EV charge. They used AHP in their smart reservation system to consider weighting the behavior of EV users.

Since the implementation of Industry 4.0 technologies requires considerable capital, businesses have to select the best-fitting technologies amongst the available alternatives. This process can be risky and requires an appropriate evaluation of all the options considering all the criteria (Soni et al., 2022). Although there are many MCDM methods, the characteristics of each method can be very different. Each method has its advantages and disadvantages, and different results can be obtained by applying different methods (Zardari et al., 2014). Therefore, selecting the appropriate method for the decision-making process can be very difficult (Bajec & Tuljak-Suban, 2019). Applying decision-making methods for Industry 4.0 technologies makes the problem even more challenging (Bai et al., 2020). First, there is a general lack of knowledge regarding the real benefit of Industry 4.0 technologies because they are relatively new. Second, the integration of these technologies with the traditional production system adds more restrictions to the application of Industry 4.0 technologies. Third, the performance of these technologies is associated with uncertainties due to the different contexts of applications and the diversity of industries. Finally, Applying an unsuitable method can lead to inaccurate decisions which might result in spending a lot of money on unfitting technology.

So far, the literature has been quiet on addressing these challenges, which made it a necessity to shed more light on the areas of Industry 4.0 where decision-making methods are most needed and to identify which MADM methods are mostly implemented for each direction of Industry 4.0. Using the most-fitting MADM method can aid organizations in further understanding and adopting Industry 4.0 technologies. Hence, a systematic literature review methodology is applied to guide the researchers as well as business practitioners to make the right decision and reach the best outcome of applying MADM methods in the scope of Industry 4.0 which is the main purpose of this literature review.

Due to the popularity of Industry 4.0 and MADM techniques, various literature review studies have been provided by the literature for both topics. Earlier review studies about the application of MCDM methods

include supplier evaluation and selection (Ho et al., 2010; Chai & Ngai, 2020), green supplier selection (Govindan et al., 2015), and corporate sustainability (Chowdhury & Paul, 2020). On the other hand, some of the literature review studies about Industry 4.0 include the past, present, and future of industry 4.0 (Liao et al., 2018), the related technologies (Alcácer & Cruz-Machado, 2019; Oztemel & Gursev, 2020), industry 4.0 and lean manufacturing (Pagliosa et al., 2019) and the smart factory as a key construct of industry 4.0 (Osterrieder et al., 2020). To the best of our knowledge, there is not a literature review study about the application of MADM methods in Industry 4.0, hence this study is the first attempt to reveal the research gaps and future trends regarding the applications of MADM methods in Industry 4.0. In addition, this study is important with respect to classifying MCDM methods employed in the domain of Industry 4.0 and being one of the first papers in this area to include subject, method, and bibliometric analysis with the clarification of trends and research gaps.

The contributions of this systematic review are as follows:

- This research shows the trend of interest in MADM applications within the scope of Industry 4.0 over the years.
- This research provides information about which MADM methods are most used by researchers for Industry 4.0 components and compares the results obtained in different components.
- This research specifically shows where MADM applications are most needed within Industry 4.0.
- This research highlights the appropriate MADM methods for each Industry 4.0 component and demonstrates the link between a particular component and a particular method.
- This research addresses the challenges researchers face and offers recommendations for managing them.

The remainder of the study is organized as follows. Section 2 provides the research methodology utilized during the review process. Theoretical background about MADM methods is provided in Section 3. Section 4 includes the components of Industry 4.0. The review results including MADM methods are presented in Section 5. Section 6 includes the trends and research gaps including the challenges and the propositions to overcome them, and finally, the conclusion is provided in Section 7.

2. Research methodology

The structure of this systematic literature review is constructed based on the works of Lange & Pfarrer (2017) and Denyer & Tranfield (2009). The methodology of Denyer & Tranfield (2009) has been implemented in many other literature reviews in the fields of supply chain management and big data analytics (Espadinha-Cruz et al., 2021; Ghadge et al., 2012; Tachizawa & Yew Wong, 2014; Shayaa et al., 2018; Tukamuhabwa et al., 2015) whereas similar methodologies are used in the studies of Castellucci et al. (2020), Xavier et al. (2017), Zhang & Banerji (2017), Zhao et al. (2019). The main framework of Denyer & Tranfield (2009) consists of 5 main steps as shown in Fig. 1.

For the first step, research questions can guide the literature review to show a clear direction toward the main objectives of the research. Our main objective is to review the applications of MADM methods in Industry 4.0 to understand the distribution of MADM applications for each Industry 4.0 component. To this end, the following research questions are proposed to show the main direction of the study as follows:

Q1: What is the shape of the literature on applying MADM methods for Industry 4.0?

Motivation for Q1: Answering this question will show if the researchers are interested in implementing MADM for Industry 4.0 applications. It will also show the trend of this interest over the years.

Q2: Which MADM classes and methods are mostly used for Industry 4.0 component applications?

Motivation for Q2: We already know that some MADM methods are

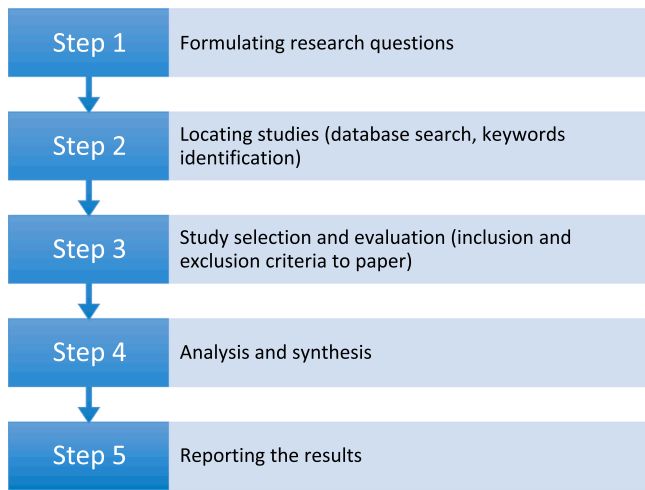


Fig. 1. The review methodology.

more popular than others in general or in a particular field based on other literature reviews (Kaya et al., 2018; Stojčić et al., 2019; Yalcin et al., 2022). Answering this question will give information on what MADM methods are mostly used by researchers for Industry 4.0 components and compare this result with the results obtained in different fields.

Q3: Which Industry 4.0 components are mostly studied by researchers with MADM methods?

Motivation for Q3: Obviously, researchers focus on some Industry 4.0 components more than others. This is probably due to the industry needs. Answering this question will particularly show where exactly MADM applications are needed the most.

Q4: Which MADM methods were frequently applied in a particular Industry 4.0 component?

Motivation for Q4: Highlighting the favorable MADM methods for each Industry 4.0 component might show a link between a particular component and a particular method.

Q5: Which MADM methods are preferred to be applied together for Industry 4.0 applications?

Motivation for Q5: It's important to point out if two or three MADM techniques are preferred to be used together.

Q6: What challenges can be encountered by researchers while dealing with MADM applications in the domain of Industry 4.0?

Motivation for Q6: Addressing the challenges that are faced by researchers and providing propositions to manage them will be very important for future applications in this field.

As the second step, the search terms are determined both for Industry 4.0 and MADM as seen in Table 1. The intersections of these search terms are looked for in either the title, abstract, or the keywords of the articles in the Scopus database.

In the third step, several inclusion and exclusion criteria are applied for the selection process. For inclusion criteria:

- Articles that include the intersection between the search terms of Industry 4.0 and for MADM in their title, abstract, or keywords.

Table 1

Search terms for Industry 4.0 and MADM.

Industry 4.0 search terms	MADM search terms
Industry 4.0; Big data; Smart factory; Internet of Things; IoT; Cyber-Physical systems; Fourth industrial revolution; Smart manufacturing; Cloud systems; Enabling technologies; Augmented reality; Digital transformation; Digitalization; Digitization	MCDM; MADM; MCDA

- Articles that are written in English.
- Articles that are published before November 2021.

As for exclusion criteria, it includes:

- Articles that don't focus on Industry 4.0 components.
- Articles that don't apply or discuss MADM methods as a subject.
- Articles that don't meet the inclusion criteria.

As seen in Fig. 2, the indexed papers resulting from the Scopus database reached a total of 549 papers. After excluding 6 papers based on language criteria and 205 based on topic, 328 papers were classified and included in the analysis of this study.

In the fourth step, the analysis framework is determined. The framework is based on three analyses. These are the method, topic, and bibliometric analysis (journal & citation analyses, sector, corresponding author country, keywords). For the fifth step, results are presented, tabular and graphical analyses are provided, and the trends and research gaps are presented.

3. Brief theoretical background about MADM methods

The MADM methods are divided into six groups including pairwise comparison, distance-based, outranking, interaction-based, utility-based, and other methods as illustrated in Fig. 3 (Yalcin et al., 2022). Each group consists of various subgroups and methods.

The main characteristic of MADM methods is that there is a limited number of alternatives in the decision-making problem. An interaction-based method class is added to the classification provided in the study of Kahraman et al. (2015). Brief information about each class is provided as follows.

Pairwise comparison methods: This group is based on pairwise comparisons of the factors (criteria, alternatives) in the decision-making process. The first and the most popular method of this class is Analytic Hierarchy Process (AHP) which is proposed by Saaty (1980). The problem is handled considering its hierarchy where the goal is at the top, followed by the criteria in the middle, and alternatives at the very bottom (Kilic et al., 2014). Besides its classical type, there are various fuzzy versions of it including many applications (Kahraman et al., 2015). Analytic Network Process (ANP), which is also proposed by Saaty (2005), can be applied when there is dependency among factors. ANP is the generalization of AHP method. Similar to AHP, ANP also has fuzzy variations. However, instead of hierarchy, ANP has a network structure. The third method is the Best Worst Method (BWM), which is proposed by Rezaei (2015). This method employs relative importance ratios of criteria in pairwise comparisons which are provided by a decision-maker (DM) based on two assessment vectors: the best factor against the other factor, and the other factor against the worst factor (Liang et al., 2020). Besides the mentioned three methods, other pairwise methods will be classified as "Other".

Outranking methods: The outranking relation is implemented by considering the superiority of one alternative over the other alternatives. Dominance is defined by terms like "at least as good as" or "not worse than" (Gong and Xu, 2006). ELimination Et Choice Translating REality (ELECTRE), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and TODIM (an acronym in Portuguese of Interactive and Multicriteria Decision Making) are the three popular methods in this group. ELECTRE approach is based on MAUT to increase effectiveness without influencing the result by considering fewer data. It is a methodology that, in sequence, decreases the number of alternatives (Chatterjee et al., 2010). The PROMETHEE method is one of the most popular MCDA approaches suggested by Brans (1982) and further developed by Brans & Vincke (1985). PROMETHEE is an outranking approach for a limited range of alternatives to be sorted and chosen from conflicting criteria. PROMETHEE is also a reasonably easy sequencing method in design and implementation compared to

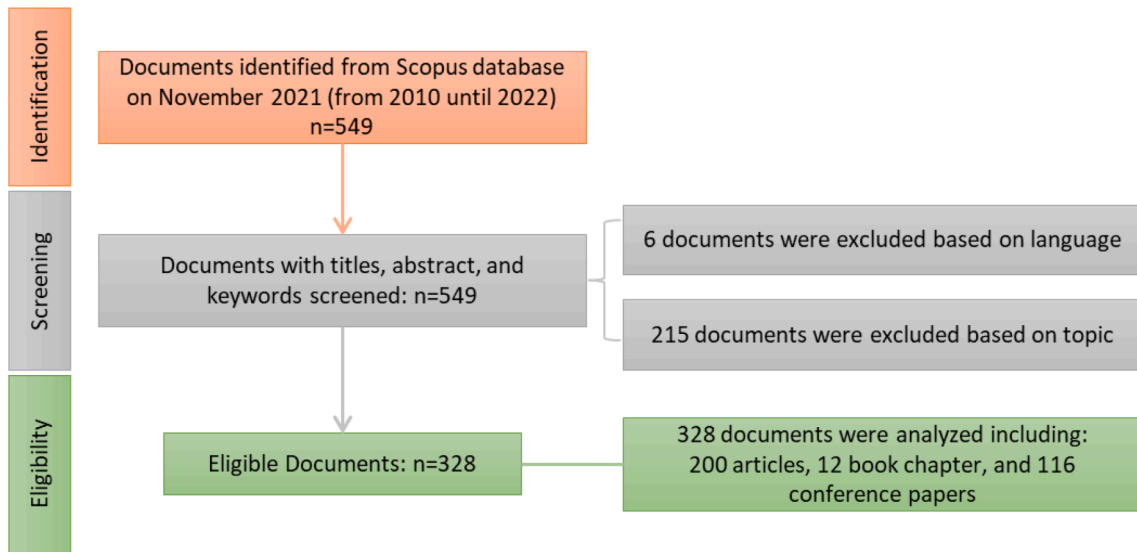


Fig. 2. The process of documents selection.

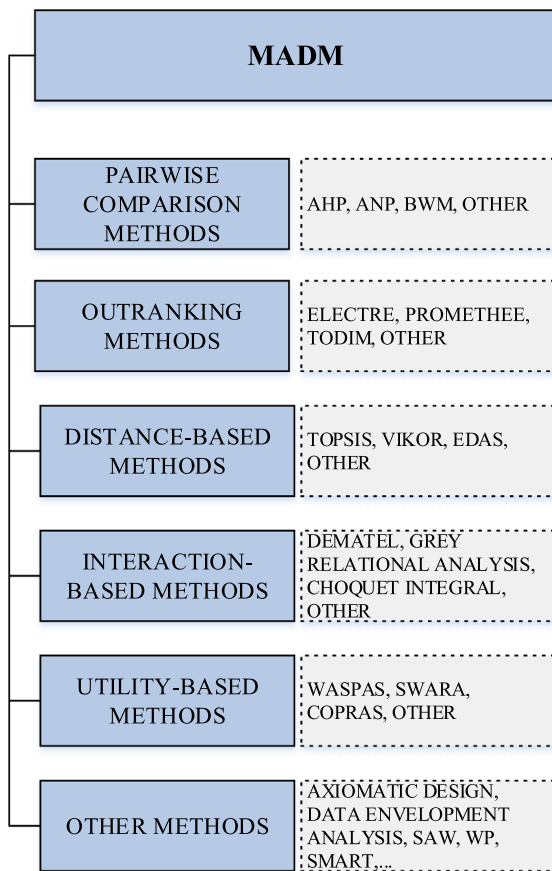


Fig. 3. The classification of MADM methods.

over the other candidates in the set (Gomes et al., 2009).

Distance-based methods: In this group, the best alternative is chosen considering the shortest distance to the ideal solution. TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution), VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje), and EDAS (Evaluation Based on Distance from Average Solution) are the three prevalent methods in this group. TOPSIS is introduced by Hwang & Yoon (1981) and developed by Yoon (1987). The most appropriate alternative is specified based on the closeness to the ideal solution (Kilic & Yalcin, 2021). VIKOR is used for discrete multi-criteria problem with unmeasurable and conflicting criteria. It concentrates on sorting and choosing from a range of alternatives and identifies compromise solutions for a problem with conflicting criteria. EDAS employs an average solution to evaluate alternatives. In this approach, two measures called PDA (distance from the positive mean) and NDA (negative distance from the mean) are taken into account for evaluation (Kahraman et al., 2017).

Interaction-based methods: If the factors in the decision-making problem have effects on each other, interaction-based methods are used. DEMATEL (The Decision-Making Trial and Evaluation Laboratory), GRA (Gray Relational Analysis) and Choquet Integral are the three popular methods in this group. DEMATEL is developed based on graph theory, allowing analyses and solving of problems by visualization approach. This structural modeling method embraces the version of a directed graph, a causal impact diagram, to introduce the interdependence relations and values of the effective influence between factors (Lin, 2013). GRA explores the ambiguous relationships between one fundamental driver and all other drivers in a system. Gray theory has been utilized in a broad array of decision-making environments relevant to engineering and industry (Rajesh & Ravi, 2015). Choquet Integral, in order to find the best interaction, focuses not only on certain subjects but also on their subsets. Choquet integral is a generalized version of the weighted average method, the ordered weighted average method, and the maximum-minimum operator (Xu & Xia, 2011).

Utility-based methods: As proposed by Mardani et al. (2017), the final category is based on determining the utilities. Dissimilar approaches are presented for MADM within the environment of multi-attribute utility theory. Amongst the suggested methods, weighted total and weighted product techniques are well recognized and broadly accepted. In order to develop the precision of WSM and WPM, a weighted batch product evaluation (WASPAS) approach using an aggregation operator in WSM and WPM was introduced (Zavadskas et al., 2014). The step-wise weight assessment ratio analysis (SWARA), which is another popular method is

other multi-criteria analysis methods (Behzadian et al., 2010). TODIM method is a discrete multi-criteria method based on Prospect Theory. The concept of presenting loss and gain expressions in the same multi-qualified function present in TODIM's formulation gives this method some resemblance to PROMETHEE which uses the net outranking concept. TODIM indeed bears a resemblance to outranking methods, because the global value of each candidate is relative to its domination

improved in 2010 and implemented to choose a rational dispute resolution method. The fundamental attribute of the SWARA approach is the probability to predict specialists or opinions of special interest groups about the importance ratio of each criterion in the process of detecting their weights (Zolfani & Saparouskas, 2014). The COPRAS approach provides a solution with the ratio to the most appropriate solution. This approach presumes a direct and proportional dependence on the importance and degree of utility of the versions examined, on a system of criteria that sufficiently identifies the alternatives, and on the values and criteria weights (Yazdani et al., 2011).

Other methods: Out of the five determined groups, there are other techniques such as Axiomatic Design, Data Envelopment Analysis (DEA), Simple Additive Weighting (SAW), Weighted Product (WP), and Simple Multi-Attribute Rating Technique (SMART).

4. Components of Industry 4.0

Industry 4.0 has attracted much attention in recent literature. The adoption of Industry 4.0 technologies has been identified as a major contributor in the context of digital and automated manufacturing environments (Kamble et al., 2018). However, there is no agreed list of Industry 4.0 enabling technologies in the literature; scholars lack mutual understanding and there are some inconsistencies among the different literature domains (Fettermann et al., 2018; Riel & Flatscher, 2017). In this paper, we focus on the main recognized components of Industry 4.0 which include:

- **Cyber-Physical Systems (CPS):** Cyber-Physical Systems (CPS) are transformative technologies for the management of interconnected systems between their computational capabilities and physical assets. CPS generally comprises of three basic factors; sensors, actuators, and controllers. These three factors help to decrease operating costs and optimize data processing time. CPS is widely applied in digital medical devices, aviation control, control technology, social system, and autonomous system (Lee et al., 2015; Jamaludin and Rohani, 2018).
- **IoT:** As defined by Sezer et al. (2017): "IoT allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path/network and any service". Today, IoT is widely used in different fields including healthcare, transportation, and the total production system. A network connected to the internet using a Thing-to-Thing, Thing-to-Human and Human-to-Human (Alcacer and Machado, 2019).
- **Smart Factory/Smart Manufacturing:** In the age of Industry 4.0, manufacturing innovation accompanies ICT integration such as the IoT and Cyber-Physical System, transforming the traditional factory into a smart factory. Smart manufacturing combines a variety of technologies, including but not limited to cyber-physical manufacturing systems, IoT, robotics/automation, big data analytics, and cloud computing, to realize the data-driven, connected supply network vision (Thoben et al., 2017; Sheen and Yang, 2018).
- **Big Data:** Industry 4.0 is a revolution toward the digital world of digital factories and smart products. Big data is an integration of multi-disciplinary technologies and facilitates customers by bringing incredible services to a click. Many data experts define Big Data by the five main characteristics. They are volume, velocity, variety, value, and veracity which respectively refer to large amounts of data; acquisition speed; diversity of data sources; possible valuation; and uncertain data quality (Bailly et al., 2018; Khan et al., 2017).
- **Cloud Systems/ Cloud Computing:** Cloud computing generates a vision of a network-based environment for users, paving the way for the sharing of computations and resources irrespective of the location. In cloud computing, since cloud service providers keep their data centers in geographically distributed locations, which leads to various security problems and threats, utilizers are not aware of the specific location of their sensitive data. Among all these issues, data

breaches, account hijacking, compromised credentials, and broken authentication are identified as some of the top security threats that need to be addressed (Subramanian and Jeyaraj, 2018).

- **Augmented Reality:** In recent years, augmented reality (AR) has been widely applied in industrial areas and has been adopted efficiently and practically, especially in maintenance, training, assembly, and collaboration operations. AR technologies have been particularly appreciated for their ability to improve the human perception of the environment by superimposing additional computer-generated visual information on the user's vision through certain appliances such as projectors, head-mounted displays, and smartphones. It is recognized as one of the key enablers of digital industrial technologies, which support the far-reaching issues of Industry 4.0 and facilitate the digitization of the production sector (Bruno et al., 2019).
- **Digital Transformation/Digitization:** Digital Transformation has always played a key role in the development of all kinds of industry and business. It concentrates on the end-to-end digitization of all physical assets and their integration into digital ecosystems with value chain partners (Reis et al., 2018).

5. Review results

As stated before, the literature review is performed based on three main analyses. These are the method, topic, and bibliometric analysis. These analyses will be performed for the studies including MADM methods.

5.1. MADM review results

The first analysis is performed considering the methods applied by scholars in the scope of Industry 4.0. There are six classes of methods under MADM including pairwise comparison, outranking, distance-based, interaction-based, utility-based, and other methods. Fig. 4 shows the number of documents for each class. Pairwise comparison methods contributed to 34 % of the total methods which is the highest proportion compared with the others, whereas utility-based methods were considered in only 4 % of the total papers.

For the pairwise comparison method class, the articles are analyzed, and the results are provided in Table 2.

AHP is the most employed method among all MADM classes. AHP and TOPSIS are the most popular MADM methods in other reviews as well (Kaya et al., 2018; Stojčić et al., 2019; Yalcin et al., 2022). Table 2 shows information regarding the used method, the consideration of fuzzy, and whether the paper included any other methods in the study. Fig. 5 provides information on the usage percentage for each MADM method based on the reviewed subject.

As shown in Table 2, 70 % of the pairwise comparison method class papers (122 papers) focused on AHP methods in solving MADM problems. Some papers involving crisp and fuzzy extensions of the AHP method are briefly described; Ramachandran et al. (2014) used AHP to evaluate Cloud Computing technology in the education sector. The authors used AHP as it is one of the remarkable MADM models that is widely used as a decision support tool in the decision-making process and can cope with many criteria. AHP is widely used in the literature to rank cloud service providers (CSPs) to make the final decision regarding the convenience of a CSP in the cloud environment. For instance, in the paper of Yadav and Goraya (2018), AHP was employed to evaluate the ranking score of both cloud service providers and service requesting customers. Sadreddini et al. (2021) suggested a smart reservation system that takes into account the behavior of electric vehicle (EV) users, the availability of parking spaces, and the state of charge of EVs. They used AHP in their smart reservation system to consider weighting the behavior of EV users. In the paper of Sangiorgio et al. (2021), Augmented Reality Based Decision Making was suggested to obtain a novel MCDA that follows the hierarchical structure of AHP. In order to validate the potential of the method, a comparison is performed with the

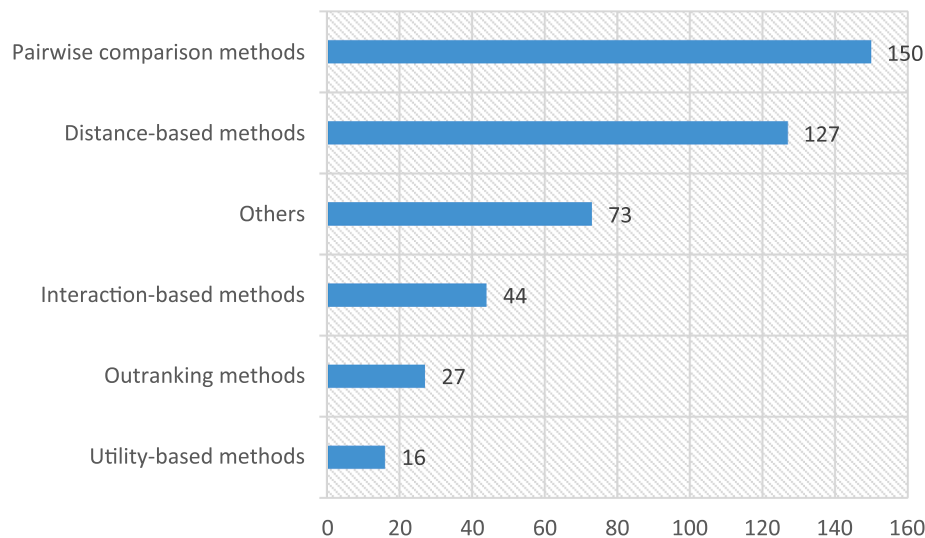


Fig. 4. The number of documents considering the used class.

classical approach and two other improved versions of AHP.

Sun et al. (2016) noted that because a cloud service environment contains many uncertainties that can prevent users from making sound decisions, fuzzy information should also be considered when choosing an appropriate service in an uncertain environment. They integrated fuzzy concepts with AHP to calculate the weights of the service ranking criteria based on user preference. In addition, Patiniotakis et al. (2013) and Kumar and Kumar (2016) presented evaluation systems for CSPs using fuzzy AHP. Moreover, in order to efficiently process ambiguous, inconsistent and incomplete information, Abdel-Basset et al. (2018b) used neutrosophic set theory. They proposed an integrated methodology for the evaluation of the security criteria of SCM systems using DEMATEL and AHP methods under the neutrosophic set concept. They noted that AHP can transform complex problems into subproblems to be solved more easily. In the paper of Nabeeh et al. (2019), AHP method is integrated with neutrosophic sets to estimate the influential factors of the business related to IoT. Their model can cope with ambiguous, impressive, and inconsistent information, thanks to the neutrosophic sets. Guan et al. (2017) proposed a novel framework based on the combination of Cloud AHP and fuzzy assessment method to effectively evaluate the earthquake relief emergency logistics capacity. Combining it with traditional AHP, cloud AHP was evaluated by the researchers as suitable for determining the weights in the evaluation index system.

The second most frequently used method after AHP is ANP with 31 papers which accounts for 17 % of the pairwise comparison methods. While AHP represents a framework with a one-way hierarchical relationship, ANP was preferred by researchers as it deals with complex relationships between decision levels and attributes. For instance, Alhubaishy and Aljuhani (2021) collected assessments from instructors and students and employed ANP method to prioritize their challenges for digital transformation in Saudi universities. In the paper of Chang et al. (2021a), an integrated method was proposed to estimate the performance improvement potential of Industry 4.0 technology in SMEs. In particular, they used ANP to solve problems of interdependence and feedback of individual elements. Fan et al. (2020) proposed an integrated MADM model using fuzzy-ANP and fuzzy-QFD to achieve an optimum selection of design schemes in the cloud environment. Specifically, the weight of each indicator under dimensions was calculated using ANP integrated with intuitionistic fuzzy and fuzzy sets that are effective in handling uncertainty and ambiguity. Abdel-Basset et al. (2020a) proposed an integrated MADM framework by using ANP and TOPSIS under bipolar neutrosophic numbers for chief executive officer selection. In this paper, neutrosophic ANP was used to deal with the indeterminate information in each quantification factor and to address

the difficulty of dependency in the problem. Several researchers such as Zoie et al. (2016), Al-Faifi et al. (2019), (cloud provider selection), Hinduja ve Pandey (2019) (Cloud-Based ERP System selection), Torbacki (2021) (assessment of cybersecurity in industry 4.0), Haghparast et al. (2021) (evaluating health security in IoT) used this method to handle sophisticated relations among criteria.

BWM has several different characteristics compared to other MADM approaches. Firstly, the method requires less comparison data and provides more trustworthy solutions. Also, experts determine the best and worst factors, so that the most influenced dimension can be easily determined. Additionally, it was preferred by researchers as it required less pairwise comparisons than AHP or other sequencing techniques and took significantly less time and resources to produce the desired results (Caliskan et al., 2020; Gupta et al., 2020). Recent BWM implementations have been used for various purposes such as cloud services selection (Nawaz et al., 2018; Hussain et al., 2020b; Youssef, 2020), identification of a list of digitization enablers that can improve SCM (Gupta et al., 2020), additive manufacturing machine selection (Palanisamy et al., 2020), Optimal Service Selection in a cloud environment (Kumar et al., 2018c; Hussain et al., 2020a; Kumar et al., 2021a), IoT technology selection (Aisyah & Dachyar, 2021), Cloud render farm services selection (Annette & Banu, 2019), selection of manufacturing simulation software in industry 4.0 (Cafasso et al., 2020), suggesting big data decision support tool for multi-scenario personnel assessment (Maghsoodi et al., 2020), evaluation of marketing strategies based on big data analysis (Mahdiraji et al., 2019), evaluating the performance of IoT based SCM (Grida et al., 2020), evaluating the organizational readiness for big data adoption (Nasrollahi and Ramezani, 2020).

Different from AHP, ANP, and BWM, other pairwise comparison methods were used in 3 papers. Choochootkaew et al. (2015) investigated the problem of sending large amounts of sensor data from a gateway to a remote server over restricted resources in multi-user IoT systems. In order to maximize satisfaction value, the researchers proposed a sensor data prioritization approach based on user requirements. The approach used the REMBRANDT technique, which adopts the concept of using pairwise comparison to collect requirements and determine a single priority value based on sensor data with different attributes. Researchers stated that they used the REMBRANDT method in the evaluation due to many criticisms of AHP.

Figs. 6 and 7 show the distribution of usages among the pairwise comparison methods. Fig. 6 also provides information on whether single or multiple techniques are used, whereas Fig. 7 focuses on the consideration of fuzzy in the reviewed documents. AHP was implemented with other methods in 63 % of the papers.

Table 2
Analysis of articles with respect to the pairwise comparison method class.

