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Review Article

A systematic review and meta-Analysis of SWARA and WASPAS methods: Theory and applications with recent fuzzy developments

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ABSTRACT

The Multiple Criteria Decision Making (MCDM) utility determining approaches and fuzzy sets are considered to be new development approaches, which have been recently presented, extended, and used by some scholars in area of decision making. There is a lack of research regarding to systematic literature review and classification of study about these approaches. Therefore; in the present study, the attempt is made to present a systematic review of methodologies and applications with recent fuzzy developments of two new MCDM utility determining approaches including Step-wise Weight Assessment Ratio Analysis (SWARA) and the Weighted Aggregated Sum Product Assessment (WASPAS) and fuzzy extensions which discussed in recent years. Regarding this, some major databases including Web of Science, Scopus and Google Scholar have been nominated and systematic and meta-analysis method which called "PRISMA" has been proposed. In addition, the selected articles were classified based on authors, the year of publication, journals and conferences names, the technique and method used, research objectives, research gap and problem, solution and modeling, and finally results and findings. The results of this study can assist decision-makers in handling information such as stakeholders' preferences, interconnected or contradictory criteria and uncertain environments. In addition, findings of this study help to practitioners and academic for adopting the new MCDM utility techniques such as WASPAS and SWARA in different application areas and presenting insight into literature.

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1. Introduction

In the operations research, mathematical modeling and sophisticated statistical analysis have been used for solving a number of business and organizational problems and improving a decision-making process [1]. Due to the increasing complexity of business environment, companies rely on analysis to make decisions, which were formerly based on managers' intuition [2]. Operations research provides the required tools for government agencies and large companies to make better decisions to reduce risks and to enhance the quality of their performance [3,4]. Challenges associated with the development of technology and global economy complicated the business environment even more. The operations research based on the advanced software tools and sophisticated mathematical models can help to evaluate all the options available to a firm with respect to possible project outcomes and perform the analysis of risks associated with making particular decisions. The results obtained in these analyses present the complete information, based on which managers, decision makers and policy makers can make the required decisions and work out an appropriate policy. As an effective approach, Multiple Criteria Decision Making (MCDM) was widely used to evaluate a finite number of decision alternatives with multiple criteria [5,6]. It was used in various scientific fields, such as business and management [7–9], risk management [10,11], computer science [7,12,13], health and medical [14–16], engineering [17–19]. In solving many real-world problems, it is difficult for decision makers to precisely assess the performance ratings and criteria weights [20]. The MCDM methods can be applied effectively to determining the value and utility degree of various areas and establishing the priority order for their implementation [21]. Using these methods, the problem of evaluating a discrete set of alternatives can be examined based on a set of decision criteria [22]. Different criteria represent various dimensions of the alternatives; as a result, they might be conflicting with each other. For example, in the construction processes, complex decisions, involving a number of conflicting and interactive criteria are analyzed. As a result, the MCDM theory was provided with the elements of mathematical statistics and MCDM methodology, considering statistical relations between the developed criteria. In this regard, some scholars in recent years have attempted to develop, extend and present the new MCDM methods and techniques, as well as utility determining approaches [1,23–29]. To reach the efficient decisions in various areas such as economic, management, computer science, mathematical modelling, and mathematical conventional (hard) or soft computing can be used successfully. Generally in the real world problems are difficult and complex and achieving the optimal decision is impossible though the single criterion [1].

Due to the nature of problems related to MCDM approaches, there are various approaches are available for solution thereof. Simple Additive Weighing (SAW) method as the first multi-criteria evaluation method was introduced by MacCrimmon [30]. In addition, MacCrimmon [30] explained the two step of weighing including; criteria normalizing values and voting in an management team for importance coefficients of a criterion. Some other partial aggregation approaches such as ELimination and Choice Expressing REality (ELECTRE) and Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) have respectively suggested by Roy [31] and Brans and Mareschal [32]. Keeney and Raiffa [33], improved and extended the MCDM approaches by using multiple attribute utility function. Zavadskas, Kaklauskas and Sarka [23], suggested the approach of Complex Proportional Assessment (COPRAS). Some other approaches based on pair-wise comparisons are Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP) [35,36]. Zavadskas, Turskis, Antucheviciene and Zakarevicius [37], suggested the new MCDM utility determining approach which called the Weighted Aggregated Sum–Product Assessment (WASPAS). Hwang and Yoon [38], was proposed the Technique for the Order Preference by Similarity to Ideal Solution (TOPSIS). Opricovic and Tzeng [39], is introduced the VlseKriterijumska Optimizacija I Kompromisno Resenje, means multi-criteria optimization and compromise solution (VIKOR) approach based on linear normalization. In addition; Brauers and Zavadskas [40] was suggested the Multi-objective Optimization by Ratio Analysis (MOORA) approach. Moreover; later, this approach was extended by Brauers and Zavadskas [41] as called MULTIMOORA (MOORA plus the full multiplicative form). These two approaches including the pair-wise alternatives comparisons. Furthermore; multi-objective optimization on the basis of simple ratio analysis approach suggested by Das, Sarkar and Ray [42]. Additive Ratio Assessment (ARAS) method is proposed by Zavadskas and Turskis [43]. Zavadskas, Turskis and Bagočius [44], used fuzzy ARAS method to measure of deep-water port alternatives. In recent years, several of previous studies reviewed and classify the application of these approaches in various areas such as; MCDM and E-learning [45], MCDM and service quality [46], MULTIMOORA [47], MCDM and transportation and tourism industries [48,49], MCDM, sustainable and renewable energy [50–53], ELECTRE [54], MCDM and supply chain [55], VIKOR [56], [57], MCDM techniques [58], Fuzzy Multiple Criteria Decision Making (FMCDM) [59]; TOPSIS [60] and [61], soft computing technology and MCDM [62], [63] and [64], MCDA analysis [65].

Various approaches have been suggested regarding the multi attribute utility theory for MCDM. In this regard; two new MCDM approaches which called Step-wise Weight Assessment Ratio Analysis (SWARA) and WASPAS were introduced in 2010 and 2012 by [37] and [66]. However, the conducted surveys did not keep up with the changing situation in this field. Therefore, the researchers believe that there is a need for a systematic review of the most important recent studies conducted in the considered area. In addition, the researchers think that there is a need for a comprehensive paper, combining the available studies and methods. The presented review attempts to systematically describe some previous studies that employed the considered methods and techniques. This paper makes some contributions to this area of research. The current study considered some new perspectives in reviewing the articles, such as classify of the papers based on authors, publication date, journal name, the technique and method, research objectives, research gap and problem solution and modeling and, finally, the results and findings. The structure of this review study is organized as follows. Section 2 reviews the literature regarding the two MCDM utility determining approaches. Section 3 presents research methodology including the systematic review, meta-analysis and the procedure of this study. Section 4 presents the results based on MCDM utility determining techniques and application areas. Finally, Section 5 presents conclusion, limitations, and recommendations for future studies.

2. Literature review

2.1. Classification of MCDM methods with fuzzy theory sets

The MCDM methods cover a wide range of distinct approaches. The MCDM methods can be classified into two categories: the discrete MCDM or discrete Multi-attribute Decision Making (MADM) and continuous Multi-Objective Decision Making (MODM) methods [67–69]. Recently, hundreds of papers have been published to provide the information about MCDM methods, their development and application in different fields. This article provides an overview of the publications describing MCDM methods. The study was performed on the Web of Science, Scopus and Google Scholar databases. The 1970s present an important period for many seminal works. The fundamentals of modern MCDM methods were developed in 1950s and 1960s. The research and development of MCDM methods increased during the 80 s and early 90s, but it seems that the exponential growth of this process continued [70]. The book by Köksalan, Wallenius and Zionts [70] provides a brief history of the development of MCDM methods. It briefly describes the development of this area from the ancient to modern times. Hwang, Masud, Paidy and Yoon [71], provided a review of the development and applications of MODM methods in a relatively short period of time. Keeney, Raiffa and Rajala [72], formulated the basics of decision with multiple objectives. Later, Tzeng and Huang [73] reviewed the MADM methods SAW, TOPSIS, ELECTRE, and The Linear Programming Technique for Multidimensional Analysis of Preference (LINMAP). Mardani, Jusoh, Md Nor, Khalifah, Zakwan and Valipour [74] and Mardani et al. [75,76] grouped MCDM and FMCDM tools in a different way.

The related studies are performed on the previously developed well-known methods, such as SAW [30], AHP [77,78], ANP [79], Decision-Making Trial and Evaluation Laboratory (DEMATEL) [80], PROMETHEE [81], ELECTRE [82–85], TOPSIS [86], VIKOR [87,88], and their modifications by applying fuzzy and grey number theory. Saaty [89], published a detailed study of the AHP. Later, Saaty [79] published a study of the further development of the ANP method. Zeleny and Cochrane [90], published a book, dealing with the problem of the compromise theory. Data Envelopment Analysis (DEA) [91,92], Roy [93], summarized the information on the ELECTRE group methods. Seminal studies were prepared by Belton and Stewart [94] and Gal, Stewart and Hanne [95], Miettinen [96].

The related literature covers a number of classifications of MCDM tools with fuzzy theory sets. For example, Peneva and Popchev [97] stated that if the weights were given as real numbers, the operators, such as Ordered Weighted Maximum (OWMAX) and Minimum (OWMIN) [98], weighted arithmetic means [99], and the ordered weighted geometric operator Chiclana, Herrera and Herrera-Viedma [100] could be applied to the aggregation of fuzzy relations. In the mathematical models, there are operators, whose weights do not adequately represent them: Min, Max, MaxMin, Gamma, and Generalized Mean [101]. The idea of using the given weights in this case is offered in [102]. Inuiguchi, Ichihashi and Tanaka [103], performed a study of recent developments in fuzzy programming. In their work, they employed such applications as flexible programming, possibilistic programming, possibilistic linear programming with fuzzy goals, possibilistic programming with fuzzy preference relations, possibilistic linear programming using fuzzy max, and robust programming. The two other categories proposed by Hwang, Chen and Hwang [104] included the ways to find a ranking based on the degree of optimality, linguistic ranking methods and the comparison function, as well as Hamming distance, proportion to the ideal, fuzzy mean and spread, centroid index, left and right scores, and area measurement. The second category contains the methods, employing different ways of evaluating the relative significance of multi-attributes, including analytic hierarchy process, fuzzy simple additive weighting methods, fuzzy outranking methods, fuzzy conjunctive/disjunctive methods, and maximin methods.

Based on the relationship among the aggregated arguments, the aggregation operators can be roughly divided into two classes: the operators that consider the dependence of aggregated arguments and those that consider these arguments independently. In the case of the first class, Yager [105] introduced the Ordered Weighted Averaging (OWA) operator for reordering the arguments prior to their aggregation. This operator motivated Chiclana, Herrera and Herrera-Viedma [100] and Xu and Da [106] to propose the ordered weighted geometric (OWG) operator. Yager [107], used the continuous interval-valued arguments to develop the Continuous Ordered Weighted Averaging (COWA) operator. Torra [108] and Torra and Narukawa [109] developed the Hesitant Fuzzy Sets (HFSs) concept to present the hesitant fuzzy information, which covers the arguments with a set of possible values. It is considered to be a new efficient tool for collecting and representing the arguments under uncertainty, particularly, in the decision making process. Zhu, Xu and Xia [110], investigated the geometric BMs combined with hesitant fuzzy information and introduced the hesitant fuzzy geometric Bonferroni means (HFGBM). Yu, Wu and Zhou [111], developed the generalized hesitant fuzzy Bonferroni means (GHFBM), with its application in the multi-criteria group decision making (MCGDM).

The aggregation techniques have a great influence on the MCDM problems, and the aggregation operators were widely applied to MCDM. In a fuzzy environment, Chen and Tan [112] developed several functions for measuring the extent, to which each alternative is suitable with respect to a set of the criteria used in MCDM. Hong and Choi [113], used the maximum and minimum operations for developing some approximate techniques to address the MCDM problems. Moreover, the aggregation operators extended to the intuitionistic fuzzy environment (IFSs) [114] which play a significant role for basic elements that reflect preference values or judgements of decision makers. Li [115], designed several linear programming models and introduced the respective decision making methods by means of IFSs. Liu and Wang [116], proposed a series of score functions to be applied to solving MCDM problems in accordance with the evaluation functions and the intuitionistic fuzzy point operators. Based on the interval-valued IFSs, Chen, Wang and Lu [117] offered a method of MCGDM. Furthermore, in the decision making process, hesitancy and uncertainty are generally considered as unavoidable problems. To express the evaluation information of decision makers more objectively, several improved tools, including a fuzzy set [118], type-2 fuzzy set [119], an intuitionistic fuzzy set [114] and a fuzzy multi-set [120,121], as well as a linguistic fuzzy set [122,123], were offered in the literature.

2.2. MCDM utility determining methods

MCDM theory was provided with the elements of mathematical statistics and MCDM methodology, considering statistical relations between the developed criteria. In this regard, some scholars in recent years have attempted to develop, extend and present new utility determining approaches, for example; Brauers [124] published a research based on the MOORA and MULTIMOORA methods. MOORA method was introduced by Brauers and Zavadskas [125] on the basis of earlier investigations. Kaklauskas, Zavadskas, Raslanas, Ginevicius, Komka and Malinauskas [126], used COPRAS approach for low-e windows selection in retrofit of public buildings. Kaklauskas, Zavadskas, Banaitis and Šatkauskas [127], used COPRAS for utility and market value of a real estate. The relatively recently developed MCDM methods, such as COPRAS [23,34,129], ARAS [129–131], MOORA [132], MULTIMOORA [41], SWARA [66] and WASPAS [133] are being rapidly developed and applied to solve real life problems [128]. Zavadskas and Turskis [28], proposed the ARAS method which can be described as a recently-formed, but easy-to-use and effective MCDM method. This method was applied to solve different decision-making problems. The fuzzy and grey extension of this method referred to as ARAS-Fuzzy (ARAS-F) (Turskis and Zavadskas [134]) and ARAS-Gray (ARAS-G) (Turskis and Zavadskas [130]), were developed. Some other studies in these areas are including [135,136], and [137]. Brauers and Zavadskas [41] extended the MOORA method and made it more robust under the name of MULTIMOORA. Yazdani, Alidoosti and Zavadskas [138], adopted the fuzzy COPRAS for risk analysis and management for critical asset protection. Podvezko [139], compared the features of SAW and COPRAS approaches based on different characteristics, definition, and properties demonstrating. In addition Chatterjee, Athawale and Chakraborty [140] used COPRAS approach and valuation of mixed data (EVAMIX) for material selection. Das, Sarkar and Ray [141], combined the FAHP and COPRAS approach for evaluating of performance in Indian technical institutions. In the area of construction management, Bitarafan, Hashemkhani Zolfani, Arefi and Zavadskas [142] integrated AHP and COPRAS-G for assessing of cold-formed steel structures. Maity, Chatterjee and Chakraborty [143], used the COPRAS-G for selection of cutting tool material. Chatterjee and Chakraborty [144], combined the COPRAS approach and PROMETHEE II for material selection. Fouladgar, Yazdani-Chamzini, Lashgari, Zavadskas and Turskis [145], integrated the FAHP and fuzzy COPRAS for selection of maintenance strategy. Barysienė [146], applied COPRAS-G approach for evaluating of the container terminal technologies. In the field of quality control, Hashemkhani Zolfani et al. [147] used AHP and COPRAS-G for selection of quality control. Baležentis and Zeng [148], extended the MULTIMOORA approach with type-2 fuzzy sets for personnel selection. Tavana, Momeni, Rezaeiniya, Mirhedayatian and Rezaeiniya [149], integrated the FANP approach with COPRAS-G for selection of social media platform. Bairagi, Dey, Sarkar and Sanyal [150], applied the FAHP, fuzzy COPRAS-G, fuzzy VIKOR and fuzzy TOPSIS for robot selection in the automated foundry. Nguyen, Dawal, Nukman and Aoyama [151], integrated the FANP and COPRAS-G approaches for selection of machine tool. Rabbani, Zamani, Yazdani-Chamzini and Zavadskas [152], used balanced scorecard (BSC) approach for evaluating of sustainability performance by applied ANP and COPRAS approaches. Adhikary, Bose, Bose and Mitra [153] and Pancholi and Bhatt [154] used COPRAS-G for Failure Mode Effect and Criticality Analysis (FMECA). In case of supplier selection, Keshavarz Ghorabaee, Amiri, Salehi Sadaghiani and Hassani Goodarzi [155] integrated COPRAS approach with interval type-2 fuzzy sets. In field of sustainability, Nuuter, Lill and Tupenaite [156] used COPRAS approach to compare the housing market sustainability in different European countries. Nguyen, Dawal, Nukman, Aoyama and Case [157], used the fuzzy linguistic preference based AHP and fuzzy COPRAS for evaluating of machine tool. Varmazyar, Dehghanbaghi and Afkhami [158], integrated four different MCDM approaches including COPRAS, ARAS, DEMATEL and TOPSIS for assessing the research centers of Research and Technology Organization (RTO). Liou, Tamošaitienė, Zavadskas and Tzeng [159], integrated the ANP and COPRAS-G for enhancing and choosing the green supplier in supply chain management system. As a result; in recent years, the development of hybrid and modular methods has been growing dramatically. Fig. 1 shows the new MCDM utility determining approaches. The present review paper attempts to systematically describe the two MCDM utility techniques including WASPAS and SWARA in following sections.