No	References	Pairwise Comparison			Crisp/ Fuzzy version				Single/ Multi Tech.			
		AHP	ANP	BWM	Other	Crisp	Classic Fuzzy	Intuition. Fuzzy	Neutrosophic	Other	Single Tech.	Multi Tech.
1	Agrawal & Vinodh, 2021; Lin et al., 2021a; Priyadarshini et al., 2021; Sadreddini et al., 2021; Sangiorgio et al., 2021; Kachaoui & Belangour, 2020; Mishra et al., 2020; Varshney et al., 2020; Munjal & Singh, 2019; Albahri et al., 2019; Khodaparas et al., 2019; Kuznichenko et al., 2019; Bouayad et al., 2018; Eswaran et al., 2018; Ghazizadeh & Cusack, 2018; Voronova et al., 2018; Yadav & Goraya, 2018; Dai et al., 2017; Lu et al., 2017; Wasim et al., 2017; Md Kassim et al., 2017; Priyadarshinee et al., 2017; Shang et al., 2017; Vafaei et al., 2016; Khowfa et al., 2015; Sundarraaj & Venkatraman, 2015; Ribas et al., 2015; Ramachandran et al., 2014; Cheng et al., 2013; Liao et al., 2013; Sun et al., 2013	31				x					x	
2	Abdel-Basset et al., 2020a; Nabeeh et al., 2019; Abdel-Basset et al., 2018a; Abdel-Basset et al., 2018b	4							x			x
3	Büyükközkcan & Güler, 2020; Dobre et al., 2019; Guan et al., 2017	3								x		x
4	Verma & Chandra, 2021; Büyükközkcan et al., 2020a; Hinduja & Pandey, 2019	3						x				x
5	Adem et al., 2022; Ozceylan et al., 2022; Helmy et al., 2021; Hossain & Thakur, 2021; Jamwal et al., 2021; Lee et al., 2021; Ortíz-Barrios et al., 2021; Seh et al., 2021; Trabay et al., 2021; Houari & Mazri, 2021; Baghapour et al., 2020; Chauhan et al., 2020; Chou & Liao, 2020; Basha et al., 2020; Mukul et al., 2020; Pramanik et al., 2020b; Ahmad et al., 2019; Bui & Perera, 2019; Drakaki et al., 2019; Güler & Büyükközkcan, 2019; He et al., 2019; Medic et al., 2019; Mohallel et al., 2019; Ouadah et al., 2019; Zadtootaghaj et al., 2019; Alam et al., 2018; Medic et al., 2018; Preeth et al., 2018; Singla et al., 2018; Son & Huh, 2018; Fouad et al., 2018; Mansouri & Leghris, 2017a; Şener et al., 2017; Alam & Ahmad, 2016; Becker & Wagner, 2016; Lee & Seo, 2016	36					x					x
6	Gautam & Kumar, 2021; Mathur et al., 2021; Akmaludin et al., 2020; Banaie et al., 2020; Bohlouli & Schrage, 2020; Büyükközkcan & Mukul, 2020; Cafasso et al., 2020; de Andrade et al., 2020; Khodaparas et al., 2020; Nayak et al., 2020; M. Singh et al., 2020; Tariq et al., 2020a; Tariq et al., 2020b; Wang et al., 2020; Zaidan et al., 2020; Annette & Banu, 2019; Mian & Al-Ahmari, 2019; Wang et al., 2019; Fouad et al., 2018; Kumar & Kumar, 2018a; Ramos et al., 2018, 2020; Salehi et al., 2018; Hioual et al., 2017; Kumar et al., 2017; Sidhu & Singh, 2017; Bhushan & Reddy, 2016; Sachdeva et al., 2016a; Lee et al., 2014; Liao et al., 2014; Rehman et al., 2012	31				x						x
7	Radhika & Sudha Sadasivam, 2021; Hasgul & Aytore, 2021; Ogundoyin & Kamil, 2020; Viriyasitavat & Bi, 2020; Yadav et al., 2020; Lu et al., 2019; Son et al., 2019; Fu et al., 2019; Tanoumand et al., 2017; Kumar & Kumar, 2016; Sun et al., 2016; Patiniotakis et al., 2015; Le et al., 2014a; Patiniotakis et al., 2013	14						x			x	
8	Alhubaishy & Aljuhani, 2021	1									x	
9	Zagradjanin et al., 2019	1						x			x	
10	Chang et al., 2021a; Chang et al., 2021b; Torbacki, 2021; Hu et al., 2021; Chuang et al., 2020; Hinduja and Pandey, 2020; Liu & Han, 2020; Yang et al., 2020; Al-Faifi et al., 2019; Li et al., 2018; Yang, 2018; Yang et al., 2018a; Yang et al., 2018b; Hu et al., 2017, 2018; Chen	20				x						x

(continued on next page)

Table 2 (continued)

No	References	Pairwise Comparison			Crisp/ Fuzzy version				Single/ Multi Tech.			
		AHP	ANP	BWM	Other	Crisp	Classic Fuzzy	Intuition. Fuzzy	Neutrosophic	Other	Single Tech.	Multi Tech.
11	et al., 2016; Lin et al., 2016; Zoie et al., 2016; Le et al., 2014b; Huang et al., 2011		1									
12	Abdel-Basset et al., 2020a; Dong et al., 2021; Haghparast et al., 2021; Yasmin et al., 2020; Fan et al., 2020; Skondras et al., 2018; Mansouri & Leghris, 2017a		6					x				x
13	Fan et al., 2020		1							x		x
14	Hinduja and Pandey, 2019		1							x		x
15	Caliskan et al., 2020; Palanisamy et al., 2020; Gupta et al., 2020; Hussain et al., 2020a; Aboutorab et al., 2018; Nawaz et al., 2018			6		x					x	
16	Aisyah & Dachyar, 2021; Gupta et al., 2021; Maghsoodi et al., 2020; Cafasso et al., 2020; Youssef, 2020; Mahdiraji et al., 2019; Annette and Banu, 2019; Kumar et al., 2018c, 2021a			9		x						x
17	Lin et al., 2021b; Grida et al., 2020			2						x		x
18	Hussain et al., 2020b; Nasrollahi and Ramezani, 2020			2				x			x	
19	Li et al., 2021a			1				x				x
20	Rafiee et al., 2019; Choochootkaew et al., 2015; Shetty and D'Mello, 2015				3	x					x	
TOTAL		122	31	20	3							

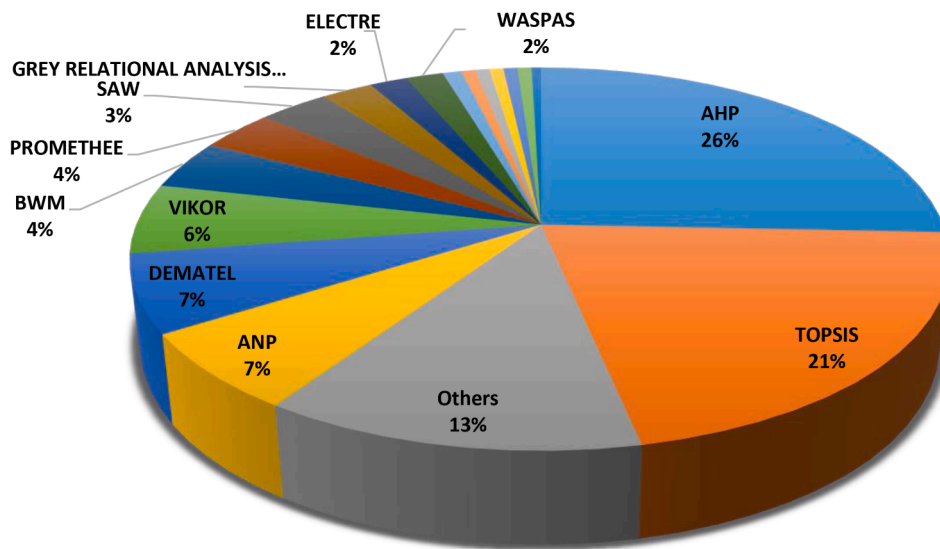


Fig. 5. The percentage of papers with respect to the MADM method.

For the outranking method class, the articles are analyzed, and the results are provided in Table 3.

PROMETHEE methods are recognized as one of the best and most popular approaches to outrank. PROMETHEE methods were the most frequently encountered ranking methods in our review, with 17 articles, as they allow experts evaluating alternatives to probably not have full and complete knowledge of all criteria, but also to clearly articulate the importance of their choices. For instance, in the paper of [Veza et al. \(2015\)](#), the PROMETHEE method was used to manage the innovative production network of smart factories, which is presented as one of the three basic elements of Industry 4.0. [Da Cruz et al. \(2018\)](#) performed the performance assessment of the IoT middleware via the PROMETHEE II method. In this paper, it was concluded that the proposed approach is beneficial when choosing the most appropriate middleware platform.

In the study of [Ramos et al. \(2020\)](#), the PROMETHEE approach, due to its nature of the relevant evaluation space, was employed to identify and rank which systems most agree with the defined criteria based on

the functional requirements obtained of Industry 4.0 projects. [Contreras-Masse et al. \(2020\)](#) implemented a novel MCDA exercise with PROMETHEE-II method to select Industrial IoT platforms for smart manufacturing. The authors noted that PROMETHEE well encompasses the aspect that the roles of experts involved in a decision of the industrial IoT platform. Recent PROMETHEE implementations have been employed for several objectives including service ranking based on network and non-network QoS ([Bhushan & Reddy, 2016](#)), trust evaluation of cloud database servers ([Sidhu and Singh, 2017](#)), assessment of cybersecurity in industry 4.0 ([Torbacki, 2021](#)), selection of organizational innovations in manufacturing companies ([Medic et al., 2018](#)). It is noteworthy that the integration of the PROMETHEE method with extensions such as intuitionistic fuzzy concept, neutrosophic or classic fuzzy concept was not found.

One of the main advantages of applying ELECTRE is that this method can handle data from various measurement scales, both quantitatively and qualitatively. According to [Samaras et al. \(2014\)](#), the strength of

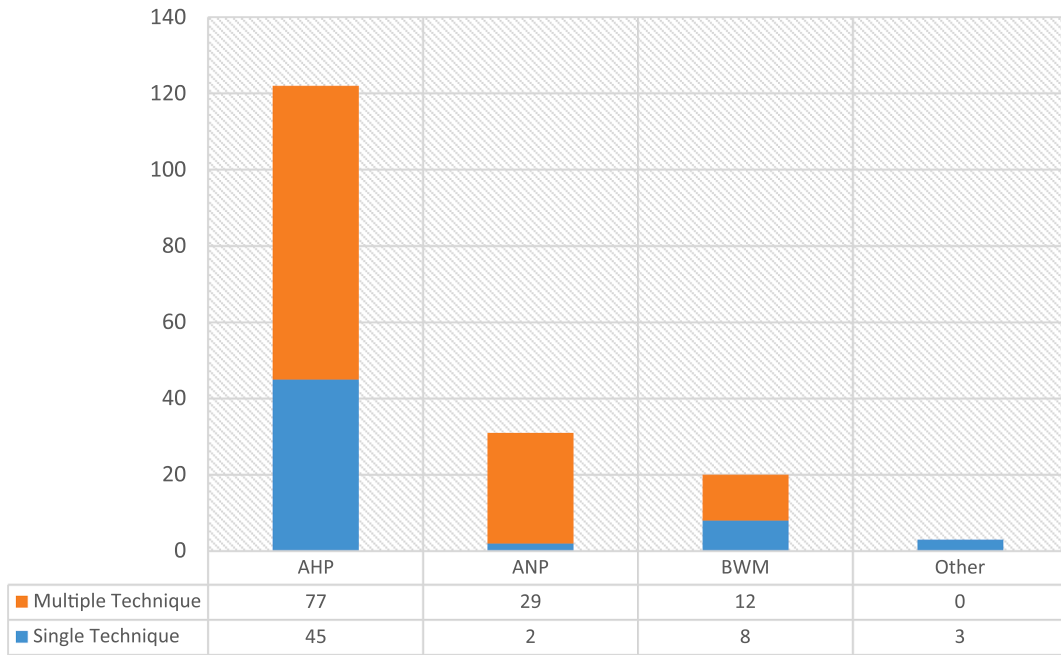


Fig. 6. Analysis of pairwise comparison method documents considering the applied technique.

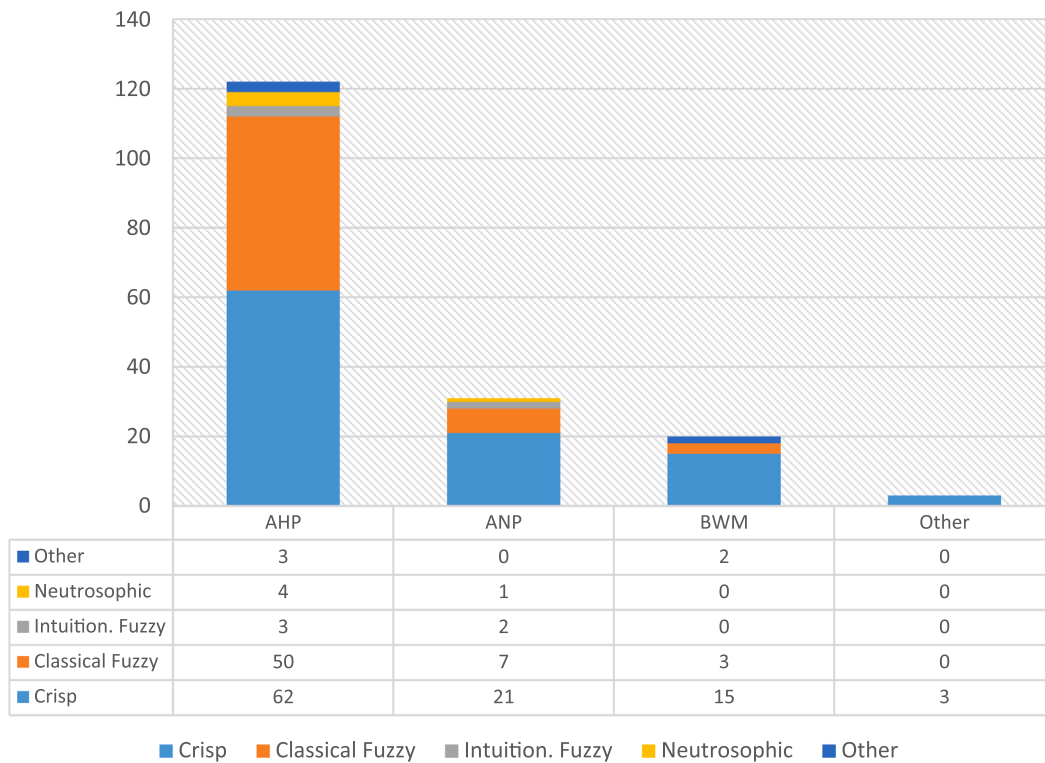


Fig. 7. Analysis of pairwise comparison method documents considering fuzzy.

ELECTRE lies in both its adaptability and mathematical precision. For instance, in order to improve road safety by predetermining hotspots and giving drivers a chance to avoid hazards, [Ait-Mlouk and Agouti \(2019\)](#) presented a web-based platform for data mining and multi-criteria decision analysis. In this study, firstly, data processing was performed, then the extraction of association rules using the Apriori algorithm and the ordering of association rules using the ELECTRE TRI method were performed. At last, they used Times Series analysis to estimate injuries and deaths. [Saidi et al. \(2019\)](#) stated that energy waste

should be prevented during resource allocation in Cloud Computing. For energy consumption awareness in cloud computing, they proposed deep supervised learning -MCDA model by using ELECTRE III and ELECTRE TRI methods. [Akmaludin et al. \(2020\)](#) selected the best programmer in generation 4.0 using AHP and ELECTRE elimination methods. [Ben Alla et al. \(2021\)](#) proposed a novel hybrid MADM method, namely ELECTRE III, and a meta-heuristic algorithm called differential evolution to assess and identify tasks' priorities in cloud computing.

[Ma et al. \(2017\)](#) used an interval neutrosophic set to precisely

Table 3
Analysis of articles with respect to the outranking method class.

No	Reference	Outranking Method				Crisp	Crisp/Fuzzy Version				Single/ Multi Tech.	
		ELECTRE	PROMETHEE	TODIM	Other		Classical Fuzzy	Intuition. Fuzzy	Neutrosophic	Other	Single Technique	Multi Techniques
1	Ait-Mlouk & Agouti, 2019	1				x					x	
2	Ben Alla et al., 2021; Akmaludin et al., 2020; Mian & Al-Ahmari, 2019; Saidi et al., 2019; Rehman et al., 2012; Yazir et al., 2012	6				x						x
3	Çalı & Balaman, 2019	1						x				x
4	Ma et al., 2017	1							x			x
5	Contreras-Masse et al., 2020; Mishra et al., 2019; Da Cruz et al., 2018; Yazir et al., 2018; Dos Santos et al., 2018; Benatia et al., 2016; Veza et al., 2015		7			x					x	
6	Torbacki, 2021; Chuang et al., 2020; Medic et al., 2019; Ouadah et al., 2019; Ramos et al., 2018, 2020; Medic et al., 2018; Sidhu & Singh, 2017; Bhushan & Reddy, 2016; Rehman et al., 2012; Yazir et al., 2012		7			x						x
7	Göçer & Büyüközkan, 2020			1				x			x	
8	Liu & Teng, 2019			1						x	x	
9	Yin & Shyr, 2019			1		x						x
10	Lin et al., 2020			1						x		x
11	Yazir et al., 2012				1	x						x
TOTAL		9	14	4	1							

describe the degree of truth, falsity, and indeterminacy in the statements of decision-makers. In their article, the time-aware trustworthiness ranking prediction problem was structured as an MADM problem of generating an ordered list of services employing interval neutrosophic set theory, and an improved ELECTRE approach was developed to solve this. Çalı and Balaman (2019) presented a two-stage decision support system to rank alternative products, considering a set of product criteria and customer comments regarding these criteria in order to suggest the most suitable alternative to potential customers. They used the VIKOR-integrated IF-ELECTRE method to rank alternative products. In particular, they integrated the IF concept with ELECTRE to effectively represent customer reviews with hesitant expressions in the decision matrix.

TODIM is an effective method based on an expectation function to capture psychological behaviors at risk (Liu and Teng, 2019). The traditional TODIM method may have been preferred in 4 papers, as it considers the psychological behavior of decision-makers to help them choose desirable alternatives. Liu and Teng (2019) proposed an extended probabilistic linguistic TODIM approach to help potential customers assess alternative products through consumer insights into product performance. The probabilistic linguistic term set (PLTS) was used by researchers as it not only describes all possible interpretations in the form of linguistic terms but also reveals the corresponding probability information. In addition, Lin et al. (2020) evaluated IoT platforms using the integrated probabilistic linguistic TODIM method. Göçer and Büyüközkan (2020) performed an evaluation of big data vendors by using IF-TODIM. They used the IF concept to comprehensively identify uncertain information.

Most of the reviewed documents focused on PROMETHEE’s method.

Figs. 8 and 9 show the visualization of this data.

For the distance-based method class, the articles are analyzed and presented in Table 4.

TOPSIS is denoted for 21 % (106 papers) of the total methods reviewed by this study. Almost half of these papers implemented other methods along with TOPSIS. 62.5 % of the papers considering TOPSIS as MADM method, applied another method along with TOPSIS. This method may have been used by scholars because it has a process that takes into account subjective and objective criteria, has a relatively easy calculation process, and is easy to understand by practitioners who may be uninformed about decision-making.

Some papers using TOPSIS approach are described in brief; Rehman et al. (2012) attempted to identify the most effective MADM method for IaaS cloud selection using an expanded dataset and a much broader set of criteria. They stated that if the number of available services is huge, TOPSIS can be used easily because of the simple calculation steps. Becker and Wagner (2016) identified key machines to support the phasing out of decentralized control of production systems. In the process of identifying key machines, they developed a structure based on FAHP and TOPSIS. Sohaib and Naderpour (2017) assessed the technological, organizational and environmental factors of public cloud computing service models in the context of e-commerce. Using the fuzzy TOPSIS approach, they found that SaaS is the best option for their e-commerce business. In the paper of Ahuja and Khosla (2019), a network selection algorithm for data collection was proposed to enable ubiquitous communication in the smart energy system. TOPSIS technique was used for network selection in a heterogeneous environment at the HAN/NAN and WAN levels of the multilayer communication infrastructure of

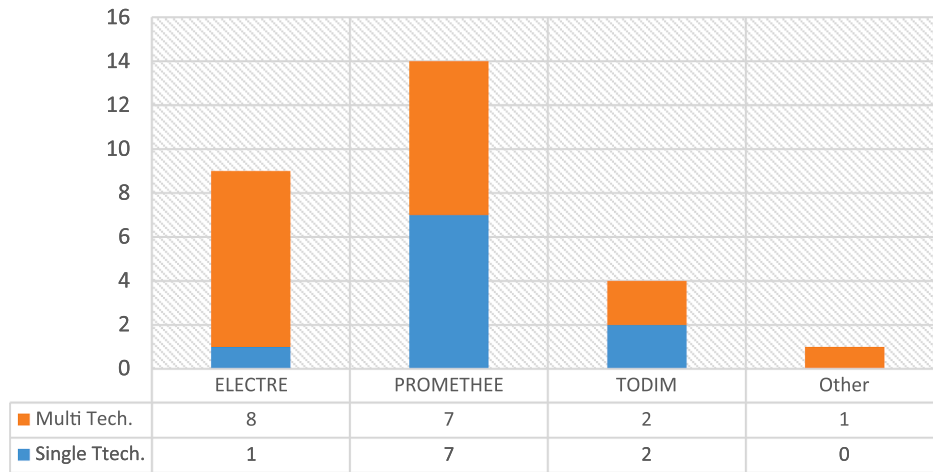


Fig. 8. Analysis of outranking method documents considering the applied technique.

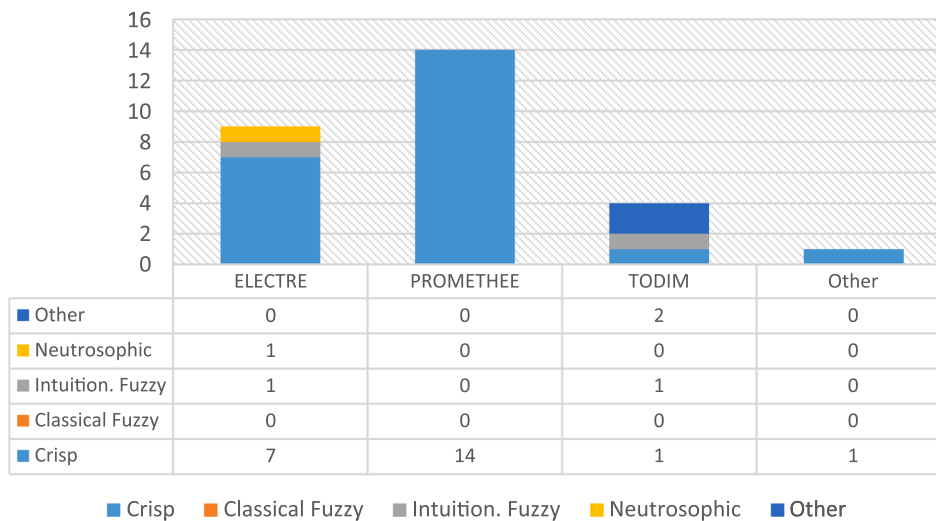


Fig. 9. Analysis of outranking method documents considering fuzzy.

the smart energy system.

In order to deal more effectively with incomplete information in the decision-making process, Sachdeva et al. (2016b) used intuitionistic fuzzy (IF) sets. They proposed an IF-TOPSIS approach for assessing and ranking the most appropriate cloud solution for implementing big data projects. Lately, the fog-to-cloud paradigm began to emerge as a tool to ease communication between several IoT sensor nodes and support the adaptation of services according to the current context of IoT devices. Since the selection of the most suitable services and their configuration is a challenging task, Bangui et al. (2018) used Fuzzy TOPSIS approach for ranking candidates to facilitate the selection of services in fog-to-cloud platforms. They used the fuzzy concept to cope with imprecise and incomplete information in the decision-making process. In the paper of Yörükoğlu and Aydın (2020), three dissimilar smart containers were assessed according to seven distinct conflicting criteria in the neutrosophic environment. The relative closeness coefficients of the alternatives were calculated using the neutrosophic TOPSIS method and the best alternative was determined.

After TOPSIS, VIKOR is the second most popular distance-based method used in 29 studies. This method may have been preferred by researchers as it can address multiple alternatives and criteria and offers a compromise solution that provides maximum group benefit for the “majority” and minimal individual regret for the “opponent”. For instance, using DEMATEL, ANP, and VIKOR, Yang (2018) conducted the

development of an intelligent building management system (IBMS) evaluation and selection for the smart factory. After determining the weights of the evaluation criteria, the VIKOR method was applied by the researcher in the IBMS smart factory selection. Farzaneh et al. (2019) indicated that IoT includes sensor networks where nodes are limited in terms of memory, energy usage, and power consumption, and routing protocol for low power and loss networks can be specially designed for IoT. In this paper, each route connection chooses the best parent according to the solution of VIKOR. To deal with uncertainty in the decision-making process, Lee et al. (2021) integrated fuzzy concepts with VIKOR. In order to effectively assess alternative technologies that incorporate microelectromechanical systems with integrated circuit, Lee et al. (2021) proposed an integrated approach by using Fuzzy AHP and Fuzzy VIKOR. In addition, Büyükoçkan et al. (2020a) used IF concept to eliminate uncertainty in decision-making processes and to take into account the hesitations and intuitions of decision-makers. They proposed an integrated approach based on IF MADM using IF-AHP and IF-VIKOR techniques to analyze the success factors of aviation 4.0.

Using the integration of modified VIKOR and DANP methods, Lin et al. (2016) explored the dynamic relationship between project risk, project management, and organizational performance target of a Cloud CRM project. In this paper, priority gaps for improvement of the Cloud CRM project are calculated by modified VIKOR. In the paper of Liu et al. (2017), the main influential factors of consumer adoption behavior in

Table 4
Analysis of articles with respect to the distance-based method class.

No	References	Distance Based Method				Crisp/Fuzzy Version					Single/Multi Tech.	
		TOPSIS	VIKOR	EDAS	Other	Crisp	Classic Fuzzy	Neutrosophic	Intuition. Fuzzy	Other	Single Techn.	Multiple.
1	Chakraborty & Das, 2021; Chakravarthi & Shyamala, 2021; Vigneshvaran & Vinodh, 2021; Vafaei et al., 2021; Zhang et al., 2021b; Al-Tarawneh, 2020; Chakravarthi et al., 2020; Mo et al., 2020; Muruganantham & Gandhi, 2020; Singh & Tiwari, 2020; Domaschka et al., 2020; Ahuja & Khosla, 2019; Bolivar et al., 2019; Nayak & Tripathy, 2019; Unnikrishnan et al., 2019; Araujo et al., 2018; Azar & Majma, 2018; Hemam et al., 2018; Kumar & Kumar, 2018b; Thomas & Silas, 2018; Chen et al., 2017; Hemam & Hioual, 2017; Dai et al., 2017; Wasim et al., 2017; Hioual & Hemam, 2016; Ravi & Peddoju, 2015; Rehman et al., 2013, 2015	28				x					x	
2	Buyukozkan & Gocer, 2019	1							x			x
3	Singh & Misra, 2021; Pramanik et al., 2020a; Bangui et al., 2018; Liu et al., 2018; Sohaib & Naderpour, 2017; Sun et al., 2016; Peng et al., 2014; Le et al., 2014a; Cheng et al., 2011; Lo et al., 2010	10					x				x	
4	Skondras et al., 2021	1								x	x	
5	Sachdeva et al., 2016b	1							x			x
6	Abdel-Basset, Gamal, Son, & Smarandache, 2020a; Yörtikoğlu & Aydın, 2020	2						x			x	
7	Nguyen et al., 2022; Brodny & Tutak, 2021; Gautam & Kumar, 2021; Liu et al., 2021; Mathur et al., 2021; Houari & Mazri, 2021; Ayoub et al., 2020; Bohlouli & Schrage, 2020; de Andrade et al., 2020; Khodaparas et al., 2020; Kumar et al., 2020; Nayak et al., 2020; Ning et al., 2020; M. Singh et al., 2020; Tariq et al., 2020a; Tariq et al., 2020b; Wang et al., 2020; Xu et al., 2020; Yang & Wang, 2020; Youssef, 2020; Zaidan et al., 2020; Annette & Banu, 2019; Mian & Al-Ahmari, 2019; Wang et al., 2019; Yin & Shyur, 2019; Fouad et al., 2018; Kumar et al., 2018c, 2021a; Li et al., 2018; Nikam & Ingle, 2018; Pu et al., 2018; Rebello & Tavares, 2018; Salehi et al., 2018; Amini & Chang, 2017; El Kassabi & Serhani, 2017; Hioual et al., 2017; Kumar & Kumar, 2017, 2018a; Sidhu & Singh, 2017; Lee et al., 2014; Rehman et al., 2012	42				x						x
8	Mahmoudi et al., 2021; Ortiz-Barrios et al., 2021; Seh et al., 2021; Shaabani et al., 2021; Trabay et al., 2021; Zhou et al., 2021; Baghapour et al., 2020; Hu et al., 2020; Ahmad et al., 2019; Bui & Perera, 2019; Drakaki et al., 2019; He et al., 2019; Mohallel et al., 2019; Preeth et al., 2018; Singla et al., 2018; Skondras et al., 2018; Kumar et al., 2017; Mansouri & Leghris, 2017a; Alam & Ahmad, 2016; Becker & Wagner, 2016; TalebiFard & Leung, 2014	21					x					x
9	Wankhede & Vinodh, 2021; Chen et al., 2020; Farzaneh et al., 2019		3								x	
10	Brodny & Tutak, 2021; Chang et al., 2021a; Chang et al., 2021b; Liu & Han, 2020; Nayak et al., 2020; Kao et al., 2019b; Rebello & Tavares, 2018; Yang et al., 2018a; Yang et al., 2018b; Yang,		14				x					x

(continued on next page)

Table 4 (continued)

No	References	Distance Based Method				Crisp/Fuzzy Version					Single/Multi Tech.	
		TOPSIS	VIKOR	EDAS	Other	Crisp	Classic Fuzzy	Neutrosophic	Intuition. Fuzzy	Other	Single Techn.	Multiple.
11	2018; Hu et al., 2017, 2018; Liu et al., 2017; Yang et al., 2017; Lin et al., 2016		3						x			x
12	Büyüközkan et al., 2020a; Mishra & Rani, 2019; Büyüközkan & Göçer, 2018		2								x	x
13	Büyüközkan & Göçer, 2021; Grida et al., 2020		6				x					x
14	Lee et al., 2021; Büyüközkan & Göçer, 2021; Çalı & Balaman, 2019; He et al., 2019; Zhou et al., 2018; Alam & Ahmad, 2016		1								x	x
15	Kao et al., 2019b		1								x	x
16	Ajay & Aldring, 2022			1							x	x
17	Belhadi et al., 2021, Gireesha et al., 2020a			2		x						x
17	Chakraborty et al., 2021; Mukul et al., 2020; Büyüközkan & Mukul, 2020; Sansabas-Villalpando et al., 2019; Hassanpour & Pamučar, 2019				5		x				x	
TOTAL		106	29	3	5							

the development and promotion of smart medical terminals were evaluated. They used the modified VIKOR approach to fulfill consumers' requirements for continuous improvement and sustainable product development. Moreover, Kao et al. (2019b) evaluated the performance of systemic innovation problems of the IoT in manufacturing industries. Different from the others, in this research, rough interval numbers and Bayesian theory are simultaneously introduced to investigate systemic innovation problems under uncertain conditions. The researchers modified the VIKOR method accordingly.

Moreover, the main advantage of the EDAS method, which is used in 3 studies in the literature, is that it requires less calculation compared to other decision-making and classification methods. Gireesha et al. (2020a) introduced an integrated approach for the determination of appropriate and reliable cloud service providers using the EDAS method. Belhadi et al. (2021) proposed an integrated technique by using Fuzzy WNN and EDAS to identify patterns in AI techniques for developing different supply chain resilience strategies. In order to evaluate catering services in Aviation 4.0, Ajay and Aldring (2022) proposed an intelligent

system on the basis of EDAS approach by employing the complex spherical fuzzy clustering operators. In addition, Chakraborty et al. (2021) proposed a distinct distance-based approach to select an ideal cloud service provider for IoT applications.

CODAS, which has been observed in 3 studies in the literature, is used to make decisions in more than one discipline and field, in cases where there is not much information. Hassanpour and Pamučar (2019) have researched the sustainability of Iranian home appliance industries considering the whole availability of industries. The CODAS model is proposed by researchers to prioritize the challenges discovered in the company. In order to increase the flexibility of obtaining linguistic knowledge through linguistic expressions, Sansabas-Villalpando et al. (2019) integrated hesitant fuzzy linguistic term sets (HFLTS) and CODAS. They used the HFLTS CODAS method to assess the corporate culture of innovation and complex technological change environments. In the paper of Büyüközkan and Mukul (2020), an integrated HFLTS MADM methodology was suggested to assess smart health technologies. The authors determined the importance weights of the criteria with the

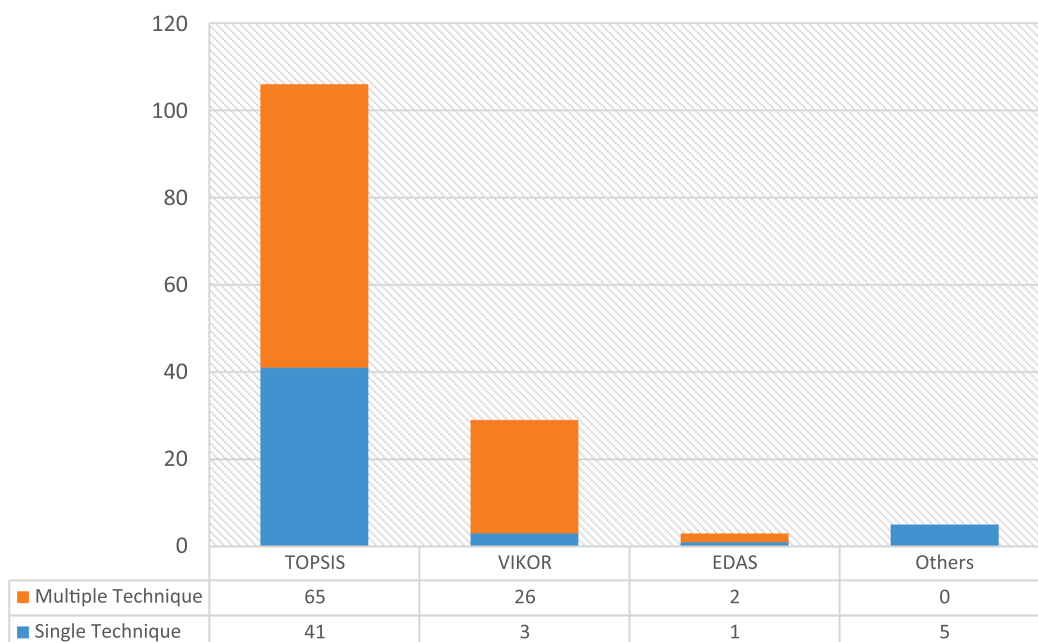


Fig. 10. Analysis of distance-based method documents considering the applied technique.