Table 1
Frequently of two new MCDM utility approaches.

Approach	Number	Percentage
WASPAS	26	47%
SWARA	23	42%
Integrating of SWARA and WASPAS	6	11%
Total	55	100%

2.3. Distribution based on the MCDM utility determining techniques

In recent years, research on the MCDM utility determining approaches has been continued, and many applications of these approaches have been found in several fields. MCDM provides effective decision making approaches for the domains, where the selection of the best alternative is highly complicated. The current study provides a details review of the main trends of considering the MCDM theory and practice. The main purpose of the review is to introduce two new MCDM utility determining approaches used in previous studies and to suggest approaches, which could be most effectively applied to identifying the best alternative. MCDM utility determining approaches were used in many areas (see Table 2). MCDM methods help to choose the best alternatives based on multiple criteria. The best alternative can be determined by analyzing the scopes and weights of the criteria and selecting the optimum ones by using any MCDM technique. The current review closely shows the process of enhancing WASPAS and SWARA and their applications in various fields from different perspectives. In total, 55 papers were classified according to two MCDM utility determining approaches including; SWARA, WASPAS and integrating of two approaches (see Table 1). Following sections discusses about literature and developments of these two techniques.

2.3.1. Weighted aggregated sum product assessment (WASPAS)

WASPAS the first time was suggested in 2012 and it is one of the robust new MCDM utility determining approaches. This approach is an integration of Weighted Product Model (WPM) and Weighted Sum Model (WSM). Zavadskas, Turskis, Antucheviciene and Zakarevicius [37], proposed WASPAS approach and argued that; the accuracy of this approach is strength than WPM and WSM. Zavadskas, Turskis, Antucheviciene and Zakarevicius [37], proposed this new method and proved that this aggregated

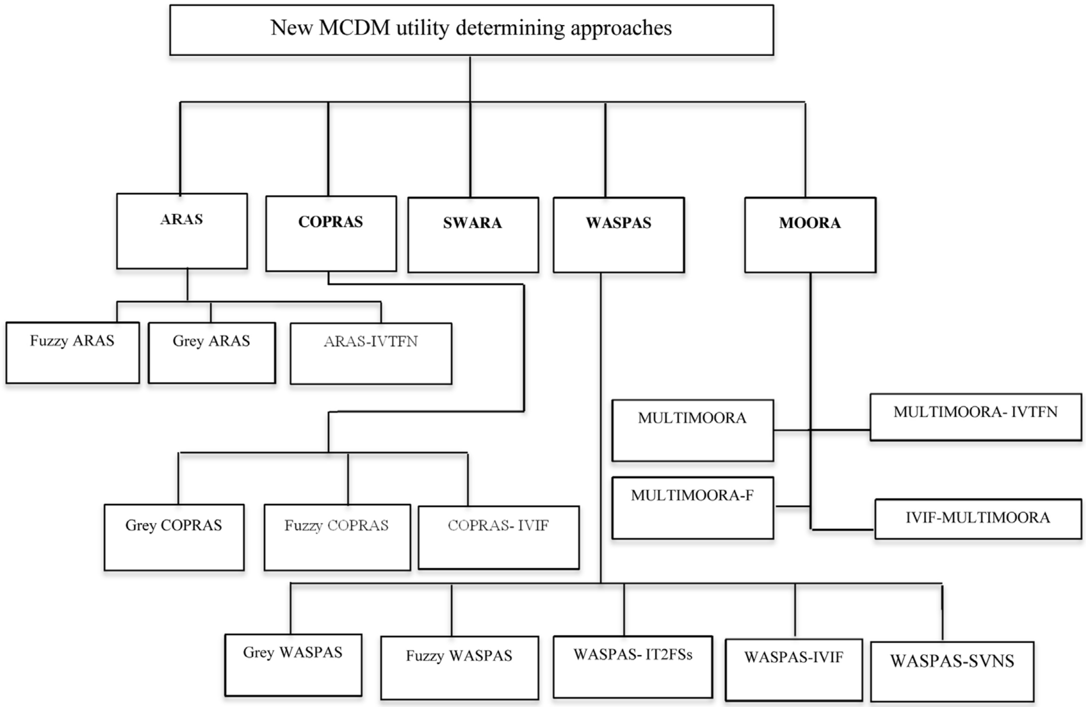


Fig. 1. New MCDM utility determining approaches.

method performs more accurately than other approaches. Recently, a number of studies conducted by using WASPAS method which is presented in the following scholars: Bagočius, Zavadskas and Turskis [160] used WASPAS to select a deep-water port; Staniūnas, Medineckienė, Zavadskas and Kalibatas [161] employed WASPAS for ecological-economic assessment of multi-dwelling house modernization; Zavadskas, Antucheviciene, Šaparauskas and Turskis [162] used WASPAS to evaluate the facade alternatives; Zavadskas, Antucheviciene, Saparauskas and Turskis [163] applied WASPAS for verification of robustness of methods to assess the alternative solutions; Bitarafan, Hashemkhani Zolfani, Arefi, Zavadskas and Mahmoudzadeh [164] used WASPAS to evaluate of real-time intelligent sensors for structural health monitoring of bridges; Dėjus and Antuchevičienė [165] used it to assess health and safety solutions on the construction site; and Hashemkhani Zolfani, Aghdaie, Derakhti, Zavadskas and Morshed Varzandeh [166] applied WASPAS to decision making with respect to business issues in the foresight perspective. The methodology of WASPAS technique is presented in Fig. 2.