HFLTS AHP and then evaluated the smart health technologies with the HFLTS CODAS method.

This can be easily noticed in Figs. 10 and 11 which show the analysis of distance-based method documents considering the applied technique and fuzzy, respectively.

For the interaction-based method class, the articles are analyzed, and the results are provided in Table 5.

The DEMATEL method, used in 33 studies, can find solutions to complex and intertwined problems by creating an impact relationship map of the criteria. This approach was implemented to establish the feedback and interrelationships in the criteria and sub-criteria and to find the pivotal criteria to represent factor effectiveness. For instance, Huang et al. (2021) proposed a novel framework for mining social media data based on text mining and they used the DEMATEL method to determine the influence relationships between aspects and criteria. In the paper of Liu and Han (2020), the MADM model was employed to validate through an empirical analysis the key criteria that influence consumer adoption of wearables. They used DEMATEL to determine the interaction between the criteria and to create the effect relationships map. Al-Faifi et al. (2019) proposed a hybrid MADM method for cloud service selection from smart data using DEMATEL, ANP, and k-means algorithm. In this paper, in order to address and validate interdependence and relationships among criteria, they used the DEMATEL method. Chang et al. (2021a) evaluated industry 4.0 technology applications in SMEs using a Hybrid MADM approach. Herein, the DEMATEL approach took on the role of constructing a matrix of total influence relationships and investigating the effect and cause interrelations among parameters.

In 12 studies, DEMATEL was used together with the classical fuzzy logic concept or its extensions. For instance, Kazancoglu and Ozkan-Ozen (2018) analyzed workforce 4.0 in the fourth industrial revolution and proposed a roadmap from the perspective of operations management. They used DEMATEL as it is useful for analyzing complex relationships using matrix operations, furthermore, the uncertainty found in the experts' assessments was handled with fuzzy logic. Vinodh and Wankhede (2020) highlighted the analysis of 20 workforce characteristics for Industry 4.0. The authors prioritized the relevant criteria using fuzzy DEMATEL. Hossain and Thakur (2021) prioritized the

relationships among the key factors of the smart healthcare supply chain (HSC) by applying the Industry 4.0 concept. In this paper, while fuzzy-AHP prioritized Industry 4.0 implementation factors in HSC, cause-effect relationships between factors were investigated using fuzzy-DEMATEL. Yasmin et al. (2020) integrated the IF concept with DEMATEL to take into account the degree of hesitation of individuals. In particular, IF-DEMATEL is used to describe interactions between BDA capabilities and to map network relationships.

However, Singh and Misra (2018) stated that the concept of gray mathematics is a powerful concept for overcoming the subjective errors of experts' input. They used interpretative structural modeling together with the grey DEMATEL to identify causal challenges and their hierarchy of cloud product lifecycle management adoption. Moreover, Kao et al. (2019a) indicated that the combination of both rough set and Bayesian theories can be a strong tool to effectively address vagueness and uncertainty in collective decision-making. They used the RF-based SMOTE technique to select 23 criteria from raw data with the 28 criteria. They then obtained causal relationships using the BR-DEMATEL analysis based on the selected criteria. Abdel-Basset et al. (2018b) used the Neutrosophic DEMATEL method to reveal the cause and effect relationship between the criteria of smart supply chain security requirements. In order to cope effectively with uncertain, vague, and incomplete information, they presented DEMATEL approach in a neutrosophic environment.

We found that the GRA method was used in 13 studies, however, it is remarkable that the GRA method integrated with the fuzzy concept was not found. Some of those papers are described; Huang et al. (2021) proposed a hybrid MADM model to assess cloud computing-based telecommunications service quality improvement. Through the GRA model, the researchers created the performance matrix of alternatives for improvement strategies. In order to compare personal cloud storage products and find the gap between them to improve service levels, an integrated method consisting of AHP-TOPSIS and GRA was presented by Dai et al. (2017). Moreover, they stated that they used GRA approach as it helps deal with weak, incomplete, and uncertain information in the process. Fang et al. (2020) introduced the Cloud model integrated GRA to deal with ambiguous linguistic judgments in photovoltaic technology selection and to overcome errors caused by a small sample size. They

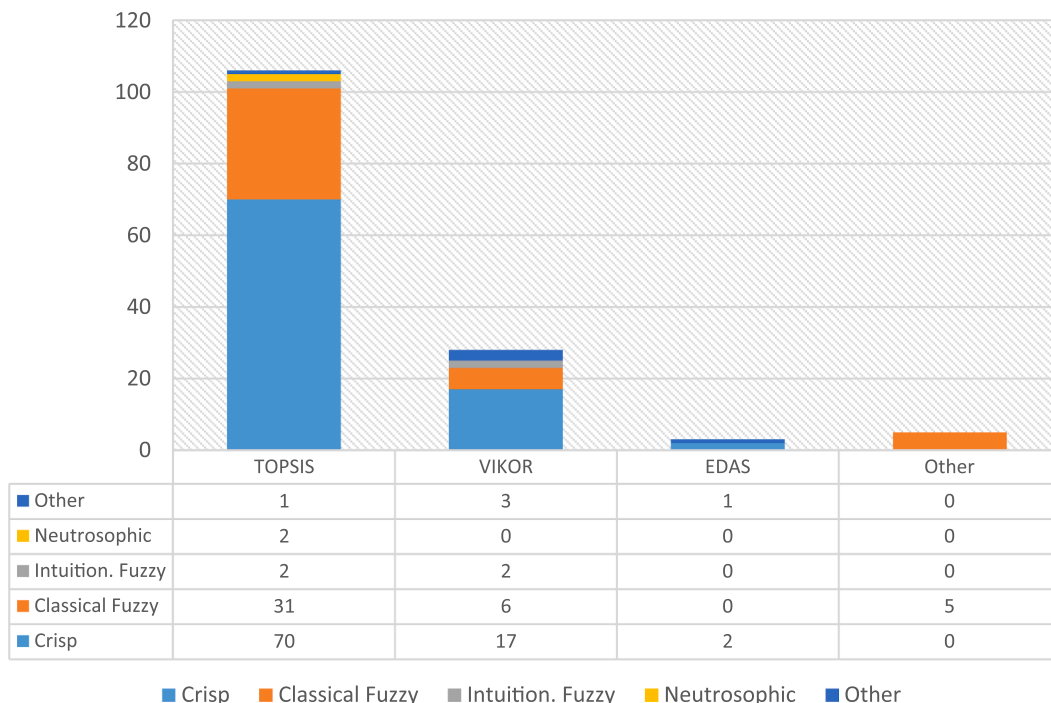


Fig. 11. Analysis of distance-based method documents considering fuzzy.

Table 5
Analysis of articles with respect to the interaction-based method class.

No	References	Interaction Based Method				Crisp/ Fuzzy Version					Single/Multi Tech.	
		DEMATEL	GRA	Choquet Int.	Other	Crisp	Classic Fuzzy	Intuition. Fuzzy	Neutrosophic	Other	Single Tech.	Multiple Tech.
1	Huang et al., 2021; Schaefer et al., 2021; Hu & Chen, 2016	3				x					x	
2	Nguyen et al., 2022; Chang et al., 2021a; Chang et al., 2021b; Jamwal et al., 2021; Hu et al., 2021; Liu & Han, 2020; Yang et al., 2020; Sharma et al., 2020; Al-Faifi et al., 2019; Hinduja & Pandey, 2019; Lamba & Singh, 2018; Yang, 2018; Yang et al., 2018a; Yang et al., 2018b; Hu et al., 2017, 2018; Liu et al., 2017; Yang et al., 2017; Lin et al., 2016; Huang et al., 2011, 2012	22				x						x
3	Abdel-Basset et al., 2018b	1							x			x
4	Kao et al., 2019a; Kao et al., 2019b	2								x		x
5	Singh & Misra, 2018	1								x		x
6	Vinodh & Wankhede, 2020; Kazancoglu & Ozkan-Ozen, 2018	2					x				x	
7	Hossain & Thakur, 2021	1					x					x
8	Yasmin et al., 2020	1						x				x
9	Lin et al., 2017; Yüksel et al., 2021		2			x					x	
11	Liu et al., 2021; Hinduja & Pandey, 2020; Yang & Wang, 2020; Fang et al., 2020; Singh & Misra, 2018; Pu et al., 2018; Dai et al., 2017; Lee et al., 2014; Li, 2012; Huang et al., 2011, 2012		11			x						x
12	Lou et al., 2021; Venkataramanan et al., 2020			2			x				x	
13	Zhang et al., 2021a			1				x			x	
14	Büyükoçkan et al., 2021			1						x		x
15	Raut et al., 2017				1							x
TOTAL		33	13	4	1							

noted that thanks to GRA, the proposed method is able to overcome errors due to the small sample size and reveal internal correlations of the system. In the paper of Yüksel et al. (2021), the assessment of the challenges of companies in the industry 4.0 transformation was performed using the GRA method. They noted that they used GRA because it can produce good outputs even with a small amount of data. An integrated MADM scheme is proposed by Liu et al. (2021) for the selection of cloud services in cloud systems. In this study, the GRA method was

used to solve for relative closeness to improve TOPSIS so that the approximate distance and degree of correlation between the alternative and ideal solution can be considered simultaneously.

Studies using the Choquet Integral (CI) method are briefly explained; Venkataramanan et al. (2020) proposed a cyber-physical security assessment metric (CP-SAM) that leverages graphical theoretical analysis, probabilistic availability model, attack graph metrics, and vulnerabilities in different layers of the microgrid system. In this paper, these

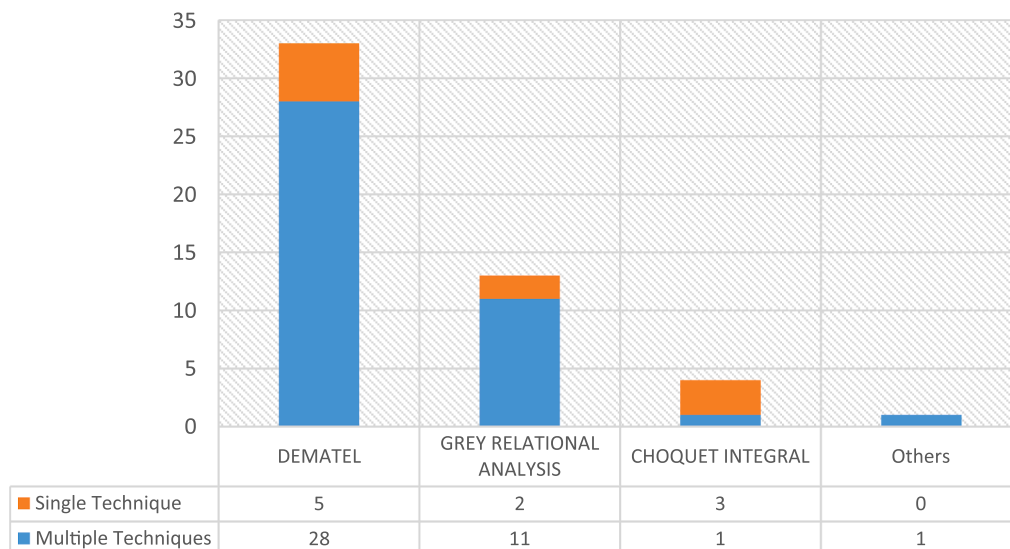


Fig. 12. Analysis of interaction-based method documents considering the applied technique.

factors are integrated into a single metric using the CI method to calculate the CP-SAM. An edge-based distributed decision-making method for product design scheme evaluation was presented by Lou et al. (2021). All evaluation results from more than one decision-maker group are combined with fuzzy measures and CI to determine the optimal design scheme. In the paper of Büyükožkan et al. (2021), a new Pythagorean fuzzy set with the CI approach was recommended for the evaluation of vertical farming technology, an indoor plant production system. They used the Pythagorean fuzzy set to manage the uncertainty in the process. Lastly, Zhang et al. (2021a) conducted a credit assessment of big data companies listed in China. In this study, experts used IF numbers to evaluate the performance of the alternative, and researchers calculated the order of the alternatives by determining fuzzy CI values.

Figs. 12 and 13 show the distribution of interaction-based methods considering the applied technique and fuzzy, respectively.

The results for the utility-based method class are presented in Table 6. This class is the least studied class among MADM classes.

With 8 studies, the WASPAS method has been the most commonly used utility-based method. Sharma and Joshi (2020) suggested that the integrated SWARA-WASPAS method is the most advanced approach in MADM for factor evaluation. Considering the uncertainty inherent in the data and the perceptions of policymakers, Kumar et al. (2021b) proposed a hybrid framework that uses the modified SWARA methodology to rank the different barriers and prioritize strategies to overcome these barriers using the WASPAS methodology. Gireesha et al. (2020b) used an integrated objective and subjective weight evaluation method and IF-WASPAS approach to identify the significance of QoS features and to rank the cloud service providers, respectively. They noted that the conversion of crisp data to IF sets enables individuals to describe their satisfaction, dissatisfaction, and ambiguity, thereby achieving the correct cloud service ranking. Ozceylan et al. (2022) proposed an integrated framework based on FAHP and WASPAS for the assessment of explosive and narcotics trace detection devices. They used WASPAS method to identify the most appropriate device for explosive and narcotics trace detection. In the remaining four studies, WASPAS was used for ranking and determining the most appropriate alternative.

COPRAS is used as an MADM technique to rank alternatives based on

decision criteria in four studies. Sriram and Vinodh (2021) used the COPRAS method to analyze the readiness factors for Industry 4.0 implementation in SMEs. In the paper of Aisyah and Dachyar (2021), COPRAS method was employed to determine the priority technology that can be applied. In the paper of Mahdiraji et al. (2019), experts clustered customers, and the most effective clusters were ranked by COPRAS and a digital banking strategy was developed for them. Saraji et al. (2021) used COPRAS method to rank the challenges of industry 4.0 adoption for a sustainable digital transformation. In addition, the MOORA method was used to rank alternatives in 5 papers. For instance, Maghsoodi et al. (2018) proposed a hybrid approach based on the integration of k-means clustering method with MULTI-MOORA technique to choose the best supplier in a big data structured supplier selection problem. The authors stated that they used the MULTIMOORA method because it is a fast and logical decision-making tool. Brodny and Tutak (2021) evaluated the digital maturity level of businesses in Central and Eastern European countries using MADM using MOORA, TOPSIS, and VIKOR. Jayant et al. (2021) proposed an integrated MADM approach using “MOORA and WASPAS” methods in the assessment of third-party logistics service providers. It also includes the weight of importance provided by the SWARA technique and helps DMs make efficient decisions. Sorting by MOORA considering a linear preference function gave the same results as ranking by WASPAS.

Hassanpour and Pamučar (2019) and Büyükožkan and Güler (2020) employed ARAS method for ranking alternatives. In addition, Kumar et al. (2020) proposed an open-source Android-based application to explore the available fog nodes and offload the computational task to the best-chosen one. Since the choice of fog node for unloading depends on multiple parameters, they integrated the multi-feature additive utility (MAAU) and TOPSIS. In the MAAU approach, the weighted sum of all criteria is calculated for each fog node or executor.

Figs. 14 and 15 show the analysis of utility-based method documents considering the applied techniques and fuzzy, respectively. WASPAS technique is used mostly with other techniques.

The SAW method, also known as the weighting sum method, has been used in 15 studies. The basic concept of the SAW method used in the papers is to find a weighted sum of performance ratings for each

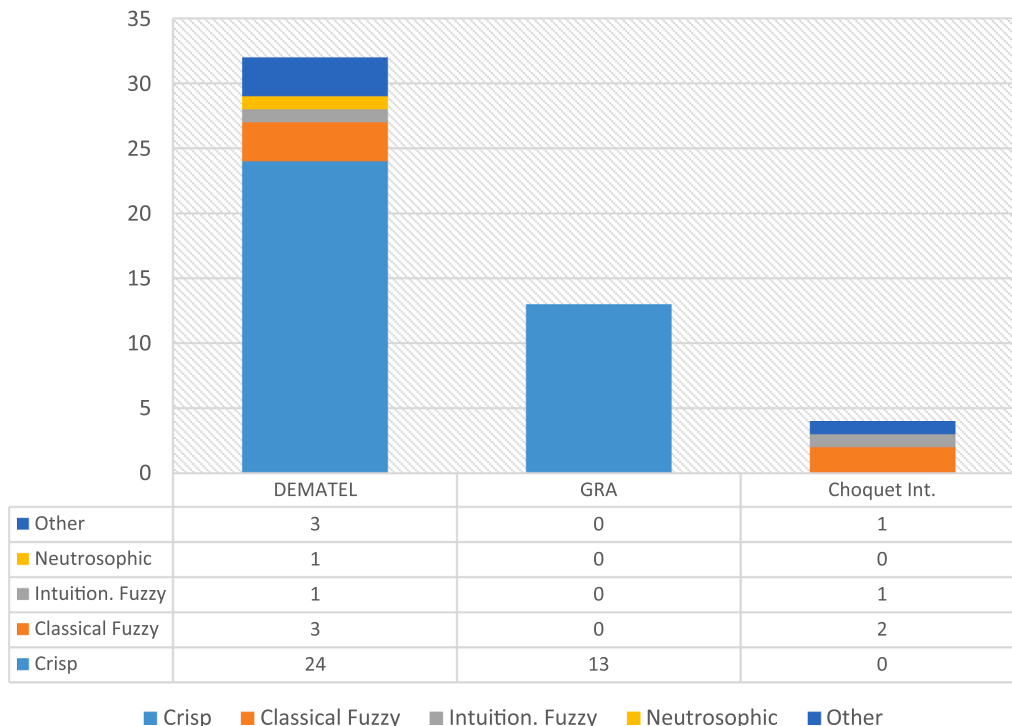


Fig. 13. Analysis of interaction-based method documents considering fuzzy.

Table 6
Analysis of articles with respect to the utility-based comparison method class.

No	References	Utility-based Method				Crisp/Fuzzy Version					Single/Multi Tech.	
		WASPAS	SWARA	COPRAS	Other	Crisp	Classic Fuzzy	Intuitionistic fuzzy	Neutrosophic	Other	Single Technique	Multiple Technique
1	Boltürk & Kutlu Gündoğdu, 2021	1				x					x	
2	Jayant et al., 2021; Kumar et al., 2021b; Sharma & Joshi, 2020; Zhang et al., 2020	4				x						x
3	Ozceylan et al., 2022; Gireesha et al., 2020b; Alam et al., 2018	3					x				x	
4	Kumar et al., 2021b; Jayant et al., 2021; Sharma & Joshi, 2020		2			x						x
5	Sriram & Vinodh, 2021			1		x					x	
6	Aisyah & Dachyar, 2021; Mahdiraji et al., 2019			2		x						x
7	Saraji et al., 2021			1						x		x
8	Büyüközkan et al., 2017				1			x			x	
9	Brodny & Tutak, 2021; Jayant et al., 2021; Büyüközkan & Güler, 2020; Maghsoodi et al., 2020; Saberi et al., 2020; Kumar et al., 2020; Hassanpour & Pamučar, 2019; Maghsoodi et al., 2018; Grygorenko et al., 2016				9	x						x
10	Lin et al., 2021b				1					x		x
TOTAL		8	2	4	11							

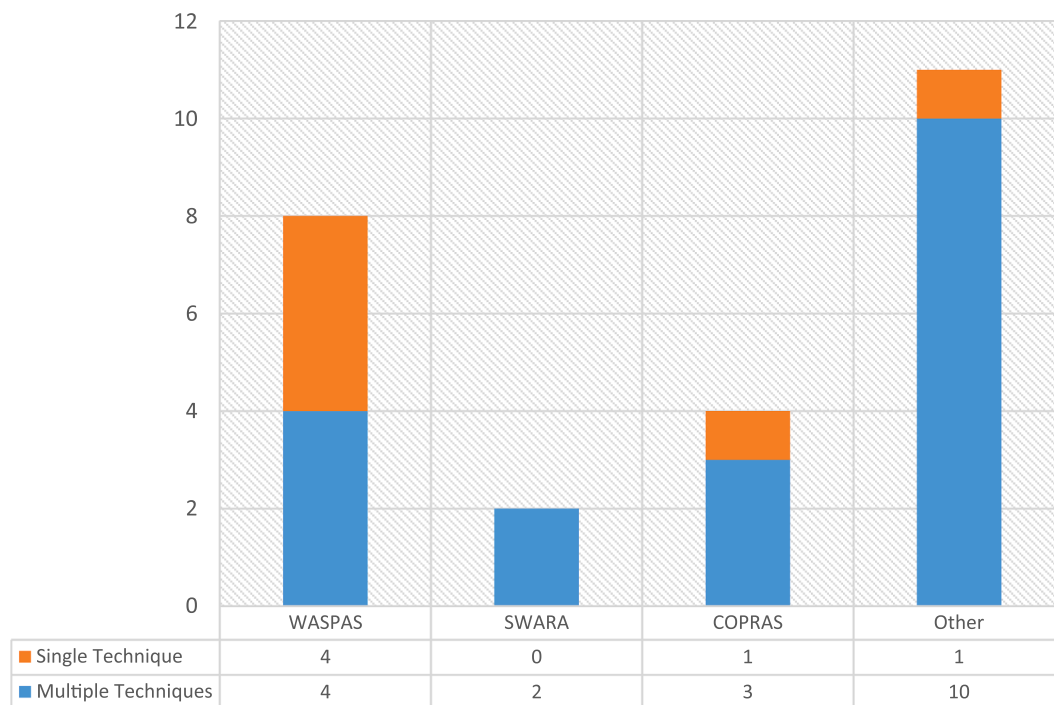


Fig. 14. Analysis of utility-based method documents considering the applied technique.

alternative over all criteria. However, Xu et al. (2019), Büyüközkan et al. (2020b) and Büyüközkan and Göçer (2021) used the SAW method to calculate the weights of several criteria. Ten of these studies considered crisp fuzzy where Friedel et al. (2020), Qi et al. (2020), Saripalli & Pingali (2011), Xu et al. (2019) and ZenAlden et al. (2018) applied SAW as a single technique. On the other hand, Ayoub et al. (2020), El Kassabi

& Serhani (2017), Hassanpour and Pamučar (2019), Hayat et al. (2019) and Mian & Al-Ahmari (2019) applied SAW with other MADM techniques. Four methods considered classical fuzzy where Büyüközkan et al. (2020b) and Dilli et al. (2018a) applied SAW as a single technique, and Mansouri and Leghris (2017a) and Yasmin et al. (2020) applied SAW with other methods. In addition, Büyüközkan and Göçer (2021)

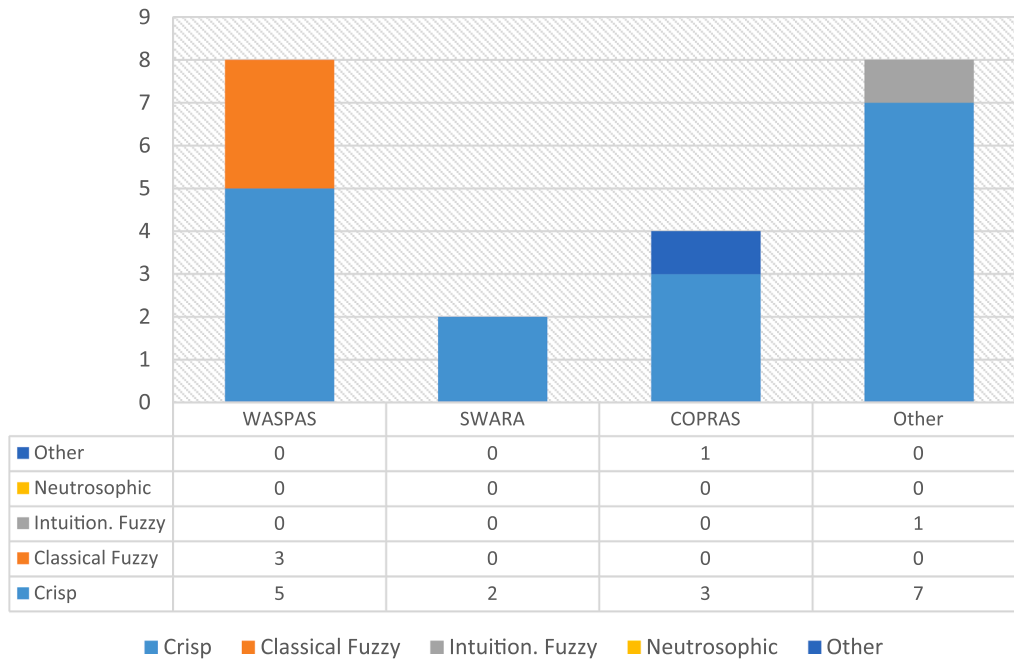


Fig. 15. Analysis of utility-based method documents considering fuzzy.

used SAW with other MADM techniques considering Pythagorean fuzzy.

The methods not included in the MADM classification in Fig. 4 are shown in Table 7. Some of the studies using these methods are briefly described; Zheng and Xu (2014) proposed an MADM method for cloud service provider selection. They integrated triangular intuitionistic fuzzy numbers with the proposed MADM problems for quantifying the subjectivity and uncertainty of the process. In the study of Kao et al. (2019a), the combination of both rough set and Bayesian theories can be a relatively good way to effectively address uncertainty and ambiguity in collective decision-making. Awajan et al. (2021) proposed an integrated methodology by using neutrosophic set (NS) theory with SA and MADM approach to rank different products on the basis of multiple online reviews. In particular, the ranking of alternatives is performed with the simplified neutrosophic number-weighted average (SNNWA) operator and cosine similarity measurement methods. Mahmoudi et al. (2021) have integrated Fuzzy TOPSIS and OPA to address the large-scale MADM problem. In this study, the reason for choosing OPA lies in its ability to deal with the big data problem with missing data, and it is also convenient to use when there is a group of alternatives with comparable attributes within a cluster. Giresha et al. (2020a) proposed a novel MADM approach for identifying appropriate and reliable cloud service providers. The researchers used WNN to calculate appropriate weights for each criterion and EDAS to rank cloud service providers. Mohammed et al. (2020) proposed a uniform intelligent prioritization to resolve various and big data generated from multiple chronic disease patients on the basis of decision making and voting method. Each MCDM method presented by the authors provides a unique ranking from those of other approaches.

In the paper by Zolfani and Derakhti (2020), the application of text mining was performed by a prospective MADM method, namely Latent Semantic Analysis. Gong et al. (2020) stated that although the conventional MADM approaches can provide technical support in the context of big data, it still faces two challenges: individuals need to pre-define the evaluated attributes and related weight parameters, and various types of uncertain data need to be effectively processed in the evaluation process. In order to deal with these shortcomings, they developed an advanced SMAA-ER approach. Hasselblad et al. (2019), proposed an MCDA approach to reduce the risk of discrimination problems found in DEA models. The novelty of this paper is the use of a mathematical

model based on MCDA and DEA to generate a health technology application evaluation score from imprecise data during a technology application. Peng and Dai (2019) proposed some MADM models based on interval neutrosophic reducible weighted (INRW) Maclaurin symmetric mean (MSM) and INRW dual MSM to solve an IoMT evaluation problem. Comparisons of the proposed algorithm with existing interval neutrosophic decision-making algorithms were created to demonstrate their validity.

As seen in Table 8, TOPSIS is used 35 times with AHP, ANP is used 15 times with DEMATEL, and VIKOR is used 11 times with DEMATEL. Also, amongst the studies that consider fuzzy, AHP and TOPSIS are the most applied MCDA methods.

5.2. Topic review results

The topic review is performed by considering two cases. In the first case, the MADM studies including only one component of Industry 4.0 are considered as shown in Table 9.

Cloud systems and cloud computing are the most studied topics with the MADM methods in 126 articles followed by IoT with 64 articles whereas augmented reality is the least studied topic. However, in the second case of the topic review analysis, the MADM studies including more than one component of Industry 4.0 are considered as shown in Table 10.

IoT and cloud systems are studied together in 14 papers. Big data and cloud systems are studied together in 9 papers, whereas IoT and big data are studied together in 6 papers. Fig. 16 shows the number of papers for each topic.

To understand the answer to research question 1, Table 11 gives information on MADM methods that are used for each topic of Industry 4.0.

AHP and TOPSIS are the most employed MADM methods by all Industry 4.0 topics. DEMATEL, VIKOR, ANP or PROMETHEE can be preferred according to the topic.

5.3. Bibliography analysis

Papers reviewed in this study extend from 2010 to 2022 with 214 sources and 328 documents. As for the document type, this review

Table 7
Other MADM methods.

No	References	Method	Crisp/Fuzzy Version					Single/Multi Tech.	
			Crisp	Classic Fuzzy	Intuitionistic Fuzzy	Neutrosophic	Other	Single Technique	Multiple Techn.
1	Awajan et al., 2021	Integration of SNNWA operator and cosine similarity measure methods				x			x
2	Ben Alla et al., 2021	Differential evolution	x						x
3	Bogensperger & Fabel, 2021	A proposed MADM method						x	
4	Bugingo et al., 2021	CRITIC						x	
5	Guo et al., 2021	Neural Network based MCDA	x						x
6	Mahmoudi et al., 2021	Ordinal Priority Approach (OPA)	x						x
7	Saraji et al., 2021	Fermatean fuzzy CRITIC						x	
8	Akhuseyinoglu et al., 2020	A proposed MADM method	x				x		x
9	Ali et al., 2020	Fuzzy MCDM approach	x						x
10	Basha et al., 2020	Artificial Neural Network	x						x
11	Fang et al., 2020	(S&O) weighting methods	x						x
12	Gireesha et al., 2020a	WNN method	x						x
13	Gong et al., 2020	Stochastic multicriteria acceptability analysis-evidential reasoning (SMAA-ER) approach						x	
14	Mishra et al., 2020	SECA	x					x	
15	Mohammed et al., 2020	Hybrid DM and voting method	x						x
16	Ning et al., 2020	CRITIC method	x						x
17	Saberi et al., 2020	A proposed MADM method	x					x	
18	Zolfani & Derakhti, 2020	Latent Semantic Analysis						x	
19	Hassanpour & Pamučar, 2019	DEA method	x						x
20	Hasselblad et al., 2019	DEA method	x					x	
21	Kao et al., 2019b	Modified Delphi	x						x
22	Mitroulis & Kitsios, 2019	Multicriteria Satisfaction Analysis (MUSA)	x					x	
23	Nikam & Ingle, 2019	A proposed MADM method	x					x	
24	Peng & Dai, 2019	MADM based on interval neutrosophic reducible weighted (INRW) Maclaurin symmetric mean (MSM), INRW dual MSM				x		x	
25	Sendhil Kumar & Jaisankar, 2019	Proposed multicriteria-based ranking framework	x					x	
26	Shreyas et al., 2019	Weighted sum method		x					x
27	De Moraes et al., 2018	DEA method	x						x
28	Dilli et al., 2018b	A proposed MADM method		x				x	
29	Sorokin & Rougier, 2018	Dedicated MADM method						x	
30	Zheng & Xu, 2014	A proposed MADM method			x			x	
31	Delias & Matsatsinis, 2013	A proposed MCDA method	x					x	
32	Shang et al., 2013	A proposed MADM method			x			x	
33	Rehman et al., 2012	Compromise programming, Min-Max, Max-Min	x						x

includes 200 articles, 12 book chapters, and 116 conference papers (see Fig. 18). Papers contain 1855 keywords plus (ID) and 1102 author's keywords (DE). The reviewed papers included 926 authors with 1178 appearances. 6 authors with single-authored documents, and 920 with multi-authored documents. As for the authors' collaboration, the documents per author rate for single-authored documents (6 documents) is 0.365, and the author per document rate is 2.74. For multi-authored documents, the rate of co-authored per document is 3.49, and the collaboration index is 2.77.

Fig. 17 shows the annual scientific production for the papers. There is a clear trend in the number of articles till 2020 which is resulting from the academic interest in the Industry 4.0 movement.

The most 20 relative sources are shown in Fig. 18. Advances in intelligent systems and computing journal is the most relative, and is the source with the greatest annual growth with 15 sources followed by IEEE access with 11 sources.

Buyukozkan G. was the author of 11 documents for the topic at hand,

followed by Hussain O.K. with 7 documents. As for the country-based analysis of this topic. China produced 277 papers, India produced 223, and Turkey produced 68 papers. The most cited paper is (Abdel-Basset et al., 2018b) which received 162 citations followed by Aboutorab et al. (2018) with 129 citations. The keywords analysis shows that decision making is mentioned 243 times. The keywords that include MADM methods are the Analytical Hierarchy Process (31 times) and TOPSIS (21 times). As for the topic-based keywords, cloud computing (74 times) is followed by IoT (58 times) and big data (32 times).

6. Trends and research gaps

By analyzing the trend topics, Fig. 19 shows an increasing interest in Industry 4.0 in general and in IoT, big data, and cloud computing in particular. Although the number of papers or keywords that targeted cloud computing was much more than IoT and big data, analyzing the data showed more recent interest in these two topics with MADM

Table 8
The Integrated Use of MADM Methods.

Method	AHP	ANP	EDAS	BWM	ELECTRE	PROMETHEE	TODIM	TOPSIS	VIKOR	CODAS	DEMATEL	GRA	CHOQUET INTEGRAL	SWARA	WASPAS	COPRAS	MOORA	SAW	Fuzzy	Other
AHP	-	2	0	2	3	8	0	35*	6	2	4	1	0	0	2	0	0	2	51*	7
ANP	-	-	0	0	0	2	0	4	9	0	15*	2	0	0	0	0	0	2	8	2
EDAS	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
BWM	-	-	-	-	0	0	0	4	1	0	0	0	0	0	0	2	0	0	4	2
ELECTRE	-	-	-	-	0	0	0	2	1	0	0	0	0	0	0	0	0	0	1	2
PROMETHEE	-	-	-	-	-	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TODIM	-	-	-	-	-	-	0	1	0	0	0	0	0	0	0	0	0	0	1	0
TOPSIS	-	-	-	-	-	-	-	-	5	0	11*	4	0	0	0	0	1	4	30*	6
VIKOR	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	1	6	1
CODAS	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	1	3	1
DEMATEL	-	-	-	-	-	-	-	-	-	-	-	3	0	0	0	0	0	1	8	1
GREY REL. ANAL.	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	2
CHOQ. INTEGRAL	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	3	0
SWARA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	0	0	0	0
WASPAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
COPRAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
MOORA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0	3	1
SAW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
Fuzzy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6

Table 9
Paper analysis based on one topic.

No	Reference	Industry 4.0 Component	No of papers
1	Sangiorgio et al., 2021	Augmented Reality	1
2	Awajan et al., 2021; Belhadi et al., 2021; Guo et al., 2021; Hu et al., 2021; Huang et al., 2021; Jayant et al., 2021; Li et al., 2021b; Mahmoudi et al., 2021; Mathur et al., 2021; Vafaei et al., 2021; Zhang et al., 2021a; Zhou et al., 2021; Baghapour et al., 2020; Bohlouli & Schrage, 2020; Büyüközkan et al., 2020b; Büyüközkan & Mukul, 2020; Chen et al., 2020; Chuang et al., 2020; Friedel et al., 2020; Fu et al., 2020; Göçer & Büyüközkan, 2020; Gong et al., 2020; Hu et al., 2020; Kachaoui & Belangour, 2020; Mohammed et al., 2020; Basha et al., 2020; Mukul et al., 2020; Muruganantham & Gandhi, 2020; Nasrollahi & Ramezani, 2020; Pramanik et al., 2020b, 2020a; Saberi et al., 2020; Yasmin et al., 2020; Zhang et al., 2020; Zolfani & Derakhti, 2020; Çalı & Balaman, 2019; Liu & Teng, 2019; Mahdiraji et al., 2019; Yin & Shyur, 2019; Aboutorab et al., 2018; Maghsoodi et al., 2018, 2020; Lamba & Singh, 2018; Rebello & Tavares, 2018; Salehi et al., 2018; Lin et al., 2017; Yang et al., 2017	Big Data	46
3	Ben Alla et al., 2021; Buingo et al., 2021; Chakravarthi & Shyamala, 2021; Chang et al., 2021b; Dong et al., 2021; Liu et al., 2021; Lou et al., 2021; Priyadarshini et al., 2021; Radhika & Sudha Sadasivam, 2021; Schaefer et al., 2021; Trabay et al., 2021; Ali et al., 2020; Chakravarthi et al., 2020; Domaschka et al., 2020; Fan et al., 2020; Fang et al., 2020; Gireesha et al., 2020a, 2020b; Gireesha et al., 2020b; Hussain et al., 2020a, 2020b; Mishra et al., 2020; Nayak et al., 2020; Ogundoyin & Kamil, 2020; Tariq et al., 2020b; Varshney et al., 2020; Yang and Wang, 2020; Youssef, 2020; Ahuja & Khosla, 2019; Al-Faifi et al., 2019; Annette & Banu, 2019; Bolivar et al., 2019; Fu et al., 2019; Hinduja & Pandey, 2019; Z. Lu et al., 2019; Mishra et al., 2019; Mohallel et al., 2019; Nayak & Tripathy, 2019; Ouadah et al., 2019; Saidi et al., 2019; Sendhil Kumar & Jaisankar, 2019; Son et al., 2019; Xu et al., 2019; Zagradjanin et al., 2019; Abdel-Basset et al., 2018a; Alam et al., 2018; Araujo et al., 2018; Azar & Majma, 2018; Büyüközkan & Göçer, 2018; De Moraes et al., 2018; Ghazizadeh & Cusack, 2018; Hemam et al., 2018; Li et al., 2018; Nawaz et al., 2018; Singh & Misra, 2018; Skondras et al., 2018; Sorokin & Rougier, 2018; Thomas & Silas, 2018; N. Yadav & Goraya, 2018; Yang et al., 2018a,b; Yazir et al., 2018; Büyüközkan et al., 2017; Chen et al., 2017; Dai et al., 2017; Guan et al., 2017; Hemam & Hioual, 2017; Hioual et al., 2017; Hu et al., 2017; Kumar et al., 2017, 2018c, 2021a; Kumar & Kumar, 2017, 2018a, 2018b; H. Lu et al., 2017; Md Kassim et al., 2017; Priyadarshinee et al., 2017; Raut et al., 2017; Şener et al., 2017; Shang et al.,	Cloud Computing/ Cloud Systems	126

(continued on next page)

Table 9 (continued)

No	Reference	Industry 4.0 Component	No of papers
	2017; Sidhu & Singh, 2017; Sohaib and Naderpour, 2017; Tanoumand et al., 2017; Wasim et al., 2017; Alam & Ahmad, 2016; Benatia et al., 2016; Bhushan & Reddy, 2016; Chen et al., 2016; Grygorenko et al., 2016; Hioual & Hemam, 2016; Hu and Chen, 2016; Kumar & Kumar, 2016; Lee & Seo, 2016; Lin et al., 2016; Ma et al., 2016, 2017; Sun et al., 2016; Zoie et al., 2016; Ravi & Peddoju, 2015; Ribas et al., 2015; Shetty & D’Mello, 2015; Sundarraj & Venkatraman, 2015; Le et al., 2014a, 2014b; Lee et al., 2014; Peng et al., 2014; Ramachandran et al., 2014; Zheng & Xu, 2014; Cheng et al., 2013; Delias & Matsatsinis, 2013; Liao et al., 2013, 2014; Patiniotakis et al., 2013, 2014, 2015; Shang et al., 2013; Sun et al., 2013; Li, 2012; Rehman et al., 2012, 2013, 2015; Yazir et al., 2012; Cheng et al., 2011; Huang et al., 2011, 2012; Saripalli and Pingali, 2011; Lo et al., 2010		
4	Ozceylan et al., 2022; Zhang et al., 2021b; Seh et al., 2021; Venkataraman et al., 2020; Nikam & Ingle, 2019; Becker & Wagner, 2016	CPS	6
5	Nguyen et al., 2022; Alhubaishy & Aljuhani, 2021; Brodny & Tutak, 2021; Büyükoğkan & Güler, 2020; Sharma and Joshi, 2020; Bui & Perera, 2019; Güler & Büyükoğkan, 2019; Hasselblad et al., 2019; Mian & Al-Ahmari, 2019; Mitroulis & Kitsios, 2019; Bouayad et al., 2018	Digital Transformation Digitalization	11
6	Ajay & Aldring, 2022; Boltürk & Kutlu Gündoğdu, 2021; Büyükoğkan, Feyzioğlu, & Havle, 2020a; Büyükoğkan, Göçer, & Uztürk, 2021; Cafasso, Calabrese, Casella, Bottani, & Murino, 2020; Chang, Chang, & Lu, 2021a; Chou & Liao, 2020; Gupta, Kumar, & Wasan, 2021; Hassanpour & Pamučar, 2019; Hossain & Thakur, 2021; Kaya, Erdoğan, Kardeş, & Özkan, 2020; Kazancoglu & Ozkan-Ozen, 2018; Kumar, Vrat, & Shankar, 2021b; Ortíz-Barríos et al., 2021; Ramos, Loures, Deschamps, & Venâncio, 2020; Sansabas-Villalpando, Pérez-Olguin, Pérez-Domínguez, Rodríguez-Picón, & Mendez-González, 2019; Singh & Misra, 2021; Skondras et al., 2021; Sriram & Vinodh, 2021; Torbacki, 2021; Vinodh & Wankhede, 2020; Wankhede & Vinodh, 2021; Yörükoğlu & Aydın, 2020; Yüksel, Basmaci, & Genç, 2021; Agrawal and Vinodh, 2021; Akmaludin et al., 2020; Amini and Chang, 2017; de Andrade et al., 2020; Drakaki et al., 2019; Jamwal et al., 2021; Medic et al., 2018; Vigneshvaran and Vinodh, 2021; Ramos et al., 2018	Industry 4.0	33
7	Adem et al., 2022; Aisyah & Dachyar, 2021; Gautam & Kumar, 2021; Haghparast et al., 2021; Houari & Mazri, 2021; Lee et al., 2021; Lin et al., 2021a; Lin et al., 2021b; Verma & Chandra, 2021; Abdel-Basset et al., 2020b; Akhuseyinoglu et al., 2020; Al-Tarawneh, 2020; Banaie et al., 2020; Contreras-Masse et al., 2020; Grida et al., 2020; Hinduja & Pandey, 2020;	IoT	64

Table 9 (continued)

No	Reference	Industry 4.0 Component	No of papers
	Kumar et al., 2020; Lin et al., 2020; Liu & Han, 2020; Mo et al., 2020; Ning et al., 2020; Sharma et al., 2020; M. Singh et al., 2020; Tariq et al., 2020a; Viriyasitavat & Bi, 2020; Wang et al., 2020; Xu et al., 2020; Yadav et al., 2020; Yang et al., 2020; Zaidan et al., 2020; Ahmad et al., 2019; Albahri et al., 2019; Dobre et al., 2019; Farzaneh et al., 2019; Hayat et al., 2019; He et al., 2019; Kao et al., 2019a, 2019b; Khodaparast et al., 2019, 2020; Kuznichenko et al., 2019; Munjal & Singh, 2019; Nabeeh et al., 2019; Peng & Dai, 2019; Rafiee et al., 2019; Shreyas et al., 2019; Wang et al., 2019; Zadtootaghaj et al., 2019; Abdel-Basset et al., 2018b; Da Cruz et al., 2018; Dilli et al., 2018a; Dilli et al., 2018b; Eswaran et al., 2018; Fouad et al., 2018; Liu et al., 2018; Preeth et al., 2018; Pu et al., 2018; ZenAlden et al., 2018; Zhou et al., 2018; Liu et al., 2017; Mansouri & Leghris, 2017a; Choochothaew et al., 2015; Li, 2012		
8	Hasgul & Aytore, 2021; Palanisamy et al., 2020; Singh & Tiwari, 2020; Unnikrishnan et al., 2019; Büyükoğkan & Göçer, 2018	Smart Manufacturing	5

methods. As for the MADM methods, AHP and TOPSIS are still favorable by most researchers due to the effectiveness and popularity of these two methods.

The purpose of the analysis is to recapitulate the information available in a particular field in order to obtain more holistic and precise information. This article sought, found, and investigated articles, proceedings, and book chapters on the MADM methods in the components of Industry 4.0 through the Scopus database. Based on the results of the review, we identified the challenges from the literature analysis and outlined below possible directions for future articles to contribute to further progress in the application of MADM methods in Industry 4.0.

6.1. Algorithms that handle uncertainty more effectively in the decision-making process

In many real-world situations, crisp values are insufficient to cope with real-life problems because human judgment is uncertain and cannot be predicted with exact numerical values. In order to handle the uncertainty that often arises in information derived from the judgment of decision-makers, fuzzy set theory has been used in many multi-criteria decision-making methods (Mustafa et al., 2019).

Approaches integrated with fuzzy set theory ignore the hesitancy that experts may encounter in dealing with uncertainty in the decision-making process. In real-world situations, however, decision-makers are likely to hesitate. Compared to traditional fuzzy sets, IFSSs are more powerful to reflect the degree of hesitation. Only 17 sampled papers in our literature have utilized IFSSs to address the degree of hesitation of experts. No matter how robust the concept of IFS is, only the sum of membership (truth degree) and non-membership function (falsity degree) values is less than 1. However, there are cases where the sum of these two functions is greater than 1, unlike the case caught in IFSSs. This limitation in the IFS structure is the motivation for introducing Pythagorean fuzzy sets (PFSs). The pythagorean fuzzy set (PFS) is a powerful tool for dealing with uncertainty that satisfies the condition that the sum of function values is greater than 1 (Ejegwa, 2020). In order to cope with uncertainty, in our literature only two papers (Büyükoğkan

Table 10
Paper analysis based on more than one topic.

No	Reference	Industry 4.0	CPS	IoT	Smart Manufacturing	Big Data	Cloud Systems/Cloud Computing	Augmented Reality	Digital Transformation / Digitalization
1	Bogensperger & Fabel, 2021	x							x
2	Saraji et al., 2021	x							x
3	Li et al., 2021a				x			x	
4	Chakraborty & Das, 2021			x		x	x		
5	Helmy et al., 2021					x	x		
6	Shaabani et al., 2021	x							x
7	Chakraborty et al., 2021			x			x		
8	Sadreddini et al., 2021				x			x	
9	Qi et al., 2020		x				x		
10	Abdel-Basset et al., 2020a			x		x			
11	Büyüközkan & Mukul, 2020				x	x			
12	Gupta et al., 2020					x			x
13	Caliskan et al., 2020	x							x
14	Ayoub et al., 2020			x	x				
15	Chauhan et al., 2020			x			x		
16	Buyukozkan & Gocer, 2019			x		x	x		x
17	Medic et al., 2019	x							x
18	Bangui et al., 2018			x			x		
19	Yang et al., 2018b			x		x	x		
20	Nikam & Ingle, 2018		x	x			x		
21	Son & Huh, 2018		x				x		
22	Yang, 2018	x			x				
23	Singla et al., 2018			x			x		
24	Voronova et al., 2018			x		x	x		x
25	Hu et al., 2018			x			x		
26	Dos Santos et al., 2018	x				x			
27	El Kassabi & Serhani, 2017					x	x		
28	Mansouri & Leghris, 2017b			x			x		
29	Sachdeva et al., 2016b					x	x		
30	Sachdeva et al., 2016a					x	x		
31	Vafaei et al., 2016		x			x			
32	Veza et al., 2015	x			x				
33	Khowfa et al., 2015					x	x		
34	TalebiFard & Leung, 2014			x			x		
		8	4	14	6	14	19	2	8

et al., 2021; Büyüközkan and Göçer, 2021) have utilized PFSSs. In I4.0 decision-making problems, more research is needed under the concept of PFS to better deal with uncertain information in cases where the sum of function values is greater than 1.

In both IFSSs and PFSSs, the degree of hesitation depends on membership and non-membership degrees. Since the degree of hesitation represents indeterminacy and ignorance stemming from the lack of knowledge, it is more suitable to express it as irrelevant to the degree of membership and degree of non-membership. Recently, Gündoğdu and Kahraman (2019) introduced three-dimensional spherical fuzzy sets (SFSs) as a new extension of IFSSs and PFSSs, where the experts' hesitancy can be expressed clearly. Accordingly, experts can express their hesitations irrespective of their degree of agreement or disagreement. Therefore, SFSs can efficiently reveal experts' judgments and preferences (Sharaf, 2021). Since SFSs are recently introduced, the literature is still limited. In our literature, only two sampled papers (i.e. Ajay and Aldring (2022); Boltürk and Kutlu Gündoğdu (2021)) have used SFSs. More research is needed using SFSs to deal with the hesitancy of the experts in I4.0 decision-making problems more adequately and accurately.

In addition, there are 14 sampled articles using the PROMETHEE method, which is considered one of the best and most popular methods

of outranking. However, it is noteworthy that the PROMETHEE method is used with crisp values in all of the sampled studies. Although the PROMETHEE method used crisp data to allow experts evaluating alternatives to clearly articulate the importance of their preferences, they fail to cope with the uncertainty arising from the ignorance and subjectivity of the experts. Essentially, neutrosophic sets can effectively deal with uncertainty by considering all aspects of a decision situation (i. e. truth, uncertainty, and falsity). Therefore, the use of PROMETHEE under the neutrosophic concept has been preferred by many researchers in recent years to cope with the uncertainty in the decision-making process (Zavadskas et al., 2019; Zhu et al., 2020; Bausys et al., 2021). In future studies, the PROMETHEE method can be used with the neutrosophic concept to cope with the uncertainty in Industry 4.0 decision-making applications.

6.2. Algorithms that more effectively handle inter-criteria interaction or interdependence features

The most popular MADM approach used to determine the importance weights of the criteria is the AHP method with 122 sampled papers. The most popular MCDM approach used to determine the

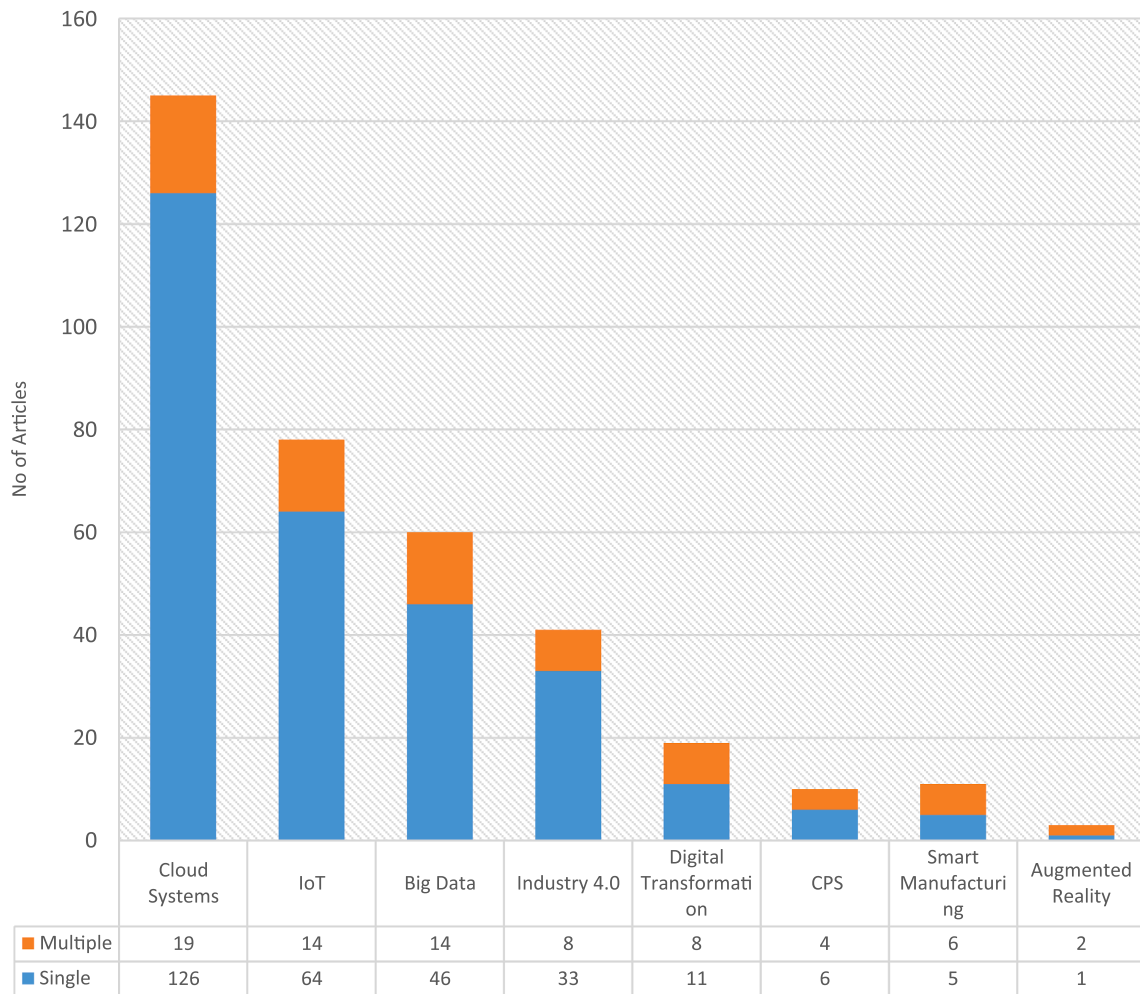


Fig. 16. Topic analysis of reviewed papers.

Table 11
Number of papers that consider each Industry 4.0 topic and MADM method.

Methods	Cloud Computing/Cloud Systems	IoT	Big Data	Industry 4.0	Digital Transformation/ Digitization	Cps	Smart Manufacturing	Augmented Reality
AHP	53*	32*	14*	14*	8	5	4	2
ANP	18*	8	4	3	1	0	1	0
EDAS	1	0	1	1	0	0	0	0
BWM	7	2	5	3	4	0	3	1
ELECTRE	4	0	2	1	1	0	0	0
PROMETHEE	6	2	2	7	2	0	1	0
TODIM	0	0	3	0	0	0	0	0
TOPSIS	47*	25*	17*	8	8	4	3	0
VIKOR	9	10	5	4	1	0	2	0
CODAS	0	0	2	2	0	0	1	0
DEMATEL	13*	8	5	6	1	0	1	0
GRA	7	2	1	1	0	0	0	0
CHOQUET	0	0	1	1	0	1	0	0
INTEGRAL								
SWARA	0	0	0	1	1	0	0	0
WASPAS	2	0	2	2	1	1	0	0
COPRAS	0	1	1	1	0	0	0	0
MOORA	1	0	1	0	1	0	0	0
SAW	5	5	4	1	1	1	1	0
Fuzzy	40*	24*	22*	16*	9	5	3	1
Others	21*	19*	13*	5	5	0	0	0

importance weights of the criteria is the AHP method with 122 studies. But in I4.0 decision-making problems, the relationships between decision criteria may have a network structure, so the problem cannot be

solved with a hierarchical structure and linear methods like AHP.

Saaty developed the ANP method, an extension of AHP, to overcome the limitations of linear techniques. ANP can also address the

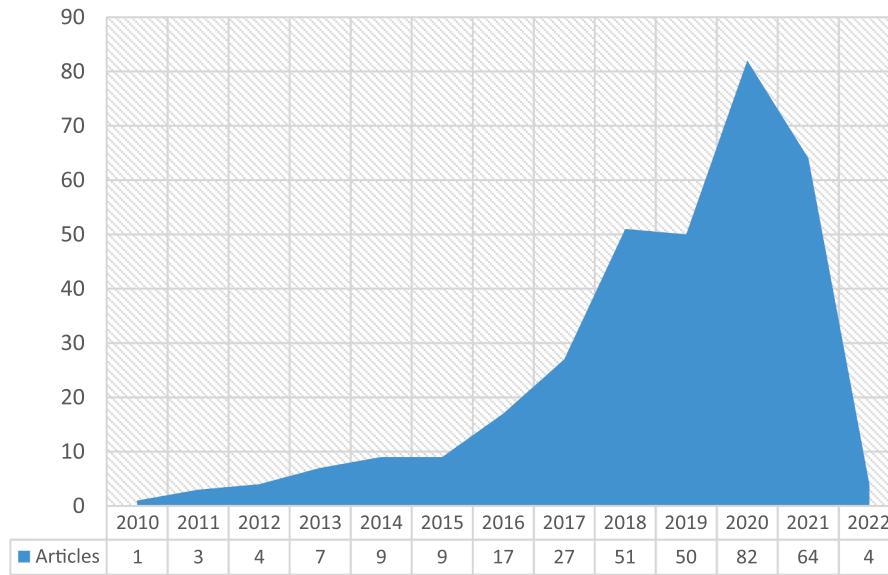


Fig. 17. Annual scientific production.

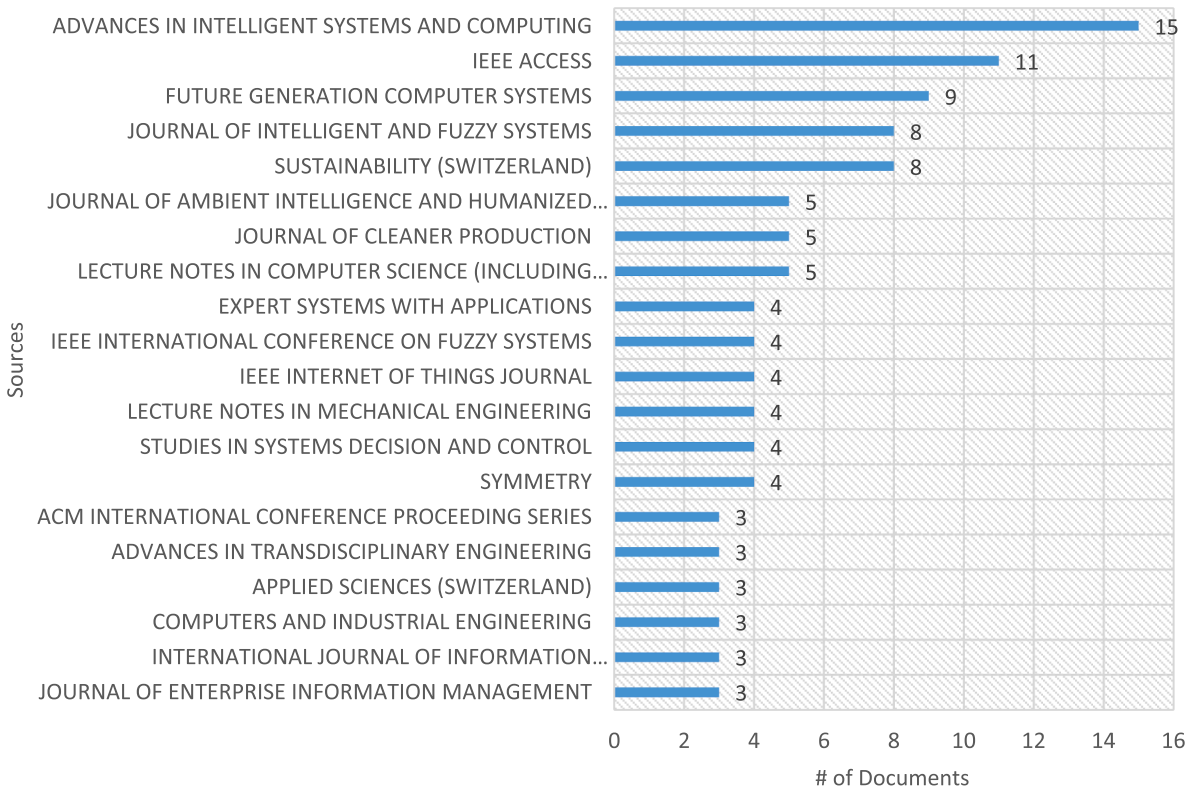


Fig. 18. Most relative sources.

interdependence and feedback between each standard and alternative in real-world problems. The ANP method divides the problem into clusters and each cluster contains multiple variables/criteria for evaluation. In order to improve the equal weighting assumption of the traditional ANP method, the DEMATEL technique was introduced to combine with the basic concept of ANP to solve complex problems in effective weights, it was called DANP (DEMATEL-based ANP). As seen in Table 10, ANP was used with DEMATEL 15 times. Eight of those papers use DANP in cloud systems decision-making problems. However, the fact that individuals' decisions are handled with crisp values in these studies creates uncertainty in evaluating the interaction between criteria or their

interdependence characteristics. Therefore, grey theory can be combined with DEMATEL methods to improve the accuracy of the decision-making process. In future articles, especially in cloud system decision-making problems, the grey theory-based DEMATEL method and ANP can be integrated to determine the interrelationships of the criteria and to address the dependencies between the criteria.

Moreover, the CI technique has a simple procedure compared to other MCDM methods and allows the modeling of dependencies among criteria in cases where traditional techniques are difficult. By doing this, the CI better reflects what can be expected of an expert (Büyükožkan et al., 2021). Also, when declaring their evaluations, the experts rely on

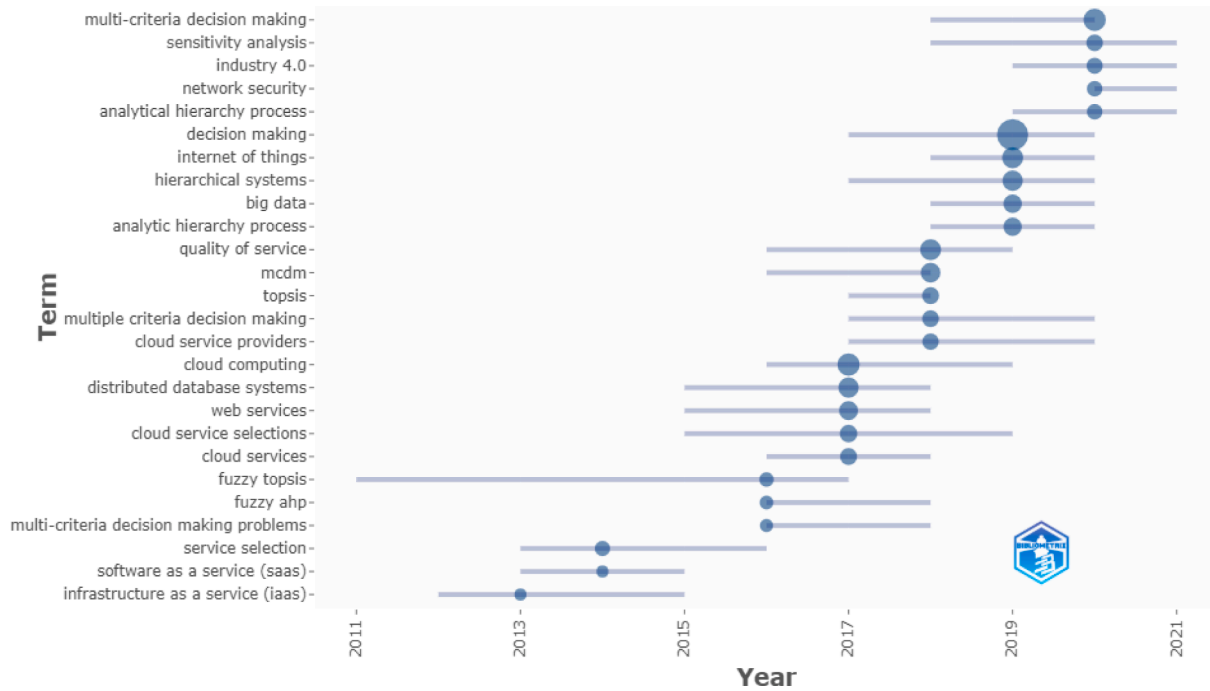


Fig. 19. Trend topic analysis.

information about all the criteria, which are usually not independent. In order to deal with this challenge, the CI method can be utilized due to its power in addressing conflicting and interactive criteria. However, in order to model criterion interactions and independence, only four sampled papers in our literature (i.e. Venkataramanan et al., 2020; Lou et al., 2021; Zhang et al., 2021a; Büyükoçkan et al., 2021) have used the CI approach. Therefore, there is a need for more studies using the CI technique, which has a practical and powerful structure in modeling criterion interactions and independence.