This method has been applied in many decision-making problems and environments. Šiožinytė and Antuchevičienė [167], developed an MCDM approach to handle the problem of daylighting and tradition continuity in a reconstructed vernacular building using the AHP, COPRAS, TOPSIS and WASPAS methods. Hashemkhani Zolfani, Aghdaie, Derakhti, Zavadskas and Varzandeh [168], developed a multi-criteria decision making approach to solve a shopping mall locating problem using the SWARA and WASPAS methods Bagočius, Zavadskas and Turskis [169], proposed an MCDM approach based on the WASPAS method for selection and ranking of the feasible location areas of wind farms and assessing the types of wind turbines in the Baltic sea offshore area. Bitarafan, Hashemkhani Zolfani, Arefi, Zavadskas and Mahmoudzadeh [164], developed a multi-criteria decision-making approach to evaluate real-time intelligent sensors for structural health monitoring of bridges based on the SWARA and WASPAS methods. Zavadskas, Antucheviciene, Razavi Hajiagha and Hashemi [1], proposed an extended WASPAS method with interval-valued intuitionistic fuzzy numbers and compared the result of it with some existing methods. Chakraborty and Zavadskas [170] applied the WASPAS method for solving some multi-criteria manufacturing problems such as selection of cutting fluid, electroplating system, forging condition, arc welding process, etc. Lashgari, Antuchevičienė, Delavari and Kheirkhah [171] developed an MCDM approach based on the Quantitative Strategic Planning Matrix (QSPM) and WASPAS method to determine outsourcing strategies. Vafaeipour, Hashemkhani Zolfani, Varzandeh, Derakhti and Eshkalag [172], applied the SWARA and WASPAS methods to evaluate the solar projects based on regions' priority. Džiugaitė-Tumėnienė and Lapinskienė [173], utilized the WASPAS method for multi-criteria assessment of an energy supply system of a low energy house. Bozorg-Haddad, Azarnivand, Hosseini-Moghari and Loáiciga [174], developed and compare multiple criteria techniques to rank Pareto solutions regarding the problems of multiobjective reservoir operation introduced the WASPAS and COPRAS.

2.3.2. WASPAS method with fuzzy theory sets

This subsection introduced the WASPAS method with fuzzy theory set which called WASPAS-F (Turskis et al. [194]). In this method used the fuzzy approach to allocate the relative important of attributes by employing fuzzy numbers instead of precise numbers. In recent years this method integrated with other MCDM approaches such as fuzzy AHP for solving MCDM problems in the fuzzy environment in order to deal with uncertain information. The methodology of WASPAS-F provided in Fig. 3.

2.3.3. WASPAS method and interval type-2 fuzzy sets

Keshavarz Ghorabaee, Zavadskas, Amiri and Esmaeili [175], suggested the new integrated approach based on interval type-2 fuzzy sets and WASPAS method which can be applicable in solving problems related to MCDM techniques. In addition, using the proposed method can help decision makers for evaluation of alternatives in the high accuracy way. For developed WASPAS method based on interval type-2 fuzzy sets, some modifications were performed for the weighted product model and normalization. In addition, in

Development of a decision/evaluation matrix, $X = \left[x_{ij}\right]$ m × n where x_{ij} is the performance of i^{th} alternative with respect to j^{th} criterion, m is the number of alternatives and n is the number of criteria

⇩

Decision matrix is normalized using the following two equations:

$$\bar{x}_{ij} = \frac{x_{ij}}{\max_i x_{ij}} \text{ for beneficial criteria and } \bar{x}_{ij} = \frac{\min_i x_{ij}}{x_{ij}} \text{ for non-beneficial criteria}$$

⇩

The total relative importance of i^{th} alternative is calculated as follows:

$$\mathrm{WSM} = Q_i^{(1)} = \sum_{j=1}^{n} \bar{x}_{ij}\, \mathrm{w_j}$$

Where w_j is weight (relative importance) of j^{th} criterion.

⇩

The total relative importance of i^{th} alternative is evaluated using the following equation:

$$\mathrm{WPM} = Q_i^{(2)} = \prod_{j=1}^{n} (\bar{x}_{ij})^{w_j}$$

⇩

A joint generalized criterion of weighted aggregation of additive and multiplicative methods is as follows:

$$Q_i = 0.5\, Q_i^{(1)} + 0.5\, Q_i^{(2)} = 0.5 \sum_{j=1}^{n} \bar{x}_{ij} w_j + 0.5 \prod_{j=1}^{n} (\bar{x}_{ij})^{w_j}$$

⇩

More generalized equation for determining the total relative importance of i^{th} alternative is as follows:

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)} = \lambda \sum_{j=1}^{n} \bar{x}_{ij} w_j + (1-\lambda) \prod_{j=1}^{n} (\bar{x}_{ij})^{w_j}, \qquad \lambda = 0, 0.1, \ldots, 1$$

⇩

The optimal values of λ can be determined while searching for the following extreme function:

$$\lambda = \frac{\sigma^2\left(Q_i^{(2)}\right)}{\sigma^2\left(Q_i^{(1)}\right) + \sigma^2\left(Q_i^{(2)}\right)}$$

⇩

The variances $\sigma^2\left(Q_i^{(1)}\right)$ and $\sigma^2\left(Q_i^{(2)}\right)$ can be computed applying the equations as given below:

$$\sigma^2\left(Q_i^{(1)}\right) = \sum_{j=1}^{n} w_j^2\, \sigma^2(\bar{x}_{ij})$$

$$\sigma^2\left(Q_i^{(2)}\right) = \sum_{j=1}^{n} \left(\frac{\prod_{j=1}^{n} (\bar{x}_{ij})^{w^j} w_j}{(\bar{x}_{ij})^{w_j} (\bar{x}_{ij})^{(1-w_j)}}\right)^2 \sigma^2(\bar{x}_{ij})$$

⇩

The estimates of variances of the normalized initial criteria values are calculated as follows:

$$\sigma^2(\bar{x}_{ij}) = (0.05\, \bar{x}_{ij})^2$$

Fig. 2. Methodology of WASPAS technique.

this integration, the new analysis developed to achieve the weights of criteria by integrating subjective weights from decision makers with objective weights resulted from entropy approach in the procedure of the new developed method. Moreover, this combination can leads to realistic weights of criteria for decision making and increases stability in various criteria weights. Fig. 4 represented the methodology of WASPAS method based on interval type-2 fuzzy sets.

2.3.4. *WASPAS method based on interval-valued intuitionistic fuzzy numbers*

Zavadskas, Antucheviciene, Razavi Hajiagha and Hashemi [1], proposed the new approach based on extended WASPAS method with integrating of interval-valued intuitionistic fuzzy sets. The objective of this integrated approach is to increase the strengths of interval-valued intuitionistic fuzzy sets for handing the uncertainty with the improved of accuracy regarding MCDM methods. WASPAS method extended by Zavadskas, Turskis, Antucheviciene and Zakarevicius [37] and can help to attain the high accuracy