6.3. Algorithms that handle experts' subjectivity more effectively

The literature review included MADM approaches applied to I4.0 decision-making problems that involve both qualitative and quantitative factors. One of the major shortcomings of current MADM models in our literature is that they depend on domain knowledge and expert experience for initial input (Chuang et al., 2020). Some studies have included fuzzy logic and its extensions (for example, intuitionistic fuzzy, neutrosophic and pythagorean) to improve the accuracy of the decision-making process. While the contributions of MADM studies cannot be underestimated, both crisp and fuzzy-based models depend on the experts' domain knowledge. Different results may arise due to different expert opinions. However, with the development of information technology, data can be gathered from alternatives, making it possible to discover meaningful patterns in the data of alternatives based on data analytics algorithms. These models are not subject to individual judgment and may objectively reflect the performance of alternatives. We concluded that models in which data analytics techniques are integrated with the judgments of decision-makers are needed to allow for a more systematic and scientific evaluation of alternatives.

As stated, MCDM is the process of selecting the most appropriate alternative from a limited set of alternatives based on a limited set of criteria. Since the importance of the criteria in this process is not the same, determining the weight of each is one of the basic elements of the MCDM process. Generally, the approaches for determining weights can be classified into two categories. In subjective methods, decision-makers play an important role in determining the importance weights of the criteria, so that the weight of each criterion is computed according to the

information obtained from their judgments. In objective methods, the weights of the criteria are deduced based on the information presented in the decision matrix and the available data, while the fact that decision-makers and their subjective judgments do not have a role in the determination of the weight of the criteria makes the assessment more precise (Yalcin et al., 2022). The most commonly employed objective methods include the standard deviation method, entropy method, and CRITIC algorithm. In our literature, only three articles have used the CRITIC algorithm to objectively determine criterion weights. However, the original CRITIC approach has a shortcoming in properly handling conflicting relationships between criteria, as it only uses Pearson's correlation. In future papers, more consistent criterion weights can be obtained using Distance Correlation-based CRITIC (D-CRITIC) algorithm since it gives a lower symmetric mean absolute percentage error, a higher average distance correlation, and a higher average Spearman rank-order correlation.

Moreover, the CCSD approach is a new technique developed to objectively determine the weight of each criterion. This method has several advantages over other methods of objective weight determination. There is no need for a specific normalization approach unlike the entropy method, specifying the weights to be more extensive and convincing than the entropy method and the SD method, and having a more transparent mechanism than the CRITIC algorithm; are some advantages of the CCSD method over other similar approaches. Therefore, in order to eliminate subjectivity in the determination of each criterion's weight, MADM applications using the CCSD method are needed.

6.4. Generalization of results from MADM methods

In the majority of MADM applications in our literature, the results are case-dependent, and can only fit the studied case. The main reason for this is the variability in the criteria and the subjectivity in the weighting of these criteria. Moreover, the results themselves are subjective to the context of the study and can only make sense in the context studied, which often involves human judgment, which leads to inconsistency in the evaluation of the modules applied. However, in order to generalize the results obtained from the MADM methods, alternative cases in similar frameworks and similar empirical studies are needed.

This would provide a more convenient analysis of the results.

Sensitivity analysis considers changes in parameters and factors of the MADM problem and shows the change reflected in the ranking of results. In other words, it demonstrates the robustness of results by enabling practitioners to understand the limits at which a particular solution can be effective. Typically, the weight adjustment method is applied when the weight of a particular attribute changes while fixing other attributes (Soni et al., 2022). In future studies, the application of sensitivity analysis may help to show tradeoffs by considering different sets of modifications, such as the inclusion/exclusion of certain criteria or changing their weighting.

6.5. Algorithms to select the most suitable technology for small and medium enterprises (SMEs)

Due to the apparent benefits of Industry 4.0 technology, most SMEs nowadays are looking forward to applying Industry 4.0 technologies and improving their performance. However, the increasing number of alternatives along with the limited budget, makes MADM problem much more complex. Masood and Sonntag (2020) pointed out four technologies that build the foundation of most of Industry 4.0. These four technologies are IoT, cloud computing, big data, and analytics. 15 alternative combinations can be made up of these 4 technologies that can be applied in SMEs. Soni et al. (2022) proposed a hesitant fuzzy-based technology selection model to determine which of Industry 4.0 technologies can be applied by SMEs focusing particularly on sustainable supply chain finance performance taking into consideration 15 economic, environmental, and social criteria in their module. Moreover, different fuzzy-based technology selection models are needed to guide in choosing the most suitable technology for small and medium-sized enterprises (SMEs): neutrosophic-based selection model, intuitive fuzzy-based selection model, pythagorean fuzzy-based selection model.

Based on the results of the review, we identified the challenges from the literature analysis and outlined below possible solutions for future articles. The summary of the challenges, research gaps, and recommended solutions are demonstrated in Table 12.

7. Summary and conclusion

The Industry 4.0 concept was first presented by the German government to encourage computerization in manufacturing. The proposed concept has received a lot of attention and become widespread due to the benefits provided by companies as a result of Industry 4.0 technologies. Hereby, businesses started to invest in Industry 4.0 technologies (Ozdemir, 2022). However, since the implementation of industry 4.0 technologies requires a significant amount of capital, firms have to choose the most suitable technologies among the available alternatives. This process can be risky and requires appropriate evaluation of all options by considering all criteria (Soni et al., 2022). MCDM methods help to select the best alternatives in situations where many criteria arise. On the other hand, there are many MCDM methods in the literature, and each method has different properties having advantages and disadvantages (Zardari et al., 2014). Thus, it can be very difficult to choose the appropriate method for the decision-making process (Bajec & Tuljak-Suban, 2019). Implementing an inappropriate method can lead to wrong decisions, which can result in spending a lot of money on inappropriate technology. In this context, we reviewed the MADM methods used in the scope of Industry 4.0 to guide researchers and business practitioners in identifying suitable MADM methods in Industry 4.0 components. Accordingly, this article identifies frequently used MADM methods for Industry 4.0 components and highlights the link between a particular component and a particular method.

This study focuses on the articles, proceedings, and book chapters. In this context, the Scopus database has been investigated using the search terms in Table 2 and a total of 328 studies that applied MADM methods within the scope of Industry 4.0 have been reviewed. As can be seen in

Table 12
Challenges, research gaps and recommended solutions.

Challenges	Research gap	Recommended solutions
Algorithms that handle uncertainty more effectively in the decision-making process	(1) In order to cope with uncertainty, in our literature only two articles have utilized PFSs. (2) Since SFSSs are recently introduced, the literature is still limited. In our literature, only two sample papers have used SFSSs. (3) PROMETHEE method is used with crisp values in all of the sampled studies.	(1) More research is needed under the concept of PFS to better deal with uncertain information in cases where the sum of function values is greater than 1. (2) More research is needed using SFSSs to deal with the hesitancy of the experts in I4.0 decision-making problems more adequately and accurately. (3) The PROMETHEE method can be used with the neutrosophic concept to cope with the uncertainty in Industry 4.0 decision-making applications.
Algorithms that more effectively handle inter-criteria interaction or interdependence features	(1) ANP has been used 15 times with DEMATEL, mostly in the cloud system component. The fact that individuals' decisions are handled with crisp values in these studies creates uncertainty in evaluating the interaction or interdependence between criteria. (2) The CI method has a simple procedure compared to others and allows modeling of dependencies between criteria where traditional techniques are difficult. This method is rarely used in our literature to model criterion interactions and independence.	(1) Especially in cloud system decision making problems, gray theory-based DEMATEL method and ANP method are needed to determine the interrelationships of the criteria and to deal with the dependencies between the criteria. (2) There is a need for more studies using the CI technique, which has a practical and powerful structure in modeling criterion interactions and independence.
Algorithms that handle experts' subjectivity more effectively	(1) Data analytics algorithms models are not subject to individual judgment and may objectively reflect the performance of alternatives. However, those are not used with MADM methods in evaluating alternatives and weighting criteria. (2) The original CRITIC approach, used in three studies in our literature, has a shortcoming in properly handling conflicting relationships between criteria, as it only uses Pearson's correlation. (3) The CCSD approach, which we have not encountered in the	(1) Models in which data analytics techniques are integrated with the judgments of decision-makers are needed to allow for a more systematic and scientific evaluation of alternatives. (2) More consistent criteria weights can be obtained using D-CRITIC algorithm since it gives a lower symmetric mean absolute percentage error, a higher average distance correlation, and a higher average Spearman rank-order correlation. (3) In order to eliminate subjectivity in the determination of each criterion's weight, MADM applications

(continued on next page)

Table 12 (continued)

Challenges	Research gap	Recommended solutions
	literature, is a new technique developed to objectively determine the weight of each criterion. This method has many advantages over other objective weight determination methods.	using the CCSD method are needed.
Generalization of results from MADM methods	(1) The results themselves are subjective to the context of the study and can only make sense in the context studied, which often involves human judgment, which leads to inconsistency in the evaluation of the modules applied. (2) Rarely used in the literature, sensitivity analysis demonstrates the robustness of results by enabling practitioners to understand the limits at which a particular solution can be effective.	(1) In order to generalize the results obtained from the MADM methods, alternative cases in similar frameworks and similar empirical studies are needed. (2) The application of sensitivity analysis may help to show tradeoffs by considering different sets of modifications, such as the inclusion/exclusion of certain criteria or changing their weighting.
Algorithms to select the most suitable technology for (SMEs)	(1) Studies that develop fuzzy algorithms for choosing the most suitable technology for small and medium-sized enterprises (SMEs) lack in our literature.	Different fuzzy-based technology selection models are needed to guide in choosing the most suitable technology for small and medium-sized enterprises (SMEs): neutrosophic-based selection model, intuitive fuzzy-based selection model, pythagorean fuzzy-based selection model.

Fig. 5, pairwise comparison methods used in 150 of 328 studies are the most popular approaches with a rate of 45.73 %, while utility-based approaches are employed in only 16 papers. When the components of Industry 4.0 seen in Fig. 17 are examined, cloud systems were the most popular in 145 of 328 studies, followed by IoT and big data with frequencies of 78 and 60, respectively. However, it is noteworthy that the augmented reality component is considered in only three papers. When it comes to the methods used in the components of Industry 4.0, Table 11 shows that the AHP method is the most popular in all components except big data. While TOPSIS is the most popular method in the big data component, both TOPSIS and AHP are the most popular methods in the digital transformation component. In addition, it is remarkable that the TODIM method is only used in big data studies.

Although there are many MCDM methods in the literature, each method has different characteristics and processes. Implementing an inappropriate method can lead to wrong decisions, which can result in spending a lot of money on inappropriate technology. In this context, our work in determining the appropriate MADM methods in Industry 4.0 components can be a guide for managers and business practitioners. In addition, this article identifies frequently used MCDM methods for Industry 4.0 components and helps managers and business practitioners to select appropriate MCDM methods for a particular component.

This study includes a number of limitations. The first limitation is the consideration of only the Scopus database in considering the relative articles whereas other libraries such as Web of Science, Springer, and Science Direct could have also been included. The second limitation is

about the theoretical analysis. Although this study highlights the main focus of researchers in addressing MADM problems in the scope of Industry 4.0 technologies, it doesn't focus on the theoretical details of the utilized methods in the considered studies. Finally, the last limitation is about the MADM classification structure and the components of Industry 4.0. Although the presented structures are highly supported by the existing literature, other MADM classification, or other Industry 4.0 components could be added to the study such as 3D printers and the use of AI and machine learning. However, there is still not a unique classification structure (i.e., a standard taxonomy) for this topic that is commonly agreed upon amongst the members of the research community.

CRedit authorship contribution statement

Wael Zayat: Conceptualization, Formal analysis, Investigation, Writing – original draft. **Huseyin Selcuk Kilic:** Methodology, Writing – original draft. **Ahmet Selcuk Yalcin:** Conceptualization, Writing – original draft. **Selim Zaim:** Supervision, Conceptualization, Methodology, Writing – review & editing. **Dursun Delen:** Conceptualization, Methodology, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

- Abdel-Basset, M., Gamal, A., Son, L. H., & Smarandache, F. (2020a). A bipolar neutrosophic multi criteria decision making framework for professional selection. *Applied Sciences (Switzerland)*, 10(4). <https://doi.org/10.3390/app10041202>
- Abdel-Basset, M., Manogaran, G., & Mohamed, M. (2018b). Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems. *Future Generation Computer Systems*, 86, 614–628. <https://doi.org/10.1016/j.future.2018.04.051>
- Abdel-Basset, M., Mohamed, M., & Chang, V. (2018a). NMCDA: A framework for evaluating cloud computing services. *Future Generation Computer Systems*, 86, 12–29. <https://doi.org/10.1016/j.future.2018.03.014>
- Abdel-Basset, M., Nabeeh, N. A., El-Ghareeb, H. A., & Aboelfetouh, A. (2020b). Utilising neutrosophic theory to solve transition difficulties of IoT-based enterprises. *Enterprise Information Systems*, 14(9–10), 1304–1324. <https://doi.org/10.1080/17517575.2019.1633690>
- Aboutorab, H., Saberi, M., Asadabadi, M. R., Hussain, O., & Chang, E. (2018). ZBWM: The Z-number extension of Best Worst Method and its application for supplier development. *Expert Systems with Applications*, 107, 115–125. <https://doi.org/10.1016/j.eswa.2018.04.015>
- Adem, A., Yilmaz Kaya, B., & Dağdeviren, M. (2022). Technology Analysis for Logistics 4.0 Applications: Criteria Affecting UAV Performances. *Studies in Systems, Decision and Control*, 372, 497–520. https://doi.org/10.1007/978-3-030-75067-1_21
- Agrawal, R., & Vinodh, S. (2021). Prioritizing Drivers of Industry 4.0 Enabling Additive Manufacturing: A Case Study. *Lecture Notes in Mechanical Engineering*, 25–34. https://doi.org/10.1007/978-981-15-5689-0_3
- Ahmad, M., Hu, J., Ahmad, M., Zaid-Ul-Huda & Khurshid, F. (2019). Optimal Cluster Leader Selection Using MCDM Methods in MWSN: A Comparative Study. In F. B. N. P. Zou L. Fang L. (Ed.), *Proceedings of IEEE 14th International Conference on Intelligent Systems and Knowledge Engineering. ISKE 2019* (pp. 240–247). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/ISKE47853.2019.9170426>
- Ahuja, K., & Khosla, A. (2019). Network selection criterion for ubiquitous communication provisioning in smart cities for smart energy system. *Journal of Network and Computer Applications*, 127, 82–91. <https://doi.org/10.1016/j.jnca.2018.11.011>
- Aisyah, S., & Dachyar, M. (2021). Internet of things technology selection for psychotherapy services in psychiatric hospital. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 1605–1612. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85114233660&partnerID=40&md5=d00579784e3ed527cdf2241fc927e66b>
- Ait-Mlouk, A., & Agouti, T. (2019). DM-MCDA: A web-based platform for data mining and multiple criteria decision analysis: A case study on road accident. *SoftwareX*, 10. <https://doi.org/10.1016/j.softx.2019.100323>

- Ajay, D., & Aldring, J. (2022). Complex Spherical Fuzzy Sets and an Application to Catering Services in Aviation 4.0. *Studies in Systems, Decision and Control*, 372, 87–121. https://doi.org/10.1007/978-3-030-75067-1_5
- Akhuseyinoglu, N. B., Karimi, M., Abdelhakim, M., & Krishnamurthy, P. (2020). On Automated Trust Computation in IoT with Multiple Attributes and Subjective Logic. In O. S. Tan H.-P. Khoukhi L. (Ed.), *Proceedings - Conference on Local Computer Networks, LCN (Vols. 2020-November, pp. 267–278)*. IEEE Computer Society. <https://doi.org/10.1109/LCN48667.2020.9314808>.
- Akmaludin, A., Hartati, T., Purwanto, H., Sukendar, T., Latifah, F., & Septiana, L. (2020). The Best Selection of Programmers in Generation 4.0 Using AHP and ELECTRE Elimination Methods. In L. C.-H. G. T. L. M. S. A. Vaidyanathan S. Mamat M.B. (Ed.), *Journal of Physics: Conference Series (Vol. 1477, Issue 3)*. Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1477/3/032001>.
- Alam, K. A., & Ahmad, R. (2016). Hybrid fuzzy multi-criteria decision model for cloud service selection and importance degree of component services in service compositions. In K. E. E. M. L. Z. X. Lu J. Koehl L. (Ed.), *Uncertainty Modelling in Knowledge Engineering and Decision Making - Proceedings of the 12th International FLINS Conference, FLINS 2016 (pp. 334–340)*. World Scientific Publishing Co. Pte Ltd. https://doi.org/10.1142/9789813146976_0056.
- Alam, K. A., Ahmed, R., Butt, F. S., Kim, S.-G., & Ko, K.-M. (2018). An Uncertainty-aware Integrated Fuzzy AHP-WASPAS Model to Evaluate Public Cloud Computing Services. In Y. A. Shakshuki E. (Ed.), *Procedia Computer Science (Vol. 130, pp. 504–509)*. Elsevier B.V. <https://doi.org/10.1016/j.procs.2018.04.068>.
- 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., al Shafeey, G. A., Baqer, M. J., Jasim, A. N., Jalood, N. S., & Shareef, A. H. (2019). Fault-Tolerant mHealth Framework in the Context of IoT-Based Real-Time Wearable Health Data Sensors. *IEEE Access*, 7, 50052–50080. <https://doi.org/10.1109/ACCESS.2019.2910411>.
- Alcácer, V., & Cruz-Machado, V. (2019). Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Engineering Science and Technology, an International Journal*, 22(3), 899–919.
- Al-Faifi, A., Song, B., Hassan, M. M., Alamri, A., & Gumaei, A. (2019). A hybrid multi criteria decision method for cloud service selection from Smart data. *Future Generation Computer Systems*, 93, 43–57. <https://doi.org/10.1016/j.future.2018.10.023>
- Alhubaishy, A., & Aljuhani, A. (2021). The challenges of instructors' and students' attitudes in digital transformation: A case study of Saudi Universities. *Education and Information Technologies*, 26(4), 4647–4662. <https://doi.org/10.1007/s10639-021-10491-6>
- Ali, S., Ullah, N., Abrar, M. F., Yang, Z., Huang, J., & Ali, R. (2020). Fuzzy Multicriteria Decision-Making Approach for Measuring the Possibility of Cloud Adoption for Software Testing. *Scientific Programming*, 2020. <https://doi.org/10.1155/2020/6597316>
- Al-Tarawneh, M. A. B. (2020). Mobility-aware container migration in cloudlet-enabled IoT systems using integrated multicriteria decision making. *International Journal of Advanced Computer Science and Applications*, 11(9), 694–701. <https://doi.org/10.14569/IJACSA.2020.0110983>
- Amini, M., & Chang, S. (2017). Assessing data veracity for data-rich manufacturing. In C. E. Nembhard H.B. Coperich K. (Ed.), *67th Annual Conference and Expo of the Institute of Industrial Engineers 2017 (pp. 1661–1666)*. Institute of Industrial Engineers. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85030997267&partnerID=40&md5=747da97a95568787595f03c0d8ada780>
- Annette, J. R., & Banu, A. (2019). Ranking cloud render farm services for a multi criteria recommender system. *Sadhana - Academy Proceedings in Engineering Sciences*, 44(1). <https://doi.org/10.1007/s12046-018-0981-0>
- Araujo, J., Maciel, P., Andrade, E., Callou, G., Alves, V., & Cunha, P. (2018). Decision making in cloud environments: An approach based on multiple-criteria decision analysis and stochastic models. *Journal of Cloud Computing*, 7(1). <https://doi.org/10.1186/s13677-018-0106-7>
- Awajan, I., Mohamad, M., & Al-Quran, A. (2021). Sentiment Analysis Technique and Neurotrophic Set Theory for Mining and Ranking Big Data from Online Reviews. *IEEE Access*, 9, 47338–47353. <https://doi.org/10.1109/ACCESS.2021.3067844>
- Ayoub, W., Ellatif Samhat, A., Mroue, M., Joumaa, H., Nouvel, F., & Prévotet, J.-C. (2020). Technology Selection for IoT-Based Smart Transportation Systems. *Advances in Intelligent Systems and Computing*, 1144, 19–29. https://doi.org/10.1007/978-981-15-3750-9_2
- Azar, H., & Majma, M. R. (2018). Using a multi criteria decision making model for managing computational resources at mobile ad-hoc computing environment. *Proceedings of 2017 International Conference on Engineering and Technology, ICET 2017, 2018-January*, 1–5. <https://doi.org/10.1109/ICEngTechnol.2017.8308161>.
- Baghapour, M. A., Shoosharian, M. R., & Zarghami, M. (2020). Process Mining Approach of a New Water Quality Index for Long-Term Assessment under Uncertainty Using Consensus-Based Fuzzy Decision Support System. *Water Resources Management*, 34(3), 1155–1172. <https://doi.org/10.1007/s11269-020-02489-5>
- Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International journal of production economics*, 229, Article 107776.
- Bailly, S., Meyfroidt, G., & Timsit, J. F. (2018). What's new in ICU in 2050: Big data and machine learning. *Intensive care medicine*, 44(9), 1524–1527.
- Bajec, P., & Tuljak-Suban, D. (2019). A Framework for Detecting the Proper Multi-Criteria Decision-Making Method Taking into Account the Characteristics of Third-Party Logistics, the Requirements of Managers, and the Type of Input Data. In (Ed.), *Application of Decision Science in Business and Management*. IntechOpen. <https://doi.org/10.5772/intechopen.87222>.
- Banaie, F., Yaghmaee, M. H., Hosseini, S. A., & Tashtarian, F. (2020). Load-Balancing Algorithm for Multiple Gateways in Fog-Based Internet of Things. *IEEE Internet of Things Journal*, 7(8), 7043–7053. <https://doi.org/10.1109/JIOT.2020.2982305>
- Bangui, H., Rakrak, S., Raghay, S., & Buhnova, B. (2018). Moving towards smart cities: A selection of middleware for fog-to-cloud services. *Applied Sciences (Switzerland)*, 8(11). <https://doi.org/10.3390/app8112220>
- Basha M.R.A., Muruganandham, R., Dinesh, J., Abuthakeer, S., & Sakthirama, V. (2020). Data analytics using intelligent optimization technique: Profitability analysis of banks using fuzzy logic decision making technique. *Journal of Advanced Research in Dynamical and Control Systems*, 12(3 Special Issue), 349–373. <https://doi.org/10.5373/JARDCS/V12SP3/20201271>.
- Bausys, R., Leščauskienė, L., & Semėnas, R. (2021). Participant trustworthiness analysis in the game-based urban planning processes by PROMETHEE-mqQNN approach. *Infinite Study*.
- Becker, T., & Wagner, D. (2016). Identification of Key Machines in Complex Production Networks. In T. R. (Ed.), *Procedia CIRP (Vol. 41, pp. 69–74)*. Elsevier B.V. <https://doi.org/10.1016/j.procir.2015.12.006>.
- Behzadian, M., Kazemzadeh, R. B., Albadvi, A., & Aghdasi, M. (2010). PROMETHEE: A comprehensive literature review on methodologies and applications. *European Journal of Operational Research*, 200(1), 198–215. <https://doi.org/10.1016/j.ejor.2009.01.021>
- Behladi, A., Kamble, S., Fosso Wamba, S., & Queiroz, M. M. (2021). Building supply-chain resilience: An artificial intelligence-based technique and decision-making framework. *International Journal of Production Research*. <https://doi.org/10.1080/00207543.2021.1950935>
- Ben Alla, H., Ben Alla, S., Ezzati, A., & Touhafi, A. (2021). A novel multiclass priority algorithm for task scheduling in cloud computing. *Journal of Supercomputing*, 77(10), 11514–11555. <https://doi.org/10.1007/s11227-021-03741-4>
- Benatia, I., Ridda, M., Bendjenna, H., & Eom, S. B. (2016). Implementing a cloud-based decision support system in a private cloud: The infrastructure and the deployment process. *International Journal of Decision Support System Technology*, 8(1), 25–42. <https://doi.org/10.4018/IJDSST.2016010102>
- Bhushan, S. B., & Reddy, P. (2016). A network qos aware service ranking using hybrid ahp-promethee method in multi-cloud domain. *International Journal of Engineering Research in Africa*, 24, 153–164. <https://doi.org/10.4028/www.scientific.net/JERA.24.153>
- Bogensperger, A., & Fabel, Y. (2021). A practical approach to cluster validation in the energy sector. *Energy Informatics*, 4. <https://doi.org/10.1186/s42162-021-00177-1>
- Bohlouli, M., & Schrage, M. (2020). Scalable multi-criteria decision-making: A mapreduce deployed big data approach for skill analytics. In X. L. H. X. T. K. O. L. S. X. W. A. S. Z. C. A.-M. E. C. Z. S. J. Wu X. Jermaine C. (Ed.), *Proceedings - 2020 IEEE International Conference on Big Data, Big Data 2020 (Vols. 2020-January)*. Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/BigData50022.2020.9439788>.
- Bolivar, H., Jaimes Parada, H. D., Roa, O., & Velandia, J. (2019). Multi-criteria Decision Making Model for Vulnerabilities Assessment in Cloud Computing regarding Common Vulnerability Scoring System. In M. M.A.R. (Ed.), *2019 Congreso Internacional de Innovación y Tendencias en Ingeniería, CONIITI 2019 - Conference Proceedings*. Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/CONIITI48476.2019.8960909>.
- Boltürk, E., & Kutlu Gündoğdu, F. (2021). Prioritizing Manufacturing Challenges of a Contract Manufacturing Company for Personal Auto by Using Spherical WASPAS Method. *Studies in Fuzziness and Soft Computing*, 392, 259–275. https://doi.org/10.1007/978-3-030-45461-6_11
- Bouayad, H., Benabbou, L., & Berrado, A. (2018). An analytic hierarchy process based approach for information technology governance framework selection. *ACM International Conference Proceeding Series*. <https://doi.org/10.1145/3289402.3289515>
- Brans, J. P., & Vincke, P.h. (1985). Note—A Preference Ranking Organisation Method. *Management Science*, 31(6), 647–656. <https://doi.org/10.1287/mnsc.31.6.647>
- Brans, J.-P. (1982). *L'ingénierie de la décision: l'élaboration d'instruments d'aide à la décision*. Université Laval, Faculté des sciences de l'administration.
- Brodny, J., & Tutak, M. (2021). Assessing the level of digital maturity of enterprises in the Central and Eastern European countries using the MCDM and Shannon's entropy methods. *PLoS ONE*, 16(7 July). <https://doi.org/10.1371/journal.pone.0253965>.
- Bruno, F., Barbieri, L., Marino, E., Muzzupappa, M., D'Oriano, L., & Colacino, B. (2019). An augmented reality tool to detect and annotate design variations in an Industry 4.0 approach. *The International Journal of Advanced Manufacturing Technology*, 105(1), 875–887.
- Bugingo, E., Wei, Z., & Defu, Z. (2021). Comparative evaluation of task priorities for processing and bandwidth capacities-based workflow scheduling for cloud environment. *Journal of Supercomputing*. <https://doi.org/10.1007/s11227-021-03979-y>
- Bui, K. Q., & Perera, L. P. (2019). The Compliance Challenges in Emissions Control Regulations to Reduce Air Pollution from Shipping. *OCEANS 2019 - Marseille*, 1–8. <https://doi.org/10.1109/OCEANSE.2019.8867420>.
- Büyükoçkan, G., Fezyioğlu, O., & Havlic, C. A. (2020a). Analysis of success factors in aviation 4.0 using integrated intuitionistic fuzzy MCDM methods. *Advances in Intelligent Systems and Computing*, 1029, 598–606. https://doi.org/10.1007/978-3-030-23756-1_73
- Büyükoçkan, G., & Göçer, F. (2018). Smart medical device selection based on interval valued intuitionistic fuzzy VIKOR. *Advances in Intelligent Systems and Computing*, 641, 306–317. https://doi.org/10.1007/978-3-319-66830-7_28
- Buyukozkan, G., & Goecer, F. (2019). Technology Selection for Logistics and Supply Chain Management by the Extended Intuitionistic Fuzzy TOPSIS. *Proceedings - 2019 3rd*

- International Conference on Data Science and Business Analytics, ICDSBA 2019, 129–134. <https://doi.org/10.1109/ICDSBA48748.2019.00036>.
- Büyükkökan, G., & Göçer, F. (2021). Evaluation of software development projects based on integrated Pythagorean fuzzy methodology. *Expert Systems with Applications*, 183. <https://doi.org/10.1016/j.eswa.2021.115355>
- Büyükkökan, G., Göçer, F., & Feyzioğlu, O. (2017). Cloud computing technology selection based on interval valued intuitionistic fuzzy group decision making using MULTIMOORA approach. *IEEE International Conference on Fuzzy Systems*. <https://doi.org/10.1109/FUZZ-IEEE.2017.8015682>
- Büyükkökan, G., Göçer, F., & Uztürk, D. (2021). A novel Pythagorean fuzzy set integrated Choquet integral approach for vertical farming technology assessment. *Computers & Industrial Engineering*, 158, Article 107384. <https://doi.org/10.1016/j.cie.2021.107384>
- Büyükkökan, G., & Güler, M. (2020). Analysis of companies' digital maturity by hesitant fuzzy linguistic MCDM methods. *Journal of Intelligent and Fuzzy Systems*, 38(1), 1119–1132. <https://doi.org/10.3233/JIFS-179473>
- Büyükkökan, G., Güler, M., & Mukul, E. (2020b). Evaluation of supply chain analytics maturity level with a hesitant fuzzy MCDM technique. *Advances in Intelligent Systems and Computing*, 1029, 1076–1084. https://doi.org/10.1007/978-3-030-23756-1_127
- Büyükkökan, G., & Mukul, E. (2020). Evaluation of smart health technologies with hesitant fuzzy linguistic MCDM methods. *Journal of Intelligent and Fuzzy Systems*, 39(5), 6363–6375. <https://doi.org/10.3233/JIFS-189103>
- Cafasso, D., Calabrese, C., Casella, G., Bottani, E., & Murino, T. (2020). Framework for selecting manufacturing simulation software in industry 4.0 environment. *Sustainability (Switzerland)*, 12(15). <https://doi.org/10.3390/SU12155909>
- Caliskan, A., Özkan Özen, Y. D., & Ozturkoglu, Y. (2020). Digital transformation of traditional marketing business model in new industry era. *Journal of Enterprise Information Management*, 34(4), 1252–1273. <https://doi.org/10.1108/JEIM-02-2020-0084>
- Çalı, S., & Balaman, Ş. Y. (2019). Improved decisions for marketing, supply and purchasing: Mining big data through an integration of sentiment analysis and intuitionistic fuzzy multi criteria assessment. *Computers and Industrial Engineering*, 129, 315–332. <https://doi.org/10.1016/j.cie.2019.01.051>
- Castellucci, H. I., Bravo, G., Arezes, P. M., & Lavallière, M. (2020). Are interventions effective at improving driving in older drivers? A systematic review. *BMC Geriatrics*, 20(1), 125. <https://doi.org/10.1186/s12877-020-01512-z>
- Chai, J., & Ngai, E. W. (2020). Decision-making techniques in supplier selection: Recent accomplishments and what lies ahead. *Expert Systems with Applications*, 140, Article 112903.
- Chakraborty, A., Jindal, M., Khosravi, M. R., Singh, P., Shankar, A., & Diwakar, M. (2021). A Secure IoT-Based Cloud Platform Selection Using Entropy Distance Approach and Fuzzy Set Theory. *Wireless Communications and Mobile Computing*, 2021. <https://doi.org/10.1155/2021/6697467>
- Chakraborty, B., & Das, S. (2021). Introducing a New Supply Chain Management Concept by Hybridizing TOPSIS, IoT and Cloud Computing. *Journal of The Institution of Engineers (India): Series C*, 102(1), 109–119. <https://doi.org/10.1007/s40032-020-00619-x>
- Chakravarthi, K. K., & Shyamala, L. (2021). TOPSIS inspired Budget and Deadline Aware Multi-Workflow Scheduling for Cloud computing. *Journal of Systems Architecture*, 114. <https://doi.org/10.1016/j.sysarc.2020.101916>
- Chakravarthi, K. K., Shyamala, L., & Vaidehi, V. (2020). TOPSIS inspired cost-efficient concurrent workflow scheduling algorithm in cloud. *Journal of King Saud University - Computer and Information Sciences*. <https://doi.org/10.1016/j.jksuci.2020.02.006>
- Chang, S.-C., Chang, H.-H., & Lu, M.-T. (2021a). Evaluating industry 4.0 technology application in smes: Using a hybrid mcdm approach. *Mathematics*, 9(4), 1–20. <https://doi.org/10.3390/math9040414>
- Chang, S.-C., Lu, M.-T., Pan, T.-H., & Chen, C.-S. (2021b). Evaluating the e-health cloud computing systems adoption in Taiwan's healthcare industry. *Life*, 11(4). <https://doi.org/10.3390/life11040310>
- Chatterjee, P., Manikrao Athawale, V., & Chakraborty, S. (2010). Selection of industrial robots using compromise ranking and outranking methods. *Robotics and Computer-Integrated Manufacturing*, 26(5), 483–489. <https://doi.org/10.1016/j.rcim.2010.03.007>
- Chauhan, N., Agarwal, R., Garg, K., & Choudhury, T. (2020). Redundant IaaS Cloud Selection with Consideration of Multi Criteria Decision Analysis. In L. K.-C. Singh V. Asari V.K. (Ed.), *Procedia Computer Science* (Vol. 167, pp. 1325–1333). Elsevier B.V. <https://doi.org/10.1016/j.procs.2020.03.448>
- Chen, P.-T., Lin, C.-L., & Wu, W.-N. (2020). Big data management in healthcare: Adoption challenges and implications. *International Journal of Information Management*, 53. <https://doi.org/10.1016/j.ijinfomgt.2020.102078>
- Chen, X., Tang, J.-R., & Zhang, Y. (2017). Towards a virtual machine migration algorithm based on multi-objective optimization. *International Journal of Mobile Computing and Multimedia Communications*, 8(3), 79–89. <https://doi.org/10.4018/IJMCMC.2017070106>
- Chen, Y.-S., Lin, C.-K., & Chuang, H.-M. (2016). Improving project risk management of cloud CRM using DANP approach. *Lecture Notes in Electrical Engineering*, 375, 1023–1031. https://doi.org/10.1007/978-981-10-0539-8_100
- Cheng, D.-Y., Chao, K.-M., Lo, C.-C., & Tsai, C.-F. (2011). A user centric service-oriented modeling approach. *World Wide Web*, 14(4), 431–459. <https://doi.org/10.1007/s11280-011-0115-7>
- Cheng, L., Zhang, L., Wu, S., & Yang, Y. (2013). Services selection method based on multiple attribute decision making theory for group user. *Journal of Computational Information Systems*, 9(6), 2149–2156.
- Choochothaew, S., Yamaguchi, H., Higashino, T., & Shibuya, M. (2015). Requirement-based prioritization system in multi-user IoT. *IEEE World Forum on Internet of Things, WF-IoT 2015 - Proceedings*, 122–127. <https://doi.org/10.1109/WF-IoT.2015.7389038>.
- Chou, T.-Y., & Liao, J.-P. (2020). Using MEC and FAHP to Establish an Evaluation Model for Food Processing Machinery Procurement. *Mathematical Problems in Engineering*, 2020. <https://doi.org/10.1155/2020/6395981>
- Chowdhury, P., & Paul, S. K. (2020). Applications of MCDM methods in research on corporate sustainability: A systematic literature review. *Management of Environmental Quality: An International Journal*, 31(4), 385–405.
- Chuang, Y.-C., Hu, S.-K., Liou, J. J. H., & Tzeng, G.-H. (2020). A data-driven madm model for personnel selection and improvement. *Technological and Economic Development of Economy*, 26(4), 751–784. <https://doi.org/10.3846/tede.2020.12366>
- Contreras-Masse, R., Ochoa-Zezzatti, A., García, V., Pérez-Dominguez, L., & Elizondo-Cortés, M. (2020). Implementing a novel use of multicriteria decision analysis to select IIoT platforms for smart manufacturing. *Symmetry*, 12(3). <https://doi.org/10.3390/sym12030368>
- Da Cruz, M. A. A., Marcondes, G. A. B., Rodrigues, J. J. P. C., Lorenz, P., & Pinheiro, P. R. (2018). Performance Evaluation of IoT Middleware through Multicriteria Decision-Making. *2018 IEEE Global Communications Conference, GLOBECOM 2018 - Proceedings*. <https://doi.org/10.1109/GLOCOM.2018.8647381>
- Dai, D., Zheng, W., & Fan, T. (2017). Evaluation of personal cloud storage products in China. *Industrial Management and Data Systems*, 117(1), 131–148. <https://doi.org/10.1108/IMDS-12-2015-0504>
- Davies, R., 2015. Industry 4.0: Digitalisation for productivity and growth, EPRS: European Parliamentary Research Service. Retrieved from <https://policycommons.net/artifacts/1335939/industry-40/1942749/> on 17 Jul 2022.
- de Andrade, J. M. M., de Leite, A. F. C. S. M., Canciglieri, M. B., Szejka, A. L., de Loures, E. F. R., & Canciglieri O., Jr. (2020). A multi-criteria approach for FMEA in product development in industry 4.0. In N. L. S. J. W. N. Pokojski J. Gil M. (Ed.), *Advances in Transdisciplinary Engineering* (Vol. 12, pp. 311–320). IOS Press BV. <https://doi.org/10.3233/ATDE200090>.
- De Moraes, L. B., Cirne, P., Matos, F., Parpinelli, R. S., & Fiorese, A. (2018). An efficiency frontier based model for cloud computing provider selection and ranking. In C. O. F. J. F. J. Hammoudi S. Smialek M. (Ed.), *ICEIS 2018 - Proceedings of the 20th International Conference on Enterprise Information Systems* (Vol. 1, pp. 543–554). SciTePress. <https://doi.org/10.5220/0006775705430554>.
- Delias, P., & Matsatsinis, N. (2013). Multiple Criteria Decision Aid and Agents: Supporting Effective Resource Federation in Virtual Organizations. In *Multicriteria Decision Aid and Artificial Intelligence*. John Wiley and Sons. <https://doi.org/10.1002/9781118522516.ch11>.
- Denyer, D., & Tranfield, D. (2009). Producing a systematic review. In *The Sage handbook of organizational research methods* (pp. 671–689). Sage Publications Ltd.
- Dilli, R., Argou, A., Pilla, M., Pernas, A. M., Reiser, R., & Yamin, A. (2018a). Fuzzy logic and MCDA in IoT resources classification. *Proceedings of the ACM Symposium on Applied Computing*, 761–766. <https://doi.org/10.1145/3167132.3167216>.
- Dilli, R., Argou, A., Reiser, R., & Yamin, A. (2018b). IoT resources ranking: Decision making under uncertainty combining machine learning and fuzzy logic. *Communications in Computer and Information Science*, 831, 119–131. https://doi.org/10.1007/978-3-319-95312-0_11
- Dobre, C., Radulescu, C. Z., & Bajenaru, L. (2019). Parameters weighting in elderly monitoring based on multi-criteria methods. *Proceedings - 2019 22nd International Conference on Control Systems and Computer Science, CSCS 2019*, 131–135. <https://doi.org/10.1109/CSCS.2019.00030>.
- Domaschka, J., Volpert, S., & Seybold, D. (2020). Hathi: An MCDM-based Approach to Capacity Planning for Cloud-hosted DBMS. *Proceedings - 2020 IEEE/ACM 13th International Conference on Utility and Cloud Computing, UCC 2020*, 143–154. <https://doi.org/10.1109/UCC48980.2020.00033>.
- Dong, J., Liu, D., Liu, Y., Huo, H., Dou, X., & Bao, A. (2021). Trading performance evaluation for traditional power generation group based on an integrated matter-element extension cloud model. *Energy Reports*, 7, 3074–3089. <https://doi.org/10.1016/j.egyr.2021.05.041>
- Dos Santos, C. F., Netto, R. J. K., Loures, E. F. R., & Santos, E. A. P. (2018). Alarm management according to isa sp 18.2 standard based on process mining and multi-criteria decision making methods. In P. M. B. C. P. M. Wognun N. Stjepandic J. (Ed.), *Advances in Transdisciplinary Engineering* (Vol. 7, pp. 633–642). IOS Press BV. <https://doi.org/10.3233/978-1-61499-898-3-633>.
- Drakaki, M., Gören, H., & Tzionas, P. (2019). A Multi-Agent based Decision Framework for Sustainable Supplier Selection, Order Allocation and Routing Problem. *Proceedings of the 5th International Conference on Vehicle Technology and Intelligent Transport Systems*, 621–628. <https://doi.org/10.5220/0007833306210628>.
- Ejegwa, P. A. (2020). Improved composite relation for Pythagorean fuzzy sets and its application to medical diagnosis. *Granular Computing*, 5(2), 277–286.
- El Kassabi, H. T., & Serhani, M. A. (2017). De-Centralized Reputation-Based Trust Model to Discriminate between Cloud Providers Capable of Processing Big Data. In Z. J. Karypis G. (Ed.), *Proceedings - 2017 IEEE 6th International Congress on Big Data, BigData Congress 2017* (pp. 266–273). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/BigDataCongress.2017.41>.
- Espadilha-Cruz, P., Godina, R., & Rodrigues, E. M. G. (2021). A Review of Data Mining Applications in Semiconductor Manufacturing. *Processes*, 9(2). <https://doi.org/10.3390/pr9020305>
- Eswaran, S. P., Sriprurushottama, S., & Jain, M. (2018). Multi Criteria Decision Making (MCDM) based Spectrum Moderator for Fog-Assisted Internet of Things. In S. E. Yasara A. (Ed.), *Procedia Computer Science* (Vol. 134, pp. 399–406). Elsevier B.V. <https://doi.org/10.1016/j.procs.2018.07.192>
- Fan, J., Yu, S., Yu, M., Chu, J., Tian, B., Li, W., ... Chen, C. (2020). Optimal selection of design scheme in cloud environment: A novel hybrid approach of multi-criteria

- decision-making based on F-ANP and F-QFD. *Journal of Intelligent and Fuzzy Systems*, 38(3), 3371–3388. <https://doi.org/10.3233/JIFS-190630>
- Fang, H., Wang, X., & Song, W. (2020). Technology selection for photovoltaic cell from sustainability perspective: An integrated approach. *Renewable Energy*, 153, 1029–1041. <https://doi.org/10.1016/j.renene.2020.02.064>
- Farzaneh, B., Ahmed, A. K., & Alizadeh, E. (2019). MC-RPL: A new routing approach based on multi-criteria RPL for the internet of things. *2019 9th International Conference on Computer and Knowledge Engineering, ICCKE 2019*, 420–425. <https://doi.org/10.1109/ICCKE48569.2019.8964675>
- Fettermann, D. C., Cavalcante, C. G. S., de Almeida, T. D., & Tortorella, G. L. (2018). How does Industry 4.0 contribute to operations management? *Journal of Industrial and Production Engineering*, 35(4), 255–268. <https://doi.org/10.1080/21681015.2018.1462863>
- Fouad, E. H., Cherkaoui, L., & Khadija, D. (2018). Optimizing WSN lifetime based on a new centrality multi-criteria routing approach. In S. P. C. E. I. B. F. A. F. Karagiannis G.K. Sofotasios P. C. (Ed.), *Proceedings - 2018 International Conference on Advanced Communication Technologies and Networking, CommNet 2018* (pp. 1–7). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/COMMNET.2018.8360275>
- Friedel, J. E., Holzer, T. H., & Sarkani, S. (2020). Development, Optimization, and Validation of Unintended Radiated Emissions Processing System for Threat Identification. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 50(6), 2208–2219. <https://doi.org/10.1109/TSMC.2018.2810305>
- Fu, C., Liu, W., & Chang, W. (2020). Data-driven multiple criteria decision making for diagnosis of thyroid cancer. *Annals of Operations Research*, 293(2), 833–862. <https://doi.org/10.1007/s10479-018-3093-7>
- Fu, H.-P., Chang, T.-S., Yeh, H.-P., & Chen, Y.-X. (2019). Analysis of factors influencing hospitals' implementation of a green e-procurement system using a cloud model. *International Journal of Environmental Research and Public Health*, 16(24). <https://doi.org/10.3390/ijerph16245137>
- Gautam, A. K., & Kumar, R. (2021). A trust based neighbor identification using MCDM model in wireless sensor networks. *Recent Advances in Computer Science and Communications*, 14(4), 1336–1351. <https://doi.org/10.2174/2666255813666190923101045>
- Geissbauer, R., Vedso, J., & Schrauf, S. (2016). A Strategist's Guide to Industry 4.0: Global businesses are about to integrate their operations into a seamless digital whole, and thereby change the world. *Strategy+business. Strateg. Bus.*
- Ghadge, A., Dani, S., & Kalawsky, R. (2012). Supply chain risk management: Present and future scope. *The International Journal of Logistics Management*, 23(3), 313–339. <https://doi.org/10.1108/09574091211289200>
- Ghazizadeh, E., & Cusack, B. (2018). Trust Assessment for Cloud Identity Providers Using Analytical Hierarchy Process. In D. L. Y. M. Q. Y. M. Q. A. H. R. Tinetti F.G. Tran Q.-N. (Ed.), *Proceedings - 2017 International Conference on Computational Science and Computational Intelligence, CSCI 2017* (pp. 1535–1541). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/CSCI.2017.268>
- Gireesha, O., Somu, N., Krithivasan, K., & V.S., S. S. (2020b). IIVIFS-WASPAS: An integrated Multi-Criteria Decision-Making perspective for cloud service provider selection. *Future Generation Computer Systems*, 103, 91–110. <https://doi.org/10.1016/j.future.2019.09.053>
- Gireesha, O., Somu, N., Raman, M. R. G., Reddy, M. S., Krithivasan, K., & Sriram, V. S. (2020a). WNN-EDAS: A Wavelet Neural Network Based Multi-criteria Decision-Making Approach for Cloud Service Selection. *Advances in Intelligent Systems and Computing*, 999, 853–865. https://doi.org/10.1007/978-981-13-9042-5_73
- Göçer, F., & Büyükköçkan, G. (2020). Assessment of big data vendors by intuitionistic fuzzy TODIM. *Advances in Intelligent Systems and Computing*, 1029, 574–582. https://doi.org/10.1007/978-3-030-23756-1_70
- Gomes, L. F. A. M., Rangel, L. A. D., & Maranhão, F. J. C. (2009). Multicriteria analysis of natural gas destination in Brazil: An application of the TODIM method. *Mathematical and Computer Modelling*, 50(1–2), 92–100.
- Gong, B., Liu, R., & Zhang, X. (2020). Market acceptability assessment of electric vehicles based on an improved stochastic multicriteria acceptability analysis-evidential reasoning approach. *Journal of Cleaner Production*, 269. <https://doi.org/10.1016/j.jclepro.2020.121990>
- Gong, J., & Xu, J. (2006). The integration of valued outranking relations in ELECTRE methods for ranking problem. *World Journal of Modelling and Simulation*, 2(1), 3–14.
- Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *Journal of cleaner production*, 98, 66–83.
- Grida, M., Mohamed, R., & Zaided, A. N. H. (2020). A Novel Plithogenic MCDM Framework for Evaluating the Performance of IoT Based Supply Chain. *Neutrosophic Sets and Systems*, 33, 223–341. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85102029050&partnerID=40&md5=37641ca0442de2d36575e11217845f66>
- Grygorenko, D., Farokhi, S., & Brandic, I. (2016). Cost-aware VM placement across distributed DCs using Bayesian networks. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 9512, 32–48. https://doi.org/10.1007/978-3-319-43177-2_3
- Guan, X., Qian, L., Li, M., Chen, H., & Zhou, L. (2017). Earthquake relief emergency logistics capacity evaluation model integrating cloud generalized information aggregation operators. *Journal of Intelligent and Fuzzy Systems*, 32(3), 2281–2294. <https://doi.org/10.3233/JIFS-16252>
- Güler, M., & Büyükköçkan, G. (2019). Analysis of digital transformation strategies with an integrated fuzzy AHP-axiomatic design methodology. In Y. F. Ivanov D. Dolgui A. (Ed.), *IFAC-PapersOnLine* (Vol. 52, Issue 13, pp. 1186–1191). Elsevier B.V. <https://doi.org/10.1016/j.ifacol.2019.11.359>
- Gündoğdu, F. K., & Kahraman, C. (2019). A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets. *Engineering Applications of Artificial Intelligence*, 85, 307–323.
- Guo, M., Zhang, Q., Liao, X., Chen, F. Y., & Zeng, D. D. (2021). A hybrid machine learning framework for analyzing human decision-making through learning preferences. *Omega (United Kingdom)*, 101. <https://doi.org/10.1016/j.omega.2020.102263>
- Gupta, H., Kumar, A., & Wasan, P. (2021). Industry 4.0, cleaner production and circular economy: An integrative framework for evaluating ethical and sustainable business performance of manufacturing organizations. *Journal of Cleaner Production*, 295. <https://doi.org/10.1016/j.jclepro.2021.126253>
- Gupta, H., Kumar, S., Kusi-Sarpong, S., Jabbour, C. J. C., & Agyemang, M. (2020). Enablers to supply chain performance on the basis of digitization technologies. *Industrial Management and Data Systems*. <https://doi.org/10.1108/IMDS-07-2020-0421>
- Hagharast, M. B., Berehliya, S., Akbari, M., & Sayadi, A. (2021). Developing and evaluating a proposed health security framework in IoT using fuzzy analytic network process method. *Journal of Ambient Intelligence and Humanized Computing*, 12(2), 3121–3138. <https://doi.org/10.1007/s12652-020-02472-3>
- Hasgul, Z., & Aytore, C. (2021). Road Selection for Autonomous Trucks in Turkey with Fuzzy AHP. *Advances in Intelligent Systems and Computing*, 1197 AISC, 582–590. https://doi.org/10.1007/978-3-030-51156-2_67
- Hassanpour, M., & Pamučar, D. (2019). Evaluation of Iranian household appliance industries using MCDM models. *Operational Research in Engineering Sciences: Theory and Applications*, 2(3), 1–25. <https://doi.org/10.31181/oresta1903001h>
- Hasselblad, A., Olsson, L., & Blusi, M. (2019). A Conceptual Model to Evaluate Technology Implementations: A Home Care Case Study. *IEEE International Conference on Industrial Engineering and Engineering Management*, 74–78. <https://doi.org/10.1109/IEEM44572.2019.8978745>
- Hayat, R., Sabir, E., Badidi, E., & Elkoutbi, M. (2019). A signaling game-based approach for Data-as-a-Service provisioning in IoT-Cloud. *Future Generation Computer Systems*, 92, 1040–1050. <https://doi.org/10.1016/j.future.2017.10.001>
- He, W., Wang, J., Wu, B., Luan, H., Liang, H., & Chen, C. (2019). IoT Nodes Equipment Selection Based on MADM: A Case Study of Groundwater Quality Detection Equipment. *2019 IEEE Intl Conf on Dependable, Autonomic and Secure Computing, Intl Conf on Pervasive Intelligence and Computing, Intl Conf on Cloud and Big Data Computing, Intl Conf on Cyber Science and Technology Congress (DASC/PiCom/CBDCom/CyberSciTech)*, 94–100. <https://doi.org/10.1109/DASC/PiCom/CBDCom/CyberSciTech.2019.00030>
- Helmy, S. E., Eladi, G. H., & Eisa, M. (2021). Fuzzy Analytical Hierarchy Process (FAHP) using geometric mean method to select best processing framework adequate to big data. *Journal of Theoretical and Applied Information Technology*, 99(1), 207–226. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101318761&partnerID=40&md5=24b8659cd646210c0204876ed2b5d23c>
- Hemam, S. M., & Hioual, O. (2017). Load balancing issue in cloud services selection by using MCDA and Markov Chain Model approaches. In E. M. Zbakh M. (Ed.), *Proceedings of 2016 International Conference on Cloud Computing Technologies and Applications, CloudTech 2016* (pp. 163–169). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/CloudTech.2016.7847694>
- Hemam, S. M., Hioual, O., & Hioual, O. (2018). Load balancing between nodes in a volunteer cloud computing by taking into consideration the number of cloud services replicas. In Z. M. Essaaidi M. (Ed.), *Proceedings of 2017 International Conference of Cloud Computing Technologies and Applications, CloudTech 2017* (Vols. 2018-January, pp. 1–8). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/CloudTech.2017.8284713>
- Hinduja, A., & Pandey, M. (2019). An Integrated Intuitionistic Fuzzy MCDM Approach to Select Cloud-Based ERP System for SMEs. *International Journal of Information Technology and Decision Making*, 18(6), 1875–1908. <https://doi.org/10.1142/S0219622019500378>
- Hinduja, A., & Pandey, M. (2020). An ANP-GRA-based evaluation model for security features of IoT systems. *Advances in Intelligent Systems and Computing*, 989, 243–253. https://doi.org/10.1007/978-981-13-8618-3_26
- Hioual, O., Boufaïda, Z., & Hemam, S. M. (2017). Load balancing, cost and response time minimisation issues in agent-based multi cloud service composition. *International Journal of Internet Protocol Technology*, 10(2), 73–88. <https://doi.org/10.1504/IJIPT.2017.085187>
- Hioual, O., & Hemam, S. M. (2016). Cloud services selection by load balancing between clouds: A hybrid MCDM/markov chain approach. In M. V. K. K.-H. Majchrzak T.A. Traverso P. (Ed.), *WEBIST 2016 - Proceedings of the 12th International Conference on Web Information Systems and Technologies* (Vol. 1, pp. 289–295). SciTePress. <https://doi.org/10.5220/0005929802890295>
- Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of operational research*, 202(1), 16–24.
- Hossain, M. K., & Thakur, V. (2021). Benchmarking health-care supply chain by implementing Industry 4.0: A fuzzy-AHP-DEMATEL approach. *Benchmarking*, 28(2), 556–581. <https://doi.org/10.1108/BIJ-05-2020-0268>
- Houari, A., & Mazri, T. (2021). A New Approach based on Fuzzy MADM for Enhancing Infrastructure Selection in the Case of VANET Network. *International Journal of Advanced Computer Science and Applications*, 12(6), 668–675. <https://doi.org/10.14569/IJACSA.2021.0120678>
- Hu, K.-H., & Chen, F.-H. (2016). Application a new DEMATEL to explore key factors of China's security risks of cloud computing for E-government. *ICIC Express Letters, Part B: Applications*, 7(8), 1813–1819. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84981163065&partnerID=40&md5=ef74a72dfed27e0ef50017f6c7679531>

- Hu, K.-H., Chen, F.-H., Hsu, M.-F., & Tzeng, G.-H. (2021). Identifying key factors for adopting artificial intelligence-enabled auditing techniques by joint utilization of fuzzy-rough theory and MRDM technique. *Technological and Economic Development of Economy*, 27(2), 459–492. <https://doi.org/10.3846/tede.2020.13181>
- Hu, K.-H., Chen, F.-H., & Tzeng, G.-H. (2018). CPA firm's cloud auditing provider for performance evaluation and improvement: An empirical case of China. *Technological and Economic Development of Economy*, 24(6), 2238–2373. <https://doi.org/10.3846/tede.2018.6619>
- Hu, K.-H., Jianguo, W., & Tzeng, G.-H. (2017). Risk factor assessment improvement for China's cloud computing auditing using a new hybrid MADM model. *International Journal of Information Technology and Decision Making*, 16(3), 737–777. <https://doi.org/10.1142/S021962201750016X>
- Hu, M., Liu, M., & Lan, J. (2020). Decision making with both diversity supporting and opposing membership information. *Economic Research-Ekonomska Istrazivanja*, 33(1), 3427–3452. <https://doi.org/10.1080/1331677X.2020.1774790>
- Huang, C.-Y., Hsu, P.-C., & Tzeng, G.-H. (2012). Evaluating cloud computing based telecommunications service quality enhancement by using a new hybrid MCDM model. *Smart Innovation, Systems and Technologies*, 15, 519–536. https://doi.org/10.1007/978-3-642-29977-3_52
- Huang, C.-Y., Tzeng, W.-C., Tzeng, G.-H., & Yuan, M.-C. (2011). Derivations of information technology strategies for enabling the cloud based banking service by a hybrid MADM framework. *Smart Innovation, Systems and Technologies*, 10 SIST, 123–134. https://doi.org/10.1007/978-3-642-22194-1_13
- Huang, C.-Y., Yang, C.-L., & Hsiao, Y.-H. (2021). A novel framework for mining social media data based on text mining, topic modeling, random forest, and danp methods. *Mathematics*, 9(17). <https://doi.org/10.3390/math9172041>
- Hussain, A., Chun, J., & Khan, M. (2020a). A novel customer-centric Methodology for Optimal Service Selection (MOSS) in a cloud environment. *Future Generation Computer Systems*, 105, 562–580. <https://doi.org/10.1016/j.future.2019.12.024>
- Hussain, A., Chun, J., & Khan, M. (2020b). A novel framework towards viable Cloud Service Selection as a Service (CSSaaS) under a fuzzy environment. *Future Generation Computer Systems*, 104, 74–91. <https://doi.org/10.1016/j.future.2019.09.043>
- Hwang, C.-L., & Yoon, K. (1981). *Methods for Multiple Attribute Decision Making* (pp. 58–191). https://doi.org/10.1007/978-3-642-48318-9_3
- Jamaludin, J., & Rohani, J. M. (2018, November). Cyber-physical system (cps): State of the art. In 2018 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube) (pp. 1–5). IEEE.IoT.
- Jamwal, A., Agrawal, R., Sharma, M., Kumar, V., & Kumar, S. (2021). Developing A sustainability framework for Industry 4.0. In H. C. Sangwan K.S. (Ed.), *Procedia CIRP* (Vol. 98, pp. 430–435). Elsevier B.V. <https://doi.org/10.1016/j.procir.2021.01.129>
- Jayant, A., Singh, S., & Walke, T. (2021). A robust hybrid multi-criteria decision-making approach for selection of third-party reverse logistics service provider. *Lecture Notes in Mechanical Engineering*, 423–443. https://doi.org/10.1007/978-981-15-5519-0_32
- Kachaoui, J., & Belangour, A. (2020). An Adaptive Control Approach for Performance of Big Data Storage Systems. *Advances in Intelligent Systems and Computing*, 1105 AISC, 89–97. https://doi.org/10.1007/978-3-030-36674-2_9
- Kahraman, C., Keshavarz Ghorabae, M., Zavadskas, E. K., Cevik Onar, S., Yazdani, M., & Oztaysi, B. (2017). Intuitionistic fuzzy EDAS method: An application to solid waste disposal site selection. *Journal of Environmental Engineering and Landscape Management*, 25(1), 1–12.
- Kahraman, C., Onar, S. C., & Oztaysi, B. (2015). Fuzzy multicriteria decision-making: A literature review. *International journal of computational intelligence systems*, 8(4), 637–666.
- Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, 117, 408–425. <https://doi.org/10.1016/j.psep.2018.05.009>
- Kao, N., Nawata, & Huang. (2019a). Systemic Functions Evaluation based Technological Innovation System for the Sustainability of IoT in the Manufacturing Industry. *Sustainability*, 11(8), 2342. <https://doi.org/10.3390/su11082342>
- Kao, Y.-S., Nawata, K., & Huang, C.-Y. (2019b). Evaluating the performance of systemic innovation problems of the IoT in manufacturing industries by novel MCDM methods. *Sustainability (Switzerland)*, 11(18). <https://doi.org/10.3390/su11184970>
- Kaya, İ., Çolak, M., & Terzi, F. (2018). Use of MCDM techniques for energy policy and decision-making problems: A review. *International Journal of Energy Research*, 42(7), 2344–2372. <https://doi.org/10.1002/er.4016>
- Kaya, İ., Erdoğan, M., Kardeş, A., & Özkan, B. (2020). Creating a road map for industry 4.0 by using an integrated fuzzy multicriteria decision-making methodology. *Soft Computing*, 24(23), 17931–17956. <https://doi.org/10.1007/s00500-020-05041-0>
- Kazancoglu, Y., & Ozkan-Ozen, Y. D. (2018). Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL. *Journal of Enterprise Information Management*, 31(6), 891–907. <https://doi.org/10.1108/JEIM-01-2017-0015>
- Khan, M., Wu, X., Xu, X., & Dou, W. (2017, May). Big data challenges and opportunities in the hype of Industry 4.0. In 2017 IEEE International Conference on Communications (ICC) (pp. 1–6). IEEE.
- Khodaparas, S., Benslimane, A., & Yousefi, S. (2020). A software-defined caching scheme for the Internet of Things. *Computer Communications*, 158, 178–188. <https://doi.org/10.1016/j.comcom.2020.05.002>
- Khodaparas, S., Yousefi, S., & Benslimane, A. (2019). A Multi Criteria Cooperative Caching Scheme for Internet of Things. *IEEE International Conference on Communications*, 2019-May. <https://doi.org/10.1109/ICC.2019.8761546>
- Khowfa, W., Silasai, O., & Kaewpruksapim, C. (2015). QoS based service selection in cloud environment: A review. *International Journal of Advances in Soft Computing and Its Applications*, 7(3), 114–125. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84949771079&partnerID=40&md5=a97fd8935234fa09e756e42c2a90ab48>
- Kilic, H. S., & Yalcin, A. S. (2021). Comparison of municipalities considering environmental sustainability via neutrosophic DEMATEL based TOPSIS. *Socio-Economic Planning Sciences*, 75, Article 100827. <https://doi.org/10.1016/j.seps.2020.100827>
- Kilic, H. S., Zaim, S., & Delen, D. (2014). Development of a hybrid methodology for ERP system selection: The case of Turkish Airlines. *Decision Support Systems*, 66, 82–92.
- Kumar, A., Yadav, R., & Baranwal, G. (2020). NearBy-Offload: An Android based Application for Computation Offloading. *2020 IEEE 15th International Conference on Industrial and Information Systems, ICIIIS 2020 - Proceedings*, 357–362. <https://doi.org/10.1109/ICIIIS51140.2020.9342724>
- Kumar, R. R., & Kumar, C. (2016). An evaluation system for cloud service selection using fuzzy AHP. *11th International Conference on Industrial and Information Systems, ICIIIS 2016 - Conference Proceedings*, 2018-January, 821–826. <https://doi.org/10.1109/ICIIIS.2016.8263052>
- Kumar, R. R., & Kumar, C. (2017). Designing an efficient methodology based on Entropy-TOPSIS for evaluating efficiency of cloud services. *ACM International Conference Proceeding Series*, 117–122. <https://doi.org/10.1145/3154979.3154982>
- Kumar, R. R., & Kumar, C. (2018a). A multi criteria decision making method for cloud service selection and ranking. *International Journal of Ambient Computing and Intelligence*, 9(3), 1–14. <https://doi.org/10.4018/IJACI.2018070101>
- Kumar, R. R., & Kumar, C. (2018b). A multicriteria decision-making method for cloud service selection and ranking. *Advances in Intelligent Systems and Computing*, 554, 139–147. https://doi.org/10.1007/978-981-10-3773-3_14
- Kumar, R. R., Kumari, B., & Kumar, C. (2021a). CCS-OSSR: A framework based on Hybrid MCDM for Optimal Service Selection and Ranking of Cloud Computing Services. *Cluster Computing*, 24(2), 867–883. <https://doi.org/10.1007/s10586-020-03166-3>
- Kumar, R. R., Mishra, S., & Kumar, C. (2017). Prioritizing the solution of cloud service selection using integrated MCDM methods under Fuzzy environment. *Journal of Supercomputing*, 73(11), 4652–4682. <https://doi.org/10.1007/s11227-017-2039-1>
- Kumar, R. R., Shameem, M., Khanam, R., & Kumar, C. (2018c). A Hybrid Evaluation Framework for QoS Based Service Selection and Ranking in Cloud Environment. *INDICON 2018 - 15th IEEE India Council International Conference*. <https://doi.org/10.1109/INDICON45594.2018.8987192>
- Kumar, V., Vrat, P., & Shankar, R. (2021b). Prioritization of strategies to overcome the barriers in Industry 4.0: A hybrid MCDM approach. *OPSEARCH*, 58(3), 711–750. <https://doi.org/10.1007/s12597-020-00505-1>
- Kuznichenko, S., Buchynska, I., Kovalenko, L., & Tereshchenko, T. (2019). Integrated information system for regional flood monitoring using internet of things. In G. Y. K. S. F.-O. Kazakova N. Sineglazov V. (Ed.), *CEUR Workshop Proceedings* (Vol. 2683, pp. 1–5). CEUR-WS. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85093365879&partnerID=40&md5=114745d6256919318a2e90fe5276b2>
- Lasi, H., Fetteke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, 6(4), 239–242.
- Lamba, K., & Singh, S. P. (2018). Modeling big data enablers for operations and supply chain management. *International Journal of Logistics Management*, 29(2), 629–658. <https://doi.org/10.1108/IJLM-07-2017-0183>
- Lange, D., & Pfarrer, M. D. (2017). Editors' comments: Sense and structure—The core building blocks of an AMR article. *Academy of Management Review*, 42(3), 407–416.
- Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing letters*, 3, 18–23.
- Le, S., Dong, H., Hussain, F. K., Hussain, O. K., Ma, J., & Zhang, Y. (2014a). A hybrid fuzzy framework for Cloud service selection. In Z. J. de Roure D. Thuraisingham B. (Ed.), *Proceedings - 2014 IEEE International Conference on Web Services, ICWS 2014* (pp. 313–320). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/ICWS.2014.53>
- Le, S., Dong, H., Hussain, F. K., Hussain, O. K., Ma, J., & Zhang, Y. (2014b). Multicriteria decision making with fuzziness and criteria interdependence in cloud service selection. *IEEE International Conference on Fuzzy Systems*, 1929–1936. <https://doi.org/10.1109/FUZZ-IEEE.2014.6891892>
- Lee, B., Oh, K. H., Park, H. J., Kim, U. M., & Yoon, H. Y. (2014). Resource reallocation of virtual machine in cloud computing with MCDM algorithm. *Proceedings - 2014 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery, CyberC 2014*, 470–477. <https://doi.org/10.1109/CyberC.2014.87>
- Lee, Q.-Y., Lee, M.-X., & Lee, Y.-C. (2021). A hybrid fuzzy decision model for evaluating mems and ic integration technologies. *Micromachines*, 12(3), 1–13. <https://doi.org/10.3390/mi12030276>
- Lee, S., & Seo, K.-K. (2016). A Hybrid Multi-Criteria Decision-Making Model for a Cloud Service Selection Problem Using BSC, Fuzzy Delphi Method and Fuzzy AHP. *Wireless Personal Communications*, 86(1), 57–75. <https://doi.org/10.1007/s11277-015-2976-z>
- Li, H. (2012). An Approach to Evaluating the Industry Development Potential of the Internet of Things with Triangular Fuzzy Information. *Journal of Convergence Information Technology*, 7(18), 147–154. <https://doi.org/10.4156/jcit.vol7.issue18.17>
- Li, S. M., Chan, F. T. S., Tsang, Y. P., & Lam, H. Y. (2021a). New product idea selection in the fuzzy front end of innovation: A fuzzy best-worst method and group decision-making process. *Mathematics*, 9(4), 1–18. <https://doi.org/10.3390/math9040337>
- Li, W., Xu, S., & Peng, X. (2021b). Research on comprehensive evaluation of data source quality in big data environment. *International Journal of Computational Intelligence Systems*, 14(1), 1831–1841. <https://doi.org/10.2991/ijcis.d.210622.001>
- Li, X., Yu, S., & Chu, J. (2018). Optimal selection of manufacturing services in cloud manufacturing: A novel hybrid MCDM approach based on rough ANP and rough TOPSIS. *Journal of Intelligent and Fuzzy Systems*, 34(6), 4041–4056. <https://doi.org/10.3233/JIFS-171379>
- Liang, F., Brunelli, M., & Rezaei, J. (2020). Consistency issues in the best worst method: Measurements and thresholds. *Omega*, 96, Article 102175.