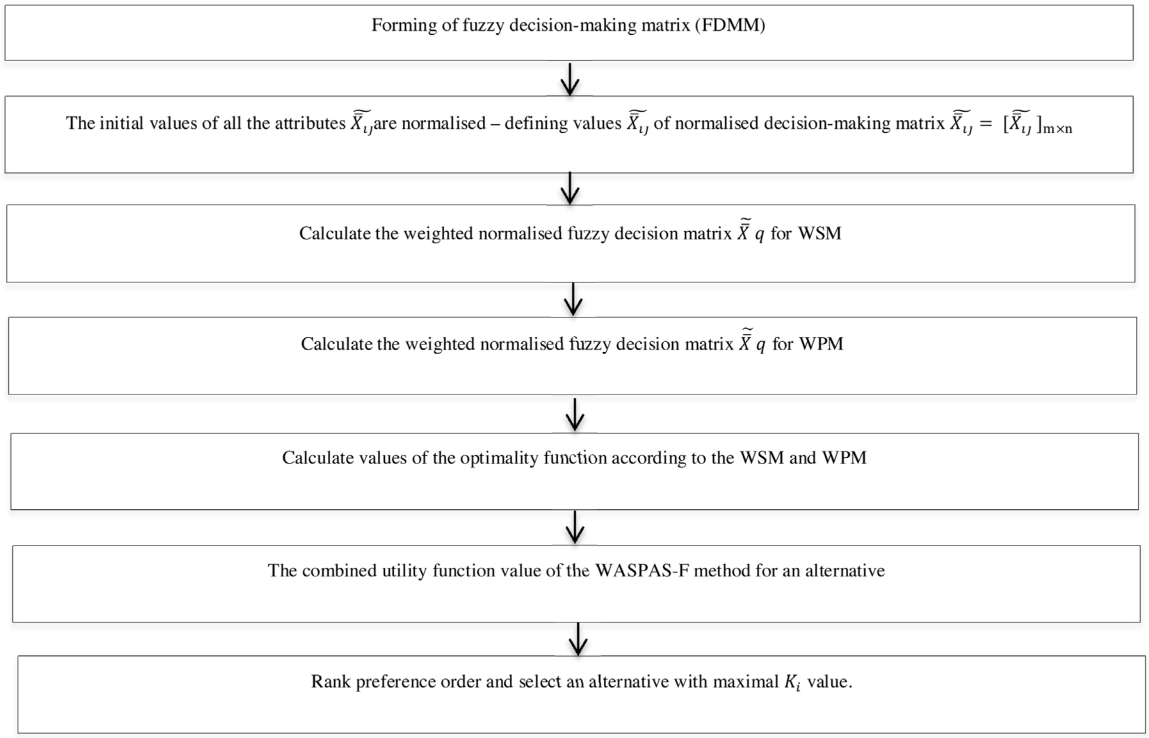


Fig. 3. The methodology of WASPAS with fuzzy theory set method (Turskis et al. [194]).

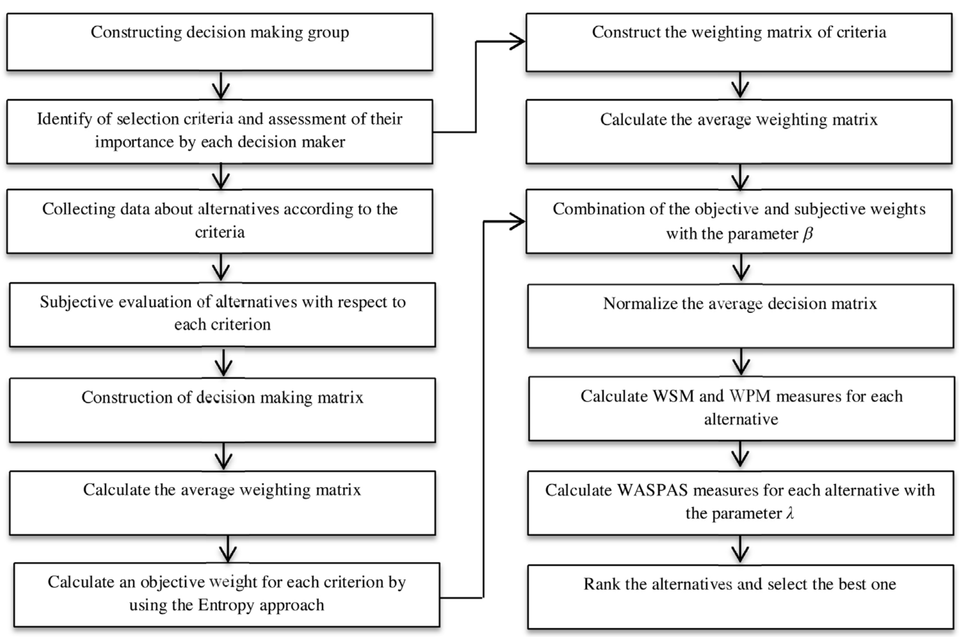


Fig. 4. Methodology of WASPAS method based on interval type-2 fuzzy sets (Keshavarz Ghorabaee, Zavadskas, Amiri and Esmaeili [175]).

of estimation using proposed methodology for optimization of weighted aggregation set. In this proposed method which called WASPAS-IVIF, the interval-valued intuitionistic fuzzy numbers were generalized based on fuzzy sets theory by focus on non-membership degree and to ordinal membership degree of fuzzy sets numbers and providing these both degrees in the interval numbers. Integrating the WASPAS method based on interval-valued intuitionistic fuzzy numbers makes the suggested approach as the effective tool for MCDM methods. The algorithm of extended approach presented in Fig. 5.

2.3.5. *WASPAS method with single-valued neutrosophic set*

Zavadskas, Baušys, Stanujkic and Magdalinovic-Kalinovic [176] and Zavadskas, Baušys and Lazauskas [177] proposed the new method based on WASPAS and single-valued neutrosophic set for assessment of the construction of a waste incineration plant and selection of lead-zinc flotation circuit design. This method is developed by using the framework of single-valued neutrosophic set for present the means to show and approach the vagueness of the initial information explicitly. This method integrated WASPAS with single-valued neutrosophic set for solving problems related

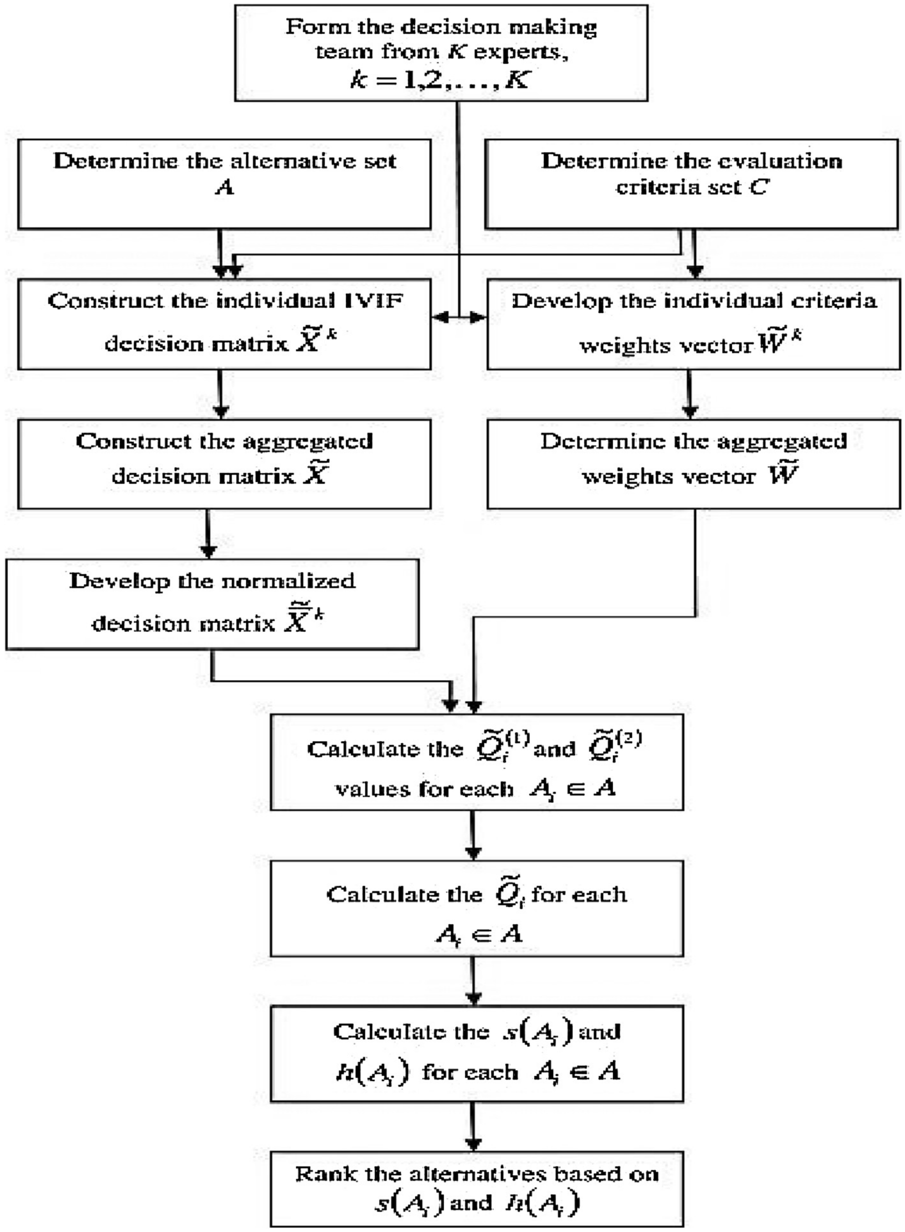


Fig. 5. Algorithm of proposed WASPAS method with interval-valued intuitionistic fuzzy sets (Zavadskas, Antucheviciene, Razavi Hajiagha and Hashemi [1]).

to MCDM approaches. Methodology of the proposed method by (Zavadskas, Baušys, Stanujkic and Magdalinovic-Kalinovic [176] and Kazimieras Zavadskas, Baušys and Lazauskas [177]) is presented in Fig. 6 .

2.3.6. WASPAS method with grey number

Grey theory can be successfully integrated with many of the decision-making processes to improve the quality of judgments. It is suitable for expressing quantitative but imprecise data. Also ambiguity in dealing with imprecise data can be reduced through linguistic assessment of attributes. The linguistic assessments can also be converted into associated grey values. The grey system theory is identified as an effective methodology that can be used to solve uncertain problems with partially known information. In the grey system theory, all information can be classified into three categories that are labelled with corresponding colours – white, grey and black. There are several types of grey numbers such as: grey numbers with only upper limits, grey numbers with only lower limits, black and white numbers. Previous papers proposed a grey system theory to study uncertain systems, and also introduced the concept of interval grey numbers. This theory provides an efficient approach for solving problems with significant uncertainty, and therefore has been successfully applied in many fields for the purpose of analysis, modeling and forecasting. On the basis of the grey system theory, many classical MCDM methods are adapted for the use of interval grey numbers, and extended for solving a number of problems. Some previous papers extended the grey theory with different MCDM approaches such as grey TOPSIS, COPRAS-G, ARAS-G, SAW-G, the grey extension of the LINMAP method, the grey extension of the MOORA method, Grey AHP and grey compromise programming. Zavadskas, Turskis and Antucheviciene [29] proposed the new version of WASPAS with the grey attributes scores. The advantages of the proposed technique are based on its capabilities of handling imprecise information due to applied grey relations and capabilities of providing decisions of enhanced accu-

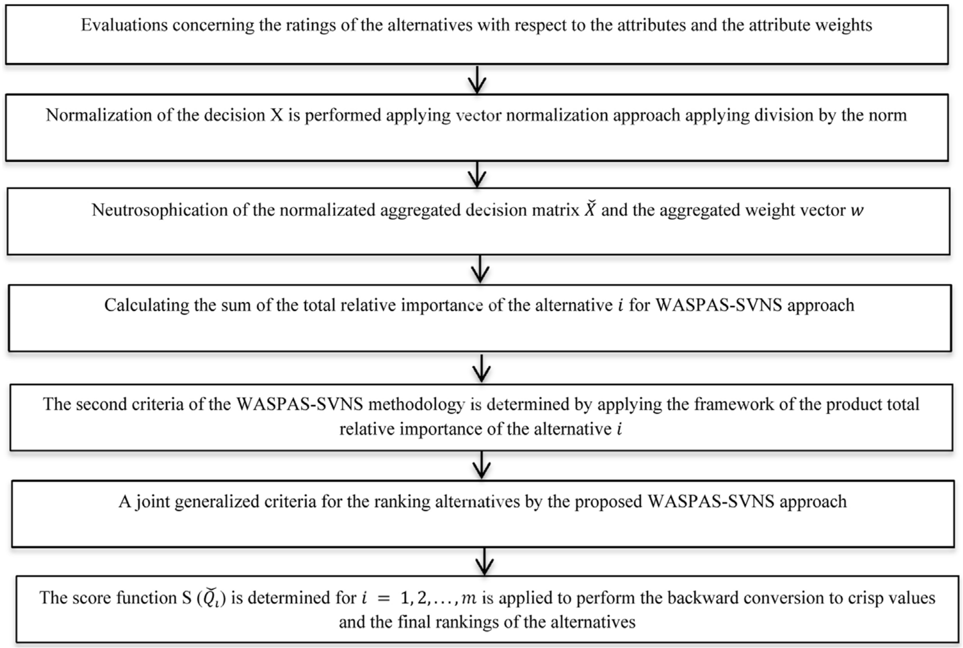


Fig. 6. Methodology of the proposed method by integrating WASPAS and single-valued neutrosophic set.

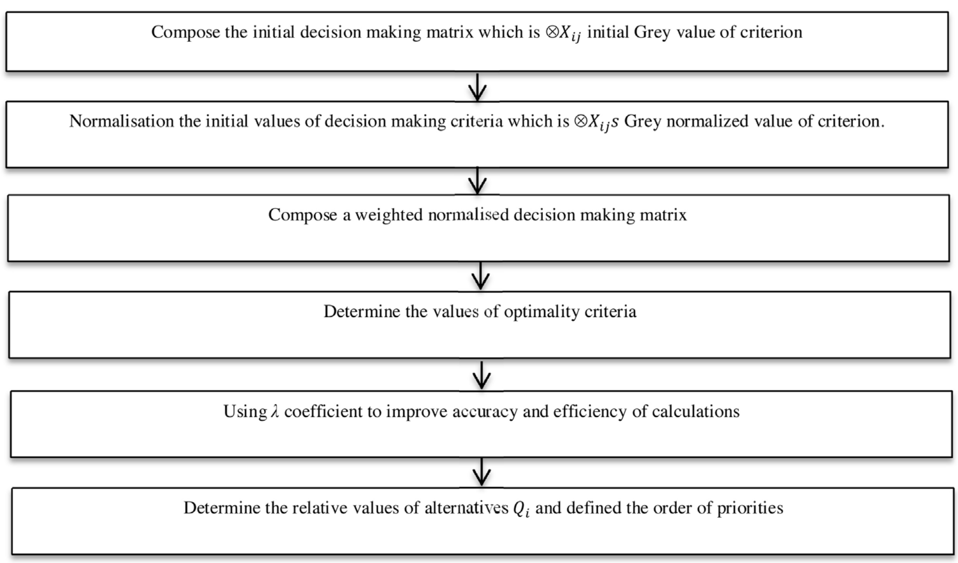


Fig. 7. Methodology of WASPAS method with Grey theory [29].

racy when optimizing weighted aggregated assessment. The steps of WASPAS-G methodology are presented in Fig. 7.

2.3.7. *Stepwise weight assessment ratio analysis (SWARA)*

There are several kinds of MADM methods for criteria weight calculation in the literature. In addition, in some methods, the calculations is very complicated, and the accuracy of the methods is not very high [178]. SWARA is a method where experts apply their own implicit knowledge, experiences, and information. In addition, it is not considered to be complicated and time consuming [179]. The main feature of the SWARA method is associated with its possibility of estimating the experts' or interest groups' opinions about the significance of the attributes in the process of weight determination [66]. The first criterion in ranking is considered to be most significant, while the last criterion is least significant [180]. The final ranks are determined by a group of experts based on their average value [181]. All previous and recent studies, SWARA methodology was used for a particular purpose, are as follows: Keršulienė and Turskis [181] used SWARA for architect selection; Keršuliene, Zavadskas and Turskis [66] employed SWARA in rational dispute resolution method selection; Hashemkhani Zolfani et al. [182] applied SWARA to select the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants; Hashemkhani Zolfani et al. [183] used SWARA in the investigation of success factors of online games based on explorer; Hashemkhani Zolfani, Zavadskas and Turskis [184] used SWARA in sustainable development of building structures in rural areas based on the local climate; Hashemkhani Zolfani, Aghdaie, Derakhti, Zavadskas and Morshed Varzandeh [166] employed SWARA in decision making on business issues with foresight perspective; Zolfani, Zavadskas and Turskis [184] used SWARA in design of products; Hashemkhani Zolfani and Saparauskas [179] used SWARA for prioritizing sustainability

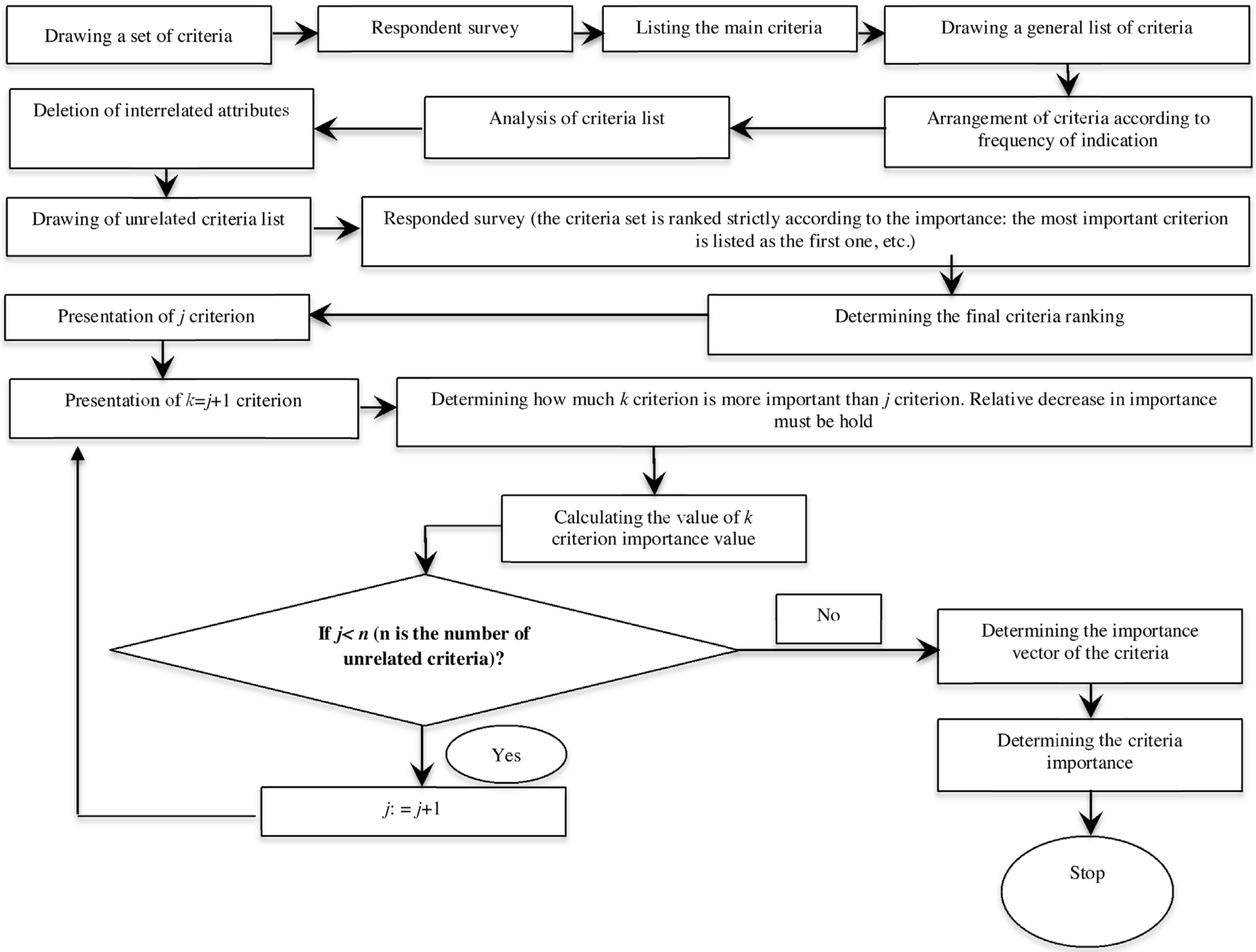


Fig. 8. SWARA methodology [37].

assessment indicators of energy system; Aghdaie, Hashemkhani Zolfani and Zavadskas [185] utilized SWARA in market segmentation and selection; Hasan Aghdaie, Hashemkhani Zolfani and Zavadskas [186] applied SWARA in the machine tool selection; Alimardani, Hashemkhani Zolfani, Aghdaie and Tamošaitienė [180] used SWARA in agile supplier selection, and Hashemkhani Zolfani and Bahrami [187] employed SWARA in the investment prioritizing in high tech industries. The methodology of SWARA technique is presented in Fig. 8.

3. Research methodology

For our research methodology, this review paper proposed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) provided by Moher, Liberati, Tetzlaff and Altman [188]. PRISMA statement has two main parts including meta-analysis and systematic reviews. Systematic reviews provide objective summaries of what has been written and found out about research topics. This is especially valuable in wide research areas, where many publications exist, each focusing on a narrow aspect of the field [189]. Systematic reviews aim to provide a full overview of research conducted on a specific field until the present date. All research procedures have to be made explicit before the actual conduct of the review to make the process objective and replicable. Meta-analysis presents a means of mathematically integrating findings employing diverse statistical approach from diverse of previous articles. In this kind of synthesis, primary studies that are compatible in their quality level are selected. This may help and highlight different facts which individual primary studies fail to do, e.g. it may prove that results are statistically considerable and important when small primary studies provide questionable and uncertain results with large confidence interval [190]. The main goal of PRISMA statement is to help researchers and practitioners for completing the report of clear literature review [191]. Several of previous studies have been conducted PRISMA statement in various fields to collecting a comprehensive literature review [191–193]. In our review study, for conducting of PRISMA method, we accomplished three main steps including; search in literature, choosing the eligible published papers, extraction of data and summarizing [45].

3.1. Literature search

In this step, we have been nominated some popular databases including of Web of Science, Scopus Google Scholar to present a systematic review of methodologies and applications of WASPAS and SWARA. The literature search was accomplished based on various keywords such as: WASPAS; SWARA; WASPAS and SWARA; WASPAS and ARAS; WASPAS and MULTIMOORA; WASPAS and COPRAS; SWARA and ARAS; SWARA and MULTIMOORA; SWARA and COPRAS and different MCDM utility determining approaches. We selected those papers which were published from 2010 to 2016. In total; 83 scholarly papers were extracted according to our strategy search. In the next step we checked the duplicated papers with redundant information and after this step 75 paper were remained. Then; we removed eight records due to duplicates; after this step; we

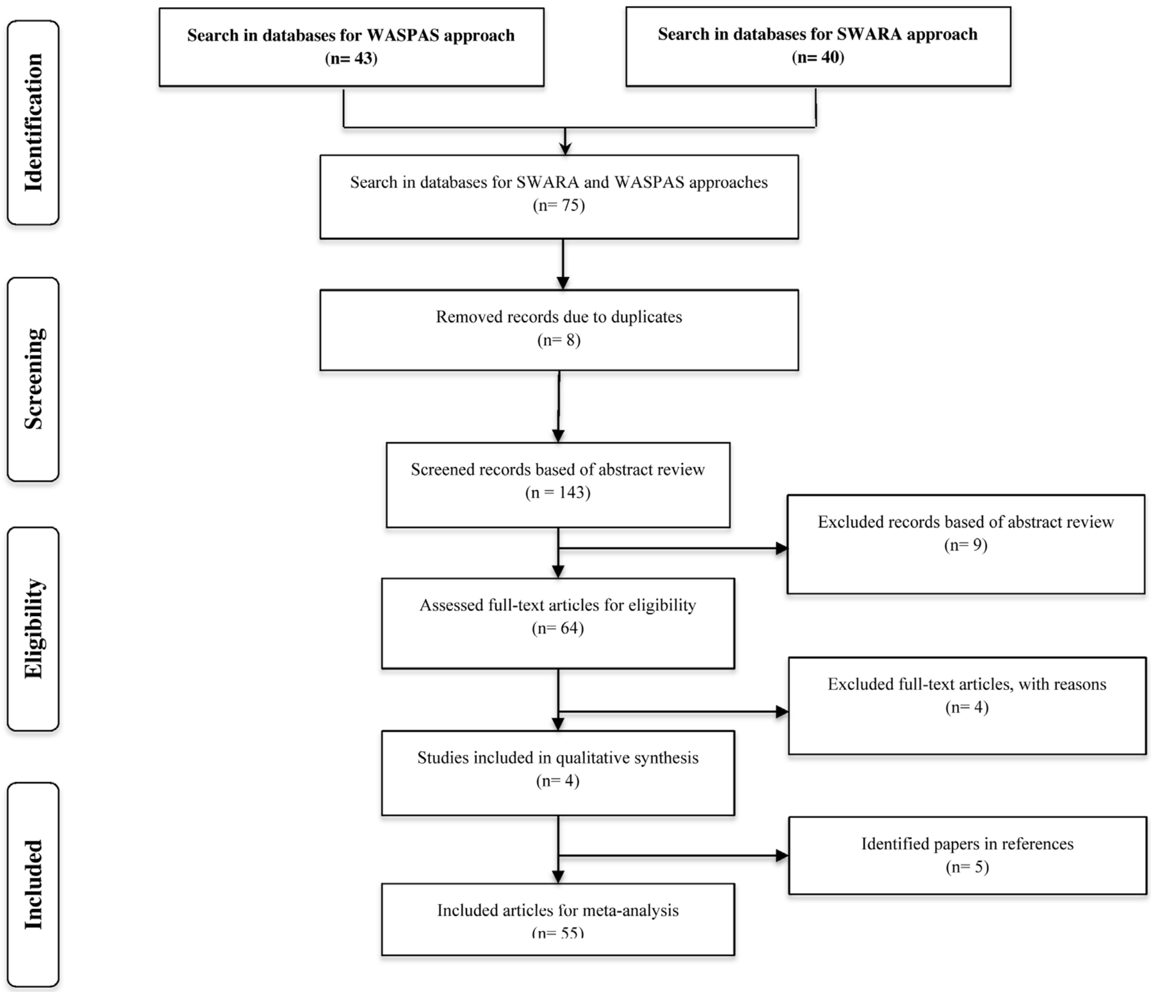


Fig. 9. Study flowchart for the identification, screening, eligibility and included of articles.

screened papers based on abstracts; topic and unrelated studies are removed and in total 64 of potentially related paper were remained (see Fig. 9).

3.2. Articles eligibility

In this step of review, for the purpose of eligibility, we reviewed the full text of each manuscript independently which extracted from last step. In the last step, carefully we identified the related articles to attain a consensus. Articles which had used WASPAS and SWARA were chosen. Book chapters, unpublished working papers, editorial notes, master dissertations and doctoral theses, textbooks and non-English papers were excluded. Several of previous studies have used other methods such as MCDM, fuzzy set etc.; therefore, in this step also we excluded those studies, because in this review paper we focused on two MCDM utility determining techniques rather than the MCDM techniques. In the end, we selected 55 articles related to DEA models in green and sustainable SCM, from 33 scholarly international journals and conferences between 2010 and 2016 which met our inclusion criteria.

3.3. Summarizing and data extraction

In the final step of our methodology, after negotiation with experts, some required information was collected and finally 55 articles were reviewed and summarized. In flowing, all selected articles were classified into different classifications including; construction management, manufacturing and operation management, computing and operation research, sustainable and renewable energy, human resource management, and other areas (see Table 2). In addition, articles were summarized and reviewed based on various criteria such as authors, the year of publication, journals and conferences names, the technique and method used, research objectives, research gap and problem, solution and modeling, and results and findings. We believe that, the reviewing, summarizing, and classifying of articles can help us to achieve various critical and importance hints. Consequently, some suggestions and recommendations for future studies were proposed. Furthermore; we believe that; this review paper was accomplished very carefully and it presented a comprehensive source regarding the application of two new MCDM approaches in various fields. We should mentioned that, the key difficult point during using PRISMA method was about implicit expressing of methodologies in abstract

Table 2
Distribution of papers based on application areas.

Application fields	Number of paper	Percentage (%)
Construction management	22	40.00%
Manufacturing and operation management	14	25.45%
Computing and operation research	7	12.73%
Sustainable and renewable energy	5	9.09%
Human resource management	4	7.27%
Other areas	3	5.45%
Total	55	100.00%

and research method section of the selected articles. Thus, we need to search on full manuscript and see the details to assess the exact applied approaches for evaluating of various fields. Although, in selection of paper we spent considerable time, but it helped us to select the most appropriate published studies for conducting this review paper.

4. Distribution of the MCDM utility determining techniques

4.1. Application areas classification

Although classifying and combining of selected articles in various fields are difficult, but, for these classifying and grouping, we used the opinions of experts in field of MCDM utility determining techniques. Consequently, based on opinions of experts, we categorized articles into six different applications areas including; construction management, manufacturing and operation management, computing and operation research, sustainable and renewable energy, human resource management and other areas (see Table 2). In the following sections, all articles were summarized and reviewed based on various criteria including; authors, the year of publication, journals and conferences names, the technique and method used, research objectives, research gap and problem, solution and modeling, results and findings.

4.2. Distribution of papers based on WASPAS approach

Table A1 in Appendix A presents the studies, where the WASPAS technique was used. Based on the results presented in this table, a total of 27 studies used WASPAS technique combined with other techniques in various application areas such as industrial robot selection, construction sites selection, manufacturing process, material selection, construction contractor, software selection, real time manufacturing, indoor environment and other areas. Some of these studies integrated WASPAS approach with fuzzy set theory (Turskis, Zavadskas, Antucheviciene and Kosareva [194], Keshavarz Ghorabaee, Zavadskas, Amiri and Esmaeili) [175] . Turskis, Zavadskas, Antucheviciene and Kosareva [194], proposed the new fuzzy Multi-Attribute Performance Measurement (MAPM) for selection of construction sites. This paper integrated fuzzy WASPAS and fuzzy AHP for selection of the best shopping centre construction site, results of this study demonstrated that; the increasing competition cause a lot of construction site selection problems and making decisions is a complex process that involves multiple, usually conflicting, objectives or attributes. Keshavarz Ghorabaee, Zavadskas, Amiri and Esmaeili [175], suggested a novel approach by combining WASPAS approach and Interval type-2 fuzzy sets (IT2FSs) for green supplier selection. For solving green supplier selection, this paper extended the WASPAS approach with interval type-2 fuzzy environment. The findings of this study found that; the proposed approach is able to solve problems regarding green supplier selection. Some studies combined the WASPAS approach with grey number (Zavadskas, Turskis and Antucheviciene [29]; Turskis, Daniūnas, Zavadskas and Medzvieckas [196]), Zavadskas, Turskis and Antucheviciene [29] proposed the WASPAS grey for choose and assess the right construction contractor. This study integrated the WASPAS with grey attributes for selecting the right contractor. The findings of this paper demonstrated that; the proposed method able to development strategy ranking, management decisions and effective investment in the area of construction contractor. Turskis, Daniūnas, Zavadskas and Medzvieckas [196], used WASPAS grey for choosing foundation of dwelling house with a single-story. The