- Liao, H., Wu, X., Liang, X., Xu, J., & Herrera, F. (2018). A New Hesitant Fuzzy Linguistic ORESTE Method for Hybrid Multicriteria Decision Making. *IEEE Transactions on Fuzzy Systems*, 26(6), 3793–3807. <https://doi.org/10.1109/TFUZZ.2018.2849368>
- Liao, R., Zhang, Y., Yang, L., Zheng, H., & She, X. (2014). A cloud and evidential reasoning integrated model for insulation condition assessment of high voltage transformers. *International Transactions on Electrical Energy Systems*, 24(7), 913–926. <https://doi.org/10.1002/etep.1738>
- Liao, R., Zhang, Y., Zheng, H., Yang, L., Wang, K., & Akram, S. (2013). A condition assessment model of oil-immersed transformers using cloud and matter element integrated method [Ocena stanu technicznego transformatora olejowego na podstawie modelu szacunkowego - wykorzystanie metod elementów chmury i materii]. *Przegląd Elektrotechniczny*, 89(4), 142–146. <https://www.scopus.com/inward/record.uri?eid=s2.0-84875680592&partnerID=40&md5=0cd35b927b1f53e07f052c6a3363d248>
- Lin, C.-K., Chen, Y.-S., & Chuang, H.-M. (2016). Improving project risk management by a hybrid MCDM model combining DEMATEL with DANP and VIKOR methods—An example of cloud CRM. *Lecture Notes in Electrical Engineering*, 375, 1033–1040. https://doi.org/10.1007/978-981-10-0539-8_101
- Lin, C.-L., Chen, J. K. C., & Ho, H.-H. (2021a). Bim for smart hospital management during covid-19 using mcdm. *Sustainability (Switzerland)*, 13(11). <https://doi.org/10.3390/su13116181>
- Lin, M., Huang, C., Xu, Z., & Chen, R. (2020). Evaluating IoT Platforms Using Integrated Probabilistic Linguistic MCDM Method. *IEEE Internet of Things Journal*, 7(11), 11195–11208. <https://doi.org/10.1109/JIOT.2020.2997133>
- Lin, R.-J. (2013). Using fuzzy DEMATEL to evaluate the green supply chain management practices. *Journal of Cleaner Production*, 40, 32–39. <https://doi.org/10.1016/j.jclepro.2011.06.010>
- Lin, X., Yin, P., Xia, Y., Yu, Y., Qiu, T., Wang, X., & Li, L. (2017). MPLB: A Load Balance Scheme of Joint Resource Scheduling in Heterogeneous Wireless Network. *Proceedings - 2017 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery, CyberC 2017, 2018-January*, 517–524. <https://doi.org/10.1109/CyberC.2017.27>
- Lin, Z., Huang, C., & Lin, M. (2021b). Probabilistic Hesitant Fuzzy Methods for Prioritizing Distributed Stream Processing Frameworks for IoT Applications. *Mathematical Problems in Engineering*, 2021, 1–12. <https://doi.org/10.1155/2021/6655477>
- Liu, L., Lu, C., Xiao, F., Liu, R., & Xiong, N. N. (2021). A Practical, Integrated Multi-Criteria Decision-Making Scheme for Choosing Cloud Services in Cloud Systems. *IEEE Access*, 9, 88391–88404. <https://doi.org/10.1109/ACCESS.2021.3089991>
- Liu, P., & Teng, F. (2019). Probabilistic linguistic TODIM method for selecting products through online product reviews. *Information Sciences*, 485, 441–455. <https://doi.org/10.1016/j.ins.2019.02.022>
- Liu, Q.-Y., Kwong, C.-F., Zhang, S., & Li, L. (2018). A hybrid fuzzy-MADM based decision-making scheme for QoS aware handover. *IET Conference Publications*, 2018 (CP754). <https://doi.org/10.1049/cp.2018.1728>
- Liu, Y., Chen, Y., & Tzeng, G.-H. (2017). Identification of key factors in consumers' adoption behavior of intelligent medical terminals based on a hybrid modified MADM model for product improvement. *International Journal of Medical Informatics*, 105, 68–82. <https://doi.org/10.1016/j.ijmedinf.2017.05.017>
- Liu, Y., & Han, M. (2020). Determining the Key Factors of Wearable Devices Consumers' Adoption Behavior Based on an MADM Model for Product Improvement. *IEEE Transactions on Engineering Management*. <https://doi.org/10.1109/TEM.2019.2960499>
- Lo, C.-C., Chen, D.-Y., Tsai, C.-F., & Chao, K.-M. (2010). Service Selection Based on Fuzzy TOPSIS Method. *2010 IEEE 24th International Conference on Advanced Information Networking and Applications Workshops*, 367–372. <https://doi.org/10.1109/WAINA.2010.117>
- Lou, S., Feng, Y., Li, Z., Zheng, H., Gao, Y., & Tan, J. (2021). An Edge-Based Distributed Decision-Making Method for Product Design Scheme Evaluation. *IEEE Transactions on Industrial Informatics*, 17(2), 1375–1385. <https://doi.org/10.1109/TII.2020.2983979>
- Lu, H., Ren, L., Chen, Y., Tian, P., & Liu, J. (2017). A cloud model based multi-attribute decision making approach for selection and evaluation of groundwater management schemes. *Journal of Hydrology*, 555, 881–893. <https://doi.org/10.1016/j.jhydrol.2017.10.009>
- Lu, Z., Sun, X., Wang, Y., & Xu, C. (2019). Green supplier selection in straw biomass industry based on cloud model and possibility degree. *Journal of Cleaner Production*, 209, 995–1005. <https://doi.org/10.1016/j.jclepro.2018.10.130>
- M. Tachizawa, E., & Yew Wong, C. (2014). Towards a theory of multi-tier sustainable supply chains: a systematic literature review. *Supply Chain Management: An International Journal*, 19(5/6), 643–663. <https://doi.org/10.1108/SCM-02-2014-0070>
- Ma, H., Hu, Z., Li, K., & Zhang, H. (2016). Toward trustworthy cloud service selection: A time-aware approach using interval neutrosophic set. *Journal of Parallel and Distributed Computing*, 96, 75–94. <https://doi.org/10.1016/j.jpdc.2016.05.008>
- Ma, H., Zhu, H., Hu, Z., Li, K., & Tang, W. (2017). Time-aware trustworthiness ranking prediction for cloud services using interval neutrosophic set and ELECTRE. *Knowledge-Based Systems*, 138, 27–45. <https://doi.org/10.1016/j.knsys.2017.09.027>
- Maghsoodi, A. I., Kaviani, A., Khalilzadeh, M., & Brauers, W. K. M. (2018). CLUS-MCDA: A novel framework based on cluster analysis and multiple criteria decision theory in a supplier selection problem. *Computers and Industrial Engineering*, 118, 409–422. <https://doi.org/10.1016/j.cie.2018.03.011>
- Maghsoodi, A. I., Riahi, D., Herrera-Viedma, E., & Zavadskas, E. K. (2020). An integrated parallel big data decision support tool using the W-CLUS-MCDA: A multi-scenario personnel assessment. *Knowledge-Based Systems*, 195. <https://doi.org/10.1016/j.knsys.2020.105749>
- Mahdiraji, H. A., Kazimieras Zavadskas, E., Kazeminiya, A., & Abbasi Kamardi, A. (2019). Marketing strategies evaluation based on big data analysis: A CLUSTERING-MCDM approach. *Economic Research-Ekonomska Istrazivanja*, 32(1), 2882–2898. <https://doi.org/10.1080/1331677X.2019.1658534>
- Mahmoudi, A., Deng, X., Javed, S. A., & Yuan, J. (2021). Large-scale multiple criteria decision-making with missing values: Project selection through TOPSIS-OPA. *Journal of Ambient Intelligence and Humanized Computing*, 12(10), 9341–9362. <https://doi.org/10.1007/s12652-020-02649-w>
- Mansouri, M., & Leghris, C. (2017a). The use of MADM methods in the vertical handover decision making context. In H. M. Y. Kobbane A. Ibrahim K. (Ed.), *Proceedings - 2017 International Conference on Wireless Networks and Mobile Communications, WINCOM 2017*. Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/WINCOM.2017.8238169>
- Mansouri, M., & Leghris, C. (2017b). Using fuzzy gray relational analysis in the vertical handover process in wireless networks. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 10299 LNCS, 396–401. https://doi.org/10.1007/978-3-319-59647-1_29
- Mardani, A., Nilashi, M., Zakuan, N., Loganathan, N., Soheilrad, S., Saman, M. Z. M., & Ibrahim, O. (2017). A systematic review and meta-Analysis of SWARA and WASPAS methods: Theory and applications with recent fuzzy developments. *Applied Soft Computing*, 57, 265–292. <https://doi.org/10.1016/j.asoc.2017.03.045>
- Masood, T., & Sonntag, P. (2020). Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, 121, 103261.
- Mathur, S., Sharma, A. K., & Meesad, P. (2021). Hybrid AI and IoT Approaches Used in Health Care for Patients Diagnosis. *Intelligent Systems Reference Library*, 209, 97–108. https://doi.org/10.1007/978-981-16-2972-3_5
- Md Kassim, S. S., Salleh, M., Zainal, A., & Che Husin, A. R. (2017). Risk tolerance and trust issues in cloud-based E-learning. In H. F. Hamdan H. Boubiche D.E. (Ed.), *ACM International Conference Proceeding Series*. Association for Computing Machinery. <https://doi.org/10.1145/3018896.3018973>
- Medic, N., Anisić, Z., Lalić, B., Marjanović, U., & Brezocnik, M. (2019). Hybrid fuzzy multi-attribute decision making model for evaluation of advanced digital technologies in manufacturing: Industry 4.0 perspective. *Advances in Production Engineering And Management*, 14(4), 483–493. <https://doi.org/10.14743/apem2019.4.343>
- Medic, N., Marjanovic, U., Zivlak, N., Anisic, Z., & Lalic, B. (2018). Hybrid Fuzzy MCDM Method for Selection of Organizational Innovations in Manufacturing Companies. *TEMS-ISIE 2018 - 1st Annual International Symposium on Innovation and Entrepreneurship of the IEEE Technology and Engineering Management Society*. <https://doi.org/10.1109/TEMS-ISIE.2018.8478445>
- Mian, S. H., & Al-Ahmari, A. (2019). Comparative analysis of different digitization systems and selection of best alternative. *Journal of Intelligent Manufacturing*, 30(5), 2039–2067. <https://doi.org/10.1007/s10845-017-1371-x>
- Mishra, A. R., & Rani, P. (2019). Shapley divergence measures with VIKOR method for multi-attribute decision-making problems. *Neural Computing and Applications*, 31(2), 1299–1316.
- Mishra, M. K., Ray, N. K., Swain, A. R., Mund, G. B., & Mishra, B. S. P. (2019). An adaptive model for resource selection and allocation in fog computing environment. *Computers and Electrical Engineering*, 77, 217–229. <https://doi.org/10.1016/j.compeleceng.2019.05.010>
- Mishra, S., Sahoo, M. N., Bakshi, S., & Rodrigues, J. J. P. C. (2020). Dynamic Resource Allocation in Fog-Cloud Hybrid Systems Using Multicriteria AHP Techniques. *IEEE Internet of Things Journal*, 7(9), 8993–9000. <https://doi.org/10.1109/JIOT.2020.30011603>
- Mitroulis, D., & Kitsios, F. (2019). Evaluating digital transformation strategies: A MCDA analysis of Greek tourism SMEs. In K. A. Liargovas P. (Ed.), *Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE (Vol. 2, pp. 667–676)*. Academic Conferences and Publishing International Limited. <https://doi.org/10.34190/ECIE.19.197>
- Mo, R., Dai, F., Liu, Q., Dou, W., & Xu, X. (2020). Multi-objective cross-layer resource scheduling for internet of things in edge-cloud computing. *IEEE International Conference on Cloud Computing, CLOUD, 2020-October*, 345–352. <https://doi.org/10.1109/CLOUD49709.2020.00055>
- Mohalle, S. N., Abdel-Hamid, A. A., & Eskaf, K. A. (2019). Enhanced fuzzy AHP-TOPSIS for cloud service selection. *29th International Conference on Computer Theory and Applications, ICCTA 2019 - Proceedings*, 54–59. <https://doi.org/10.1109/ICCTA48790.2019.9478831>
- Mohammed, K. I., Jaafar, J., Zaidan, A. A., Albahri, O. S., Zaidan, B. B., Abdulkareem, K. H., ... Alamoody, A. H. (2020). A Uniform Intelligent Prioritisation for Solving Diverse and Big Data Generated from Multiple Chronic Diseases Patients Based on Hybrid Decision-Making and Voting Method. *IEEE Access*, 8, 91521–91530. <https://doi.org/10.1109/ACCESS.2020.2994746>
- Mukul, E., Güller, M., & Büyükköçkan, G. (2020). Evaluation of smart health technologies with hesitant fuzzy MCDM methods. *Advances in Intelligent Systems and Computing*, 1029, 1059–1067. https://doi.org/10.1007/978-3-030-23756-1_125
- Munjal, M., & Singh, N. P. (2019). QoS and Cost-Aware Protocol Selection for Next Generation Wireless Network. *Journal of Network and Systems Management*, 27(2), 327–350. <https://doi.org/10.1007/s10922-018-9467-y>
- Muruganantham, A., & Gandhi, G. M. (2020). Framework for Social Media Analytics based on Multi-Criteria Decision Making (MCDM) model. *Multimedia Tools and Applications*, 79(5–6), 3913–3927. <https://doi.org/10.1007/s11042-019-7470-2>
- Mustafa, S., Fatimah, I., & Jun, Y. B. (2019). Modelling the logistic processes using fuzzy decision approach. *Hacettepe Journal of Mathematics and Statistics*, 48(2), 552–563.

- Nabeeh, N. A., Abdel-Basset, M., El-Ghareeb, H. A., & Aboelfetouh, A. (2019). Neutrosophic Multi-Criteria Decision Making Approach for IoT-Based Enterprises. *IEEE Access*, 7, 59559–59574. <https://doi.org/10.1109/ACCESS.2019.2908919>
- Nasrollahi, M., & Ramezani, J. (2020). A model to evaluate the organizational readiness for big data adoption. *International Journal of Computers, Communications and Control*, 15(3). <https://doi.org/10.15837/IJCCC.2020.3.3874>
- Nawaz, F., Asadabadi, M. R., Janjua, N. K., Hussain, O. K., Chang, E., & Saberi, M. (2018). An MCDM method for cloud service selection using a Markov chain and the best-worst method. *Knowledge-Based Systems*, 159, 120–131. <https://doi.org/10.1016/j.knsys.2018.06.010>
- Nayak, S. C., Parida, S., Tripathy, C., Pati, B., & Panigrahi, C. R. (2020). Multicriteria decision-making techniques for avoiding similar task scheduling conflict in cloud computing. *International Journal of Communication Systems*, 33(13). <https://doi.org/10.1002/dac.4126>
- Nayak, S. C., & Tripathy, C. (2019). An improved task scheduling mechanism using multi-criteria decision making in cloud computing. *International Journal of Information Technology and Web Engineering*, 14(2), 92–117. <https://doi.org/10.4018/IJITWE.2019040106>
- Nguyen, P.-H., Tsai, J.-F., Hu, Y.-C., & Ajay Kumar, G. v. (2022). A Hybrid Method of MCDM for Evaluating Financial Performance of Vietnamese Commercial Banks Under COVID-19 Impacts. *Studies in Systems, Decision and Control*, 382, 23–45. https://doi.org/10.1007/978-3-030-79610-5_2
- Nikam, S., & Ingle, R. (2018). Service composition algorithms in cyber physical systems. *Journal of Theoretical and Applied Information Technology*, 96(11), 3383–3399. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85048610204&partnerID=40&md5=3f83abe9d6f37944c061b0e0ff7628d>
- Nikam, S., & Ingle, R. (2019). Autonomics of Self-management for Service Composition in Cyber Physical Systems. *Advances in Intelligent Systems and Computing*, 851, 455–463. https://doi.org/10.1007/978-981-13-2414-7_42
- Ning, L., Ali, Y., Ke, H., Nazir, S., & Huanli, Z. (2020). A Hybrid MCDM Approach of Selecting Lightweight Cryptographic Cipher Based on ISO and NIST Lightweight Cryptography Security Requirements for Internet of Health Things. *IEEE Access*, 8, 220165–220187. <https://doi.org/10.1109/ACCESS.2020.3041327>
- Ogundoyin, S. O., & Kamil, I. A. (2020). A Fuzzy-AHP based prioritization of trust criteria in fog computing services. *Applied Soft Computing Journal*, 97. <https://doi.org/10.1016/j.asoc.2020.106789>
- Ortiz-Barrios, M., Petrillo, A., de Felice, F., Jaramillo-Rueda, N., Jiménez-Delgado, G., & Borrero-López, L. (2021). A dispatching-fuzzy ahp-topsis model for scheduling flexible job-shop systems in industry 4.0 context. *Applied Sciences (Switzerland)*, 11(11). <https://doi.org/10.3390/app11115107>
- Osterrieder, P., Budde, L., & Friedli, T. (2020). The smart factory as a key construct of industry 4.0: A systematic literature review. *International Journal of Production Economics*, 221, Article 107476.
- Ouahad, A., Hadjali, A., & Nader, F. (2019). A Hybrid MCDM Framework for Efficient Web Services Selection Based on QoS. *Proceedings of the 2018 International Conference on Applied Smart Systems, ICASS 2018*. <https://doi.org/10.1109/ICASS.2018.8652037>
- Ozceylan, E., Ozkan, B., & Cetinkaya, C. (2022). A Hybrid Model Based on FAHP and WASPAS for Evaluation of Explosive and Narcotics Trace Detection Devices. *Studies in Systems, Decision and Control*, 372, 335–360. https://doi.org/10.1007/978-3-030-75067-1_15
- Ozdemir, Y. S. (2022). A Spherical Fuzzy Multi-Criteria Decision-Making Model for Industry 4.0 Performance Measurement. *Axioms*, 11(7), 325.
- Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, 31(1), 127–182.
- Pagliosa, M., Tortorella, G., & Ferreira, J. C. E. (2019). Industry 4.0 and Lean Manufacturing: A systematic literature review and future research directions. *Journal of Manufacturing Technology Management*, 32(3), 543–569.
- Palanisamy, M., Pugalendhi, A., & Ranganathan, R. (2020). Selection of suitable additive manufacturing machine and materials through best-worst method (BWM). *International Journal of Advanced Manufacturing Technology*, 107(5–6), 2345–2362. <https://doi.org/10.1007/s00170-020-05110-6>
- Patiniotakis, I., Rizou, S., Verginadis, Y., & Mentzas, G. (2013). Managing imprecise criteria in cloud service ranking with a fuzzy multi-criteria decision making method. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 8135 LNCS, 34–48. https://doi.org/10.1007/978-3-642-40651-5_4
- Patiniotakis, I., Verginadis, Y., & Mentzas, G. (2014). Preference-based cloud service recommendation as a brokerage service. *Proceedings of the 2nd International Workshop on Cross-Cloud Systems, CrossCloud Brokers 2014 - Held in Conjunction with the 15th ACM/IFIP/USENIX International Middleware Conference, Middleware 2014*. <https://doi.org/10.1145/2676662.2676677>
- Patiniotakis, I., Verginadis, Y., & Mentzas, G. (2015). PuLSar: Preference-based cloud service selection for cloud service brokers. *Journal of Internet Services and Applications*, 6(1), 1–14. <https://doi.org/10.1186/s13174-015-0042-4>
- Peng, C., Zhang, L., Pang, Z., & Chen, L. (2014). Fuzzy QoS-driven service selection method for group user. *International Journal of Innovative Computing, Information and Control*, 10(6), 2251–2262. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84923339914&partnerID=40&md5=326318a49aeeb5a1f0053df1a003ee03>
- Peng, X., & Dai, J. (2019). Interval Neutrosophic Reducible Weighted Maclaurin Symmetric Means with Internet of Medical Things (IoMT) Industry Evaluation. *IEEE Access*, 7, 62479–62495. <https://doi.org/10.1109/ACCESS.2019.2916791>
- Pramanik, D., Mondal, S. C., & Haldar, A. (2020a). A framework for managing uncertainty in information system project selection: An intelligent fuzzy approach. *International Journal of Management Science and Engineering Management*, 15(1), 70–78. <https://doi.org/10.1080/17509653.2019.1604191>
- Pramanik, D., Mondal, S. C., & Haldar, A. (2020b). Resilient supplier selection to mitigate uncertainty: Soft-computing approach. *Journal of Modelling in Management*, 15(4), 1339–1361. <https://doi.org/10.1108/JM2-01-2019-0027>
- Preeth, S. K. S. L., Dhanalakshmi, R., Kumar, R., & Shakeel, P. M. (2018). An adaptive fuzzy rule based energy efficient clustering and immune-inspired routing protocol for WSN-assisted IoT system. *Journal of Ambient Intelligence and Humanized Computing*. <https://doi.org/10.1007/s12652-018-1154-z>
- Priyadarshinee, P., Jha, M. K., Raut, R. D., Kharat, M. G., & Kamble, S. S. (2017). To identify the critical success factors for cloud computing adoption by MCDM technique. *International Journal of Business Information Systems*, 24(4), 469–510. <https://doi.org/10.1504/IJBIS.2017.082888>
- Priyadarshini, I., Kumar, R., Sharma, R., Singh, P. K., & Satapathy, S. C. (2021). Identifying cyber insecurities in trustworthy space and energy sector for smart grids. *Computers and Electrical Engineering*, 93. <https://doi.org/10.1016/j.compeleceng.2021.107204>
- Pu, Y., Ma, F., Zhang, J., & Yang, M. (2018). Optimal Lightweight Material Selection for Automobile Applications Considering Multi-Perspective Indices. *IEEE Access*, 6, 8591–8598. <https://doi.org/10.1109/ACCESS.2018.2804904>
- Qi, L., Chen, Y., Yuan, Y., Fu, S., Zhang, X., & Xu, X. (2020). A QoS-aware virtual machine scheduling method for energy conservation in cloud-based cyber-physical systems. *World Wide Web*, 23(2), 1275–1297. <https://doi.org/10.1007/s11280-019-00684-y>
- Vigneshwaran, R., & Vinodh, S. (2021). Prioritizing the Challenges for Lean and Industry 4.0 Integration Using Fuzzy TOPSIS. *Lecture Notes in Mechanical Engineering*, 495–513. https://doi.org/10.1007/978-981-15-9809-8_37
- Radhika, E. G., & Sudha Sadasivam, G. (2021). Budget optimized dynamic virtual machine provisioning in hybrid cloud using fuzzy analytic hierarchy process. *Expert Systems with Applications*, 183. <https://doi.org/10.1016/j.eswa.2021.115398>
- Rafiee, P., Nouri, N., & Mirjalili, G. (2019). On the Performance Enhancement of Routing Protocols in the Internet of Underwater Things. *ICEE 2019 - 27th Iranian Conference on Electrical Engineering*, 1265–1271. <https://doi.org/10.1109/IranianCEE.2019.8786467>
- Rajesh, R., & Ravi, V. (2015). Supplier selection in resilient supply chains: A grey relational analysis approach. *Journal of Cleaner Production*, 86, 343–359. <https://doi.org/10.1016/j.jclepro.2014.08.054>
- Ramachandran, N., Sivaprakasam, P., Thangamani, G., & Anand, G. (2014). Selecting a suitable cloud computing technology deployment model for an academic institute: A case study. *Campus-Wide Information Systems*, 31(5), 319–345. <https://doi.org/10.1108/CWIS-09-2014-0018>
- Ramos, L., Loures, E., Deschamps, F., Giesel, E., & Savaris, E. (2018). Systems evaluation methodology to attend the digital projects requirements for industry 4.0. In P. M. B. C. P. M. Wognum N. Stjepandic J. (Ed.), *Advances in Transdisciplinary Engineering* (Vol. 7, pp. 3–12). IOS Press BV. <https://doi.org/10.3233/978-1-61499-898-3-3>
- Ramos, L., Loures, E., Deschamps, F., & Venancio, A. (2020). Systems evaluation methodology to attend the digital projects requirements for industry 4.0. *International Journal of Computer Integrated Manufacturing*, 33(4), 398–410. <https://doi.org/10.1080/0951192X.2019.1699666>
- Raut, R. D., Gardas, B. B., Jha, M. K., & Priyadarshinee, P. (2017). Examining the critical success factors of cloud computing adoption in the MSMEs by using ISM model. *Journal of High Technology Management Research*, 28(2), 125–141. <https://doi.org/10.1016/j.hitech.2017.10.004>
- Ravi, A., & Peddoju, S. K. (2015). Handoff Strategy for Improving Energy Efficiency and Cloud Service Availability for Mobile Devices. *Wireless Personal Communications*, 81(1), 101–132. <https://doi.org/10.1007/s11277-014-2119-y>
- Rebello, C., & Tavares, E. (2018). Big data privacy context: Literature effects on secure informational assets. *Transactions on Data Privacy*, 11(3), 199–217. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85052560502&partnerID=40&md5=dcf612add3db4cfa09188396639f7e8>
- Rehman, Z. U., Hussain, O. K., Chang, E., & Dillon, T. (2015). Decision-making framework for user-based inter-cloud service migration. *Electronic Commerce Research and Applications*, 14(6), 523–531. <https://doi.org/10.1016/j.elerap.2015.08.002>
- Rehman, Z. U., Hussain, O. K., & Hussain, F. K. (2012). IaaS cloud selection using MCDM methods. *Proceedings - 9th IEEE International Conference on E-Business Engineering, ICEBE 2012*, 246–251. <https://doi.org/10.1109/ICEBE.2012.47>
- Rehman, Z. U., Hussain, O. K., & Hussain, F. K. (2013). Multi-Criteria IaaS service selection based on QoS history. *Proceedings - International Conference on Advanced Information Networking and Applications, AINA, 1129–1135*. <https://doi.org/10.1109/AINA.2013.158>
- Reis, J., Amorim, M., Melão, N., & Matos, P. (2018, March). Digital transformation: A literature review and guidelines for future research. In *World conference on information systems and technologies* (pp. 411–421). Cham: Springer.
- Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega*, 53, 49–57.
- Ribas, M., Furtado, C. G., de Souza, J. N., Barroso, G. C., Moura, A., Lima, A. S., & Sousa, F. R. C. (2015). A Petri net-based decision-making framework for assessing cloud services adoption: The use of spot instances for cost reduction. *Journal of Network and Computer Applications*, 57, 102–118. <https://doi.org/10.1016/j.jnca.2015.07.002>
- Riel, A., & Flatscher, M. (2017). A Design Process Approach to Strategic Production Planning for Industry 4.0 (pp. 323–333). https://doi.org/10.1007/978-3-319-64218-5_27
- Saaty, T. L. (1980). *The Analytic Hierarchy Process*. McGraw-Hill.
- Saaty, T. L. (2005). *Theory and applications of the analytic network process*. RWS Publications.
- Saberi, M., Saberi, Z., Asadabadi, M. R., Hussain, O. K., & Chang, E. (2020). A Customer-Oriented Assortment Selection in the Big Data Environment. *Lecture Notes on Data*

- Engineering and Communications Technologies*, 41, 161–172. https://doi.org/10.1007/978-3-030-34986-8_11
- Sachdeva, N., Kapur, P. K., & Singh, G. (2016a). Selecting appropriate cloud solution for managing big data projects using hybrid AHP-entropy based assessment. In J. J. S. S. G. Kumar B. Kapur P.K. (Ed.), *2016 1st International Conference on Innovation and Challenges in Cyber Security, ICICCS 2016* (pp. 135–140). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/ICICCS.2016.7542351>.
- Sachdeva, N., Singh, O., Kapur, P. K., & Galar, D. (2016b). Multi-criteria intuitionistic fuzzy group decision analysis with TOPSIS method for selecting appropriate cloud solution to manage big data projects. *International Journal of Systems Assurance Engineering and Management*, 7(3), 316–324. <https://doi.org/10.1007/s13198-016-0455-x>
- Sadreddini, Z., Guner, S., & Erdinc, O. (2021). Design of a Decision-Based Multi-Criteria Reservation System for the EV Parking Lot. *IEEE Transactions on Transportation Electrification*. <https://doi.org/10.1109/TTE.2021.3067953>
- Saidi, K., Hioual, O., & Siam, A. (2019). A DSL-MCDA Model for Energy Consumption-Aware in Cloud Computing. *2019 International Conference on Internet of Things, Embedded Systems and Communications, IINTEC 2019 - Proceedings*, 168–173. <https://doi.org/10.1109/IINTEC48298.2019.9112111>.
- Salehi, S., Amiri, M., Ghahremani, P., & Abedini, M. (2018). A novel integrated AHP-TOPSIS model to deal with big data in group decision making. *Proceedings of the International Conference on Industrial Engineering and Operations Management, 2018 (SEP)*, 1043–1053. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85067076615&partnerID=40&md5=08e4635fcb1b8c5422bb72e0747cfb3b>.
- Samaras, G. D., Gkanas, N. I., & Vitsa, K. C. (2014). Assessing risk in dam projects using AHP and ELECTRE I. *International Journal of Construction Management*, 14(4), 255–266.
- Sangiorgio, V., Martiradonna, S., Fatiguso, F., & Lombillo, I. (2021). Augmented reality based - decision making (AR-DM) to support multi-criteria analysis in constructions. *Automation in Construction*, 124. <https://doi.org/10.1016/j.autcon.2021.103567>
- Sansabas-Villalpando, V., Pérez-Olguin, I. J. C., Pérez-Domínguez, L. A., Rodríguez-Picón, L. A., & Mendez-González, L. C. (2019). CODAS HFLTS Method to Appraise Organizational Culture of Innovation and Complex Technological Changes Environments. *Sustainability (Switzerland)*, 11(24). <https://doi.org/10.3390/su11247045>
- Saraji, M. K., Streimikiene, D., & Kyriakopoulos, G. L. (2021). Fermatean fuzzy criticopras method for evaluating the challenges to industry 4.0 adoption for a sustainable digital transformation. *Sustainability (Switzerland)*, 13(17). <https://doi.org/10.3390/su13179577>
- Saripalli, P., & Pingali, G. (2011). MADMAC: Multiple Attribute Decision Methodology for Adoption of Clouds. *2011 IEEE 4th International Conference on Cloud Computing*, 316–323. <https://doi.org/10.1109/CLOUD.2011.61>.
- Schaefer, J. L., Siluk, J. C. M., & Carvalho, P. S. D. (2021). An MCDM-based approach to evaluate the performance objectives for strategic management and development of Energy Cloud. *Journal of Cleaner Production*, 320. <https://doi.org/10.1016/j.jclepro.2021.128853>
- Seh, A. H., Al-Amri, J. F., Subahi, A. F., Jamal Ansari, M. T., Kumar, R., Bokhari, M. U., & Khan, R. A. (2021). Hybrid computational modeling for web application security assessment. *Computers, Materials and Continua*, 70(1), 469–489. <https://doi.org/10.32604/cmc.2022.019593>
- Sendhil Kumar, K. S., & Jaisankar, N. (2019). Multicriteria-based ranking framework for measuring performance of cloud service providers. *Advances in Intelligent Systems and Computing*, 900, 419–427. https://doi.org/10.1007/978-981-13-3600-3_39
- Sezer, O. B., Dogdu, E., & Ozbayoglu, A. M. (2017). Context-aware computing, learning, and big data in internet of things: A survey. *IEEE Internet of Things Journal*, 5(1), 1–27.
- Şener, U., Gökulp, E., & Eren, P. E. (2017). CloudSS: A decision support system for cloud service selection. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 10537 LNCS, 249–261. https://doi.org/10.1007/978-3-319-68066-8_19
- Shaabani, A., Olfat, L., & Vanani, I. R. (2021). Analytical evaluation of the barriers to blockchain technology implementation in supply chains. *International Journal of Applied Decision Sciences*, 14(5), 518–541. <https://doi.org/10.1504/IJADS.2021.117459>
- Shang, X., Ma, P., & Chao, T. (2017). Performance Evaluation of Electromagnetic Railgun Exterior Ballistics Based on Cloud Model. *IEEE Transactions on Plasma Science*, 45(7), 1614–1621. <https://doi.org/10.1109/TPS.2017.2706365>
- Shang, Y., Lu, J., & Zhang, L. (2013). QoS-aware SaaS services selection with intuitionistic fuzzy set for group user. *ICIC Express Letters, Part B: Applications*, 4(6), 1603–1608. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84893186678&partnerID=40&md5=8131dc6f0134dafed17bb36a29b0e253>.
- Sharaf, I. M. (2021). Global supplier selection with spherical fuzzy analytic hierarchy process. *Decision Making with Spherical Fuzzy Sets. Theory and Applications*, 323–348.
- Sharma, M., & Joshi, S. (2020). Digital supplier selection reinforcing supply chain quality management systems to enhance firm's performance. *The TQM Journal*. <https://doi.org/10.1108/TQM-07-2020-0160>
- Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., & Purohit, H. C. (2020). Internet of Things (IoT) adoption barriers of smart cities' waste management: An Indian context. *Journal of Cleaner Production*, 270. <https://doi.org/10.1016/j.jclepro.2020.122047>
- Shayaa, S., Jaafar, N. I., Bahri, S., Sulaiman, A., Seuk Wai, P., Wai Chung, Y., ... Al-Garadi, M. A. (2018). Sentiment Analysis of Big Data: Methods, Applications, and Open Challenges. *IEEE Access*, 6, 37807–37827. <https://doi.org/10.1109/ACCESS.2018.2851311>
- Sheen, D. P., & Yang, Y. (2018, June). Assessment of readiness for smart manufacturing and innovation in Korea. In *2018 IEEE Technology and Engineering Management Conference (TEMSCON)* (pp. 1–5). IEEE.
- Shetty, J., & D'Mello, D. A. (2015). Quality of service driven cloud service ranking and selection algorithm using REMBRANDT approach. *2015 International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials, ICSTM 2015 - Proceedings*, 126–132. <https://doi.org/10.1109/ICSTM.2015.7225401>.
- Shreyas, J., Singh, H., Bhutani, J., Pandit, S., Srinidhi, N. N., & Kumar, D. S. M. (2019). Congestion Aware Algorithm using Fuzzy Logic to Find an Optimal Routing Path for IoT Networks. *Proceedings of 2019 International Conference on Computational Intelligence and Knowledge Economy, ICCIKE 2019*, 141–145. <https://doi.org/10.1109/ICCIKE47802.2019.9004351>.
- Sidhu, J., & Singh, S. (2017). Design and Comparative Analysis of MCDM-based Multi-dimensional Trust Evaluation Schemes for Determining Trustworthiness of Cloud Service Providers. *Journal of Grid Computing*, 15(2), 197–218. <https://doi.org/10.1007/s10723-017-9396-0>
- Singh, A., & Misra, S. C. (2021). Identifying Challenges in the Adoption of Industry 4.0 in the Indian Construction Industry. *Advances in Intelligent Systems and Computing*, 1198, 380–398. https://doi.org/10.1007/978-981-15-6584-7_37
- Singh, M., Baranwal, G., & Tripathi, A. K. (2020). QoS-Aware Selection of IoT-Based Service. *Arabian Journal for Science and Engineering*, 45(12), 10033–10050. <https://doi.org/10.1007/s13369-020-04601-8>
- Singh, S., & Misra, S. C. (2018). Migration of PLM systems to cloud. *International Journal of Communication Systems*, 31(18). <https://doi.org/10.1002/dac.3815>
- Singh, S., & Tiwari, R. K. (2020). Quality of service-based service selection in smart Parking. *International Journal of Information and Decision Sciences*, 12(2), 154–175. <https://doi.org/10.1504/IJIDS.2020.106722>
- Singla, C., Mahajan, N., Kaushal, S., Verma, A., & Sangaiah, A. K. (2018). Modelling and analysis of multi-objective service selection scheme in iot-cloud environment. *Lecture Notes on Data Engineering and Communications Technologies*, 14, 63–77. https://doi.org/10.1007/978-3-319-70688-7_3
- Skondras, E., Michailidis, E. T., Michalas, A., Vergados, D. J., Miridakis, N. I., & Vergados, D. D. (2021). A network slicing framework for uav-aided vehicular networks. *Drones*, 5(3). <https://doi.org/10.3390/drones5030070>
- Skondras, E., Michalas, A., Tsolis, N., Sgora, A., & Vergados, D. D. (2018). A network selection scheme for healthcare vehicular cloud computing systems. *2017 8th International Conference on Information, Intelligence, Systems and Applications, IISA 2017, 2018-January*, 1–6. <https://doi.org/10.1109/IISA.2017.8316378>.
- Sohaib, O., & Naderpour, M. (2017). Decision making on adoption of cloud computing in e-commerce using fuzzy TOPSIS. *IEEE International Conference on Fuzzy Systems*. <https://doi.org/10.1109/FUZZ-IEEE.2017.8015404>
- Son, A.-Y., & Huh, E.-N. (2018). QoS-driven migration scheme based on priority in cloud computing. *Journal of Theoretical and Applied Information Technology*, 96(4), 1038–1047. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85043784699&partnerID=40&md5=a1b278920c741bf0b0638cd6daf6f26f>.
- Son, A.-Y., Lim, Y. S., & Huh, E.-N. (2019). Energy Efficient VM Placement Scheme Based on Fuzzy-AHP System for Sustainable Cloud Computing. In Y. X.-S. Joshi A. Dey N. (Ed.), *Proceedings of the 2nd World Conference on Smart Trends in Systems, Security and Sustainability, Worlds4 2018* (pp. 303–307). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/Worlds4.2018.8611618>.
- Soni, G., Kumar, S., Mahto, R. V., Mangla, S. K., Mittal, M. L., & Lim, W. M. (2022). A decision-making framework for Industry 4.0 technology implementation: The case of FinTech and sustainable supply chain finance for SMEs. *Technological Forecasting and Social Change*, 180, Article 121686.
- Sorokin, R., & Rougier, J.-L. (2018). Video conference in the fog: An economical approach based on enterprise desktop grid. *Annales Des Telecommunications/Annals of Telecommunications*, 73(5–6), 305–316. <https://doi.org/10.1007/s12243-017-0613-4>
- Sriram, R. M., & Vinodh, S. (2021). Analysis of readiness factors for Industry 4.0 implementation in SMEs using COPRAS. *International Journal of Quality and Reliability Management*, 38(5), 1178–1192. <https://doi.org/10.1108/IJQRM-04-2020-0121>
- Stojić, M., Zavadskas, E., Pamučar, D., Stević, Ž., & Mardani, A. (2019). Application of MCDM Methods in Sustainability Engineering: A Literature Review 2008–2018. *Symmetry*, 11(3), 350. <https://doi.org/10.3390/sym11030350>
- Subramanian, N., & Jeyaraj, A. (2018). Recent security challenges in cloud computing. *Computers & Electrical Engineering*, 71, 28–42.
- Sun, L., Ma, J., Zhang, Y., Dong, H., & Hussain, F. K. (2016). Cloud-FuSeR: Fuzzy ontology and MCDM based cloud service selection. *Future Generation Computer Systems*, 57, 42–55. <https://doi.org/10.1016/j.future.2015.11.025>
- Sun, M., Zang, T., Xu, X., & Wang, R. (2013). Consumer-centered cloud services selection using AHP. *Proceedings of International Conference on Service Science, ICSS, 1–6*. <https://doi.org/10.1109/ICSS.2013.26>
- Sundarraj, R. P., & Venkatraman, S. (2015). On integrating an IS success model and multicriteria preference analysis into a system for cloud-computing investment decisions. *Lecture Notes in Business Information Processing*, 218, 357–368. https://doi.org/10.1007/978-3-319-19515-5_28
- TalebiFard, P., & Leung, V. C. M. (2014). Context-aware dissemination of information and services in heterogeneous network environments. *Journal of Ambient Intelligence and Humanized Computing*, 5(6), 775–787. <https://doi.org/10.1007/s12652-013-0210-y>
- Tanoumand, N., Ozdemir, D. Y., Kilic, K., & Ahmed, F. (2017). Selecting cloud computing service provider with fuzzy AHP. *IEEE International Conference on Fuzzy Systems*. <https://doi.org/10.1109/FUZZ-IEEE.2017.8015681>

- Tariq, M. I., Mian, N. A., Sohail, A., Alyas, T., & Ahmad, R. (2020a). Evaluation of the challenges in the internet of medical things with multicriteria decision making (AHP and TOPSIS) to overcome its obstruction under fuzzy environment. *Mobile Information Systems*, 2020. <https://doi.org/10.1155/2020/8815651>
- Tariq, M. I., Tayyaba, S., Ali Mian, N., Sarfraz, M. S., De-La-Hoz-Franco, E., Butt, S. A., Santarcangelo, V., & Rad, D. v. (2020b). Combination of AHP and TOPSIS methods for the ranking of information security controls to overcome its obstructions under fuzzy environment. *Journal of Intelligent and Fuzzy Systems*, 38(5), 6075–6088. <https://doi.org/10.3233/JIFS-179692>.
- Thoben, K. D., Wiesner, S., & Wuest, T. (2017). "Industrie 4.0" and smart manufacturing—a review of research issues and application examples. *International journal of automation technology*, 11(1), 4–16.
- Thomas, T. K., & Silas, S. (2018). An analysis on selection of cloud vendors based on subjective and objective parameters. *Proceedings of the 2nd International Conference on Inventive Systems and Control, ICISC 2018*, 974–977. <https://doi.org/10.1109/ICISC.2018.8398947>.
- Torbacki, W. (2021). A hybrid mcdm model combining danp and promethee ii methods for the assessment of cybersecurity in industry 4.0. *Sustainability (Switzerland)*, 13(16). <https://doi.org/10.3390/su13168833>
- Trabay, D., Asem, A., El-Henawy, I., & Gharibi, W. (2021). A hybrid technique for evaluating the trust of cloud services. *International Journal of Information Technology (Singapore)*, 13(2), 687–695. <https://doi.org/10.1007/s41870-020-00609-3>
- Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: Definition, review and theoretical foundations for further study. *International Journal of Production Research*, 53(18), 5592–5623. <https://doi.org/10.1080/00207543.2015.1037934>
- Steiner, F. (2019). Industry 4.0 and business process management. *Tehnički glasnik*, 13(4), 349–355.
- Unnikrishnan, G., Mathew, D., Jose, B. A., & Arvind, R. (2019). Hybrid Route Recommender System for Smarter Logistics. *2019 IEEE 5th Intl Conference on Big Data Security on Cloud (BigDataSecurity), IEEE Intl Conference on High Performance and Smart Computing, (HPSC) and IEEE Intl Conference on Intelligent Data and Security (IDS)*, 239–244. <https://doi.org/10.1109/BigDataSecurity-HPSC-IDS.2019.00053>.
- Vafaei, N., Ribeiro, R. A., & Camarinha-Matos, L. M. (2016). Normalization techniques for multi-criteria decision making: Analytical hierarchy process case study. *IFIP Advances in Information and Communication Technology*, 470, 261–268. https://doi.org/10.1007/978-3-319-31165-4_26
- Vafaei, N., Ribeiro, R. A., & Camarinha-Matos, L. M. (2021). Assessing Normalization Techniques for TOPSIS Method. *IFIP Advances in Information and Communication Technology*, 626, 132–141. https://doi.org/10.1007/978-3-030-78288-7_13
- Varshney, S., Sandhu, R., & Gupta, P. K. (2020). QoE-Based Multi-Criteria Decision Making for Resource Provisioning in Fog Computing Using AHP Technique. *International Journal of Knowledge and Systems Science*, 11(4), 17–30. <https://doi.org/10.4018/IJKSS.2020100102>
- Venkataraman, V., Hahn, A., & Srivastava, A. (2020). CP-SAM: Cyber-Physical Security Assessment Metric for Monitoring Microgrid Resiliency. *IEEE Transactions on Smart Grid*, 11(2), 1055–1065. <https://doi.org/10.1109/TSG.2019.2930241>
- Verma, R., & Chandra, S. (2021). Interval-Valued Intuitionistic Fuzzy-Analytic Hierarchy Process for evaluating the impact of security attributes in Fog based Internet of Things paradigm. *Computer Communications*, 175, 35–46. <https://doi.org/10.1016/j.comcom.2021.04.019>
- Veza, I., Mladineo, M., & Gjeldum, N. (2015). Managing innovative production network of smart factories. In Z. M. Dolgui, A. Sasiadek J. (Ed.), *IFAC-PapersOnline* (Vol. 28, Issue 3, pp. 555–560). <https://doi.org/10.1016/j.ifacol.2015.06.139>.
- Vinodh, S., & Wankhede, V. A. (2020). Application of fuzzy DEMATEL and fuzzy CODAS for analysis of workforce attributes pertaining to Industry 4.0: A case study. *International Journal of Quality and Reliability Management*, 38(8), 1695–1721. <https://doi.org/10.1108/IJQRM-09-2020-0322>
- Viriyaivatav, W., & Bi, Z. (2020). Service selection and workflow composition in modern business processes. *Journal of Industrial Information Integration*, 17. <https://doi.org/10.1016/j.jii.2020.100126>
- Vogel-Heuser, B., & Hess, D. (2016). Guest editorial industry 4.0—prerequisites and visions. *IEEE Transactions on Automation Science and Engineering*, 13(2), 411–413.
- Voronova, I., Shatrech, V., & Freimane, G. (2018). The impact of digital transformation on development of Latvian insurance companies' digitalization strategies and shift of perception values. In S. K.S. (Ed.), *Proceedings of the 32nd International Business Information Management Association Conference, IBIMA 2018 - Vision 2020: Sustainable Economic Development and Application of Innovation Management from Regional expansion to Global Growth* (pp. 5058–5069). International Business Information Management Association, IBIMA. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85063065693&partnerID=40&md5=24f97a9e72fe5f58b9e5076407c6f3dd>.
- Wang, J., Yeh, W.-C., Xiong, N. N., Wang, J., He, X., & Huang, C.-L. (2019). Building an Improved Internet of Things Smart Sensor Network Based on a Three-Phase Methodology. *IEEE Access*, 7, 141728–141737. <https://doi.org/10.1109/ACCESS.2019.2925044>
- Wang, L., Ali, Y., Nazir, S., & Niazi, M. (2020). ISA Evaluation Framework for Security of Internet of Health Things System Using AHP-TOPSIS Methods. *IEEE Access*, 8, 152316–152332. <https://doi.org/10.1109/ACCESS.2020.3017221>
- Wankhede, V. A., & Vinodh, S. (2021). Design Strategies Enabling Industry 4.0. *Smart Innovation, Systems and Technologies*, 222, 793–803. https://doi.org/10.1007/978-981-16-0119-4_64
- Wasim, M. U., Ibrahim, A. A. Z. A., Bouvry, P., & Limba, T. (2017). Self-Regulated Multi-criteria Decision Analysis: An Autonomous Brokerage-Based Approach for Service Provider Ranking in the Cloud. *Proceedings of the International Conference on Cloud Computing Technology and Science, CloudCom, 2017-December*, 33–40. <https://doi.org/10.1109/CloudCom.2017.44>.
- Watrobski, J., Jankowski, J., Ziemia, P., Karczmarczyk, A., & Ziolo, M. (2019). Generalised framework for multi-criteria method selection. *Omega*, 86, 107–124.
- Xavier, A. F., Naveiro, R. M., Aoussat, A., & Reyes, T. (2017). Systematic literature review of eco-innovation models: Opportunities and recommendations for future research. *Journal of Cleaner Production*, 149, 1278–1302. <https://doi.org/10.1016/j.jclepro.2017.02.145>
- Xu, X., Chen, Y., Qi, L., He, J., & Zhang, X. (2019). A Balanced Cloudlet Management Method for Wireless Metropolitan Area Networks. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICTS*, 270, 62–75. https://doi.org/10.1007/978-3-030-12971-2_4
- Xu, X., Liu, X., Xu, Z., Dai, F., Zhang, X., & Qi, L. (2020). Trust-Oriented IoT Service Placement for Smart Cities in Edge Computing. *IEEE Internet of Things Journal*, 7(5), 4084–4091. <https://doi.org/10.1109/JIOT.2019.2959124>
- Xu, Z., & Xia, M. (2011). Induced generalized intuitionistic fuzzy operators. *Knowledge-Based Systems*, 24(2), 197–209. <https://doi.org/10.1016/j.knsys.2010.04.010>
- Yadav, N., & Goraya, M. S. (2018). Two-way Ranking Based Service Mapping in Cloud Environment. *Future Generation Computer Systems*, 81, 53–66. <https://doi.org/10.1016/j.future.2017.11.027>
- Yadav, S., Garg, D., & Luthra, S. (2020). Selection of third-party logistics services for internet of things-based agriculture supply chain management. *International Journal of Logistics Systems and Management*, 35(2), 204–230. <https://doi.org/10.1504/IJLSM.2020.104780>
- Yalcin, A. S., Kilic, H. S., & Delen, D. (2022). The use of multi-criteria decision-making methods in business analytics: A comprehensive literature review. *Technological Forecasting and Social Change*, 174, Article 121193. <https://doi.org/10.1016/j.techfore.2021.121193>
- Yang, C. H. (2018). Development of intelligent building management system evaluation and selection for smart factory: An integrated MCDM approach. *IEEE International Conference on Industrial Engineering and Engineering Management, 2017-December*, 1505–1509. <https://doi.org/10.1109/IEEM.2017.8290144>.
- Yang, C.-H., Lee, K.-C., & Li, S.-E. (2020). A mixed activity-based costing and resource constraint optimal decision model for IoT-oriented intelligent building management system portfolios. *Sustainable Cities and Society*, 60. <https://doi.org/10.1016/j.scs.2020.102142>
- Yang, C.-L., Huang, C.-Y., Kao, Y.-S., & Tasi, Y.-L. (2017). Disaster recovery site evaluations and selections for information systems of academic Big Data. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(8), 4553–4589. <https://doi.org/10.12973/eurasia.2017.00951a>
- Yang, M.-H., Su, C.-H., & Wang, W.-C. (2018a). Use of hybrid MCDM model in evaluation for cloud service application improvement. *Eurasip Journal on Wireless Communications and Networking*, 2018(1). <https://doi.org/10.1186/s13638-018-1110-9>
- Yang, Y., Guo, L., Zhong, Z., & Zhang, M. (2018b). Selection of Technological Innovation for Service-Oriented Enterprises. *Sustainability*, 10(11), 3906. <https://doi.org/10.3390/su10113906>
- Yang, Z., & Wang, Y. (2020). The cloud model based stochastic multi-criteria decision making technology for river health assessment under multiple uncertainties. *Journal of Hydrology*, 581, Article 124437. <https://doi.org/10.1016/j.jhydrol.2019.124437>
- Yasmin, M., Tatoglu, E., Kilic, H. S., Zaim, S., & Delen, D. (2020). Big data analytics capabilities and firm performance: An integrated MCDM approach. *Journal of Business Research*, 114, 1–15. <https://doi.org/10.1016/j.jbusres.2020.03.028>
- Yazdani, M., Alidoosti, A., & Zavadskas, E. K. (2011). Risk Analysis of Critical Infrastructures Using Fuzzy Copras. *Economic Research-Ekonomska Istraživanja*, 24(4), 27–40. <https://doi.org/10.1080/1331677X.2011.11517478>
- Yazir, Y. O., Akbulut, Y., Farahbod, R., Guitouni, A., Neville, S. W., Ganti, S., & Coody, Y. (2012). Autonomous resource consolidation management in clouds using IMPROMPTU extensions. *Proceedings - 2012 IEEE 5th International Conference on Cloud Computing, CLOUD 2012*, 614–621. <https://doi.org/10.1109/CLOUD.2012.105>.
- Yazir, Y. O., Guitouni, A., Neville, S. W., & Farahbod, R. (2018). IMPROMPTU: A reactive and distributed resource consolidation manager for clouds. *International Journal of Information Technology and Decision Making*, 17(5), 1499–1535. <https://doi.org/10.1142/S0219622018500487>
- Yin, L., & Shyr, H.-J. (2019). A dynamic MADM method for the selection of a big data service provider. *International Journal of Information and Management Sciences*, 30(1), 57–71. [https://doi.org/10.6186/IJIMS.201903_30\(1\).0004](https://doi.org/10.6186/IJIMS.201903_30(1).0004)
- Yoon, K. (1987). A Reconciliation Among Discrete Compromise Solutions. *Journal of the Operational Research Society*, 38(3), 277–286. <https://doi.org/10.1057/jors.1987.44>
- Yörükoğlu, M., & Aydın, S. (2020). Smart container evaluation by neutrosophic MCDM method. *Journal of Intelligent and Fuzzy Systems*, 38(1), 723–733. <https://doi.org/10.3233/JIFS-179444>
- Youssef, A. E. (2020). An integrated MCDM approach for cloud service selection based on TOPSIS and BWM. *IEEE Access*, 8, 71851–71865. <https://doi.org/10.1109/ACCESS.2020.2987111>
- Yüksel, H., Basmacı, G., & Genç, S. (2021). Evaluation of the Challenges of Companies in Industry 4.0 Transformation by GRA Method. *Lecture Notes. Mechanical Engineering*, 312–323. https://doi.org/10.1007/978-3-030-62784-3_26
- Zadtootaghaj, P., Mohammadian, A., Mahbanoeei, B., & Ghasemi, R. (2019). Internet of things: A survey for the individuals' e-health applications. *Journal of Information Technology Management*, 11(1), 102–129. <https://doi.org/10.22059/jitm.2019.288695.2398>
- Zagradjanin, N., Pamućar, D., & Jovanovic, K. (2019). Cloud-based multi-robot path planning in complex and crowded environment with multi-criteria decision making

- using full consistency method. *Symmetry*, 11(10). <https://doi.org/10.3390/sym11101241>
- Zaidan, A. A., Zaidan, B. B., Alsalem, M. A., Albahri, O. S., Albahri, A. S., & Qahtan, M. Y. (2020). Multi-agent learning neural network and Bayesian model for real-time IoT skin detectors: A new evaluation and benchmarking methodology. *Neural Computing and Applications*, 32(12), 8315–8366. <https://doi.org/10.1007/s00521-019-04325-3>
- Zardari, N. H., Ahmed, K., Shirazi, S. M., & Yusop, Z. B. (2014). *Weighting Methods and Their Effects on Multi-Criteria Decision Making Model Outcomes in Water Resources Management* (Vol. XI), 166.
- Zavadskas, E. K., Antucheviciene, J., Razavi Hajiagha, S. H., & Hashemi, S. S. (2014). Extension of weighted aggregated sum product assessment with interval-valued intuitionistic fuzzy numbers (WASPAS-IVIF). *Applied Soft Computing*, 24, 1013–1021. <https://doi.org/10.1016/j.asoc.2014.08.031>
- ZenAlden, F., Hassan, S., & Habbal, A. (2018). Based Mode Selection Mechanism for Device-to-device Communication for Internet of Things Devices in Future Wireless Networks. *ISTT 2018 - 2018 IEEE 4th International Symposium on Telecommunication Technologies*. <https://doi.org/10.1109/ISTT.2018.8701722>.
- Zavadskas, E. K., Bausys, R., Kaklauskas, A., & Raslanas, S. (2019). Hedonic shopping rent valuation by one-to-one neuromarketing and neutrosophic PROMETHEE method. *Applied Soft Computing*, 85, 105832.
- Zhang, H., Dong, S., Ling, J., Zhang, L., & Cheang, B. (2020). A modified method for the safety factor parameter: The use of big data to improve petroleum pipeline reliability assessment. *Reliability Engineering and System Safety*, 198. <https://doi.org/10.1016/j.res.2020.106892>
- Zhang, M., Li, S.-S., & Zhao, B.-B. (2021a). A 2-order additive fuzzy measure identification method based on intuitionistic fuzzy sets and its application in credit evaluation. *Journal of Intelligent and Fuzzy Systems*, 40(6), 10589–10601. <https://doi.org/10.3233/JIFS-201368>
- Zhang, W., & Banerji, S. (2017). Challenges of servitization: A systematic literature review. *Industrial Marketing Management*, 65, 217–227. <https://doi.org/10.1016/j.indmarman.2017.06.003>
- Zhang, X., Jiang, J., Qi, L., & Xu, X. (2021b). An Edge Server Placement Method with Cyber-Physical-Social Systems in 5G. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering*, LNICST, 370, 127–139. <https://doi.org/10.1007/978-3-030>
- Zhao, G., Liu, S., Lopez, C., Lu, H., Elgueta, S., Chen, H., & Boshkoska, B. M. (2019). Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions. *Computers in Industry*, 109, 83–99. <https://doi.org/10.1016/j.compind.2019.04.002>
- Zheng, Y.-F., & Xu, J. (2014). Multiple attribute decision making with triangular intuitionistic fuzzy numbers and application to cloud service provider selection. *Proceedings of 2nd International Conference on Information Technology and Electronic Commerce, ICITEC 2014*, 311–315. <https://doi.org/10.1109/ICITEC.2014.7105625>.
- Zhou, F., Wang, X., & Goh, M. (2018). Fuzzy extended VIKOR-based mobile robot selection model for hospital pharmacy. *International Journal of Advanced Robotic Systems*, 15(4). <https://doi.org/10.1177/1729881418787315>
- Zhou, J., Wu, Y., Tao, Y., Gao, J., Zhong, Z., & Xu, C. (2021). Geographic information big data-driven two-stage optimization model for location decision of hydrogen refueling stations: An empirical study in China. *Energy*, 225. <https://doi.org/10.1016/j.energy.2021.120330>
- Zhu, J., Shuai, B., Li, G., Chin, K. S., & Wang, R. (2020). Failure mode and effect analysis using regret theory and PROMETHEE under linguistic neutrosophic context. *Journal of Loss Prevention in the Process Industries*, 64, 104048.
- Zoie, R. C., Alexandru, B., Delia Mihaela, R., & Mihail, D. (2016). A decision making framework for weighting and ranking criteria for Cloud provider selection. In B. M. Petre E. (Ed.), *2016 20th International Conference on System Theory, Control and Computing, ICSTCC 2016 - Joint Conference of SINTES 20, SACCS 16, SIMSIS 20 - Proceedings* (pp. 590–595). Institute of Electrical and Electronics Engineers Inc. <https://doi.org/10.1109/ICSTCC.2016.7790730>.
- Zolfani, S. H., & Derakhti, A. (2020). Synergies of text mining and multiple attribute decision making: A criteria selection and weighting system in a prospective MADM outline. *Symmetry*, 12(5). <https://doi.org/10.3390/SYM12050868>
- Zolfani, S. H., & Sapauskas, J. (2014). New Application of SWARA Method in Prioritizing Sustainability Assessment Indicators of Energy System. *Engineering Economics*, 24(5). <https://doi.org/10.5755/j01.ee.24.5.4526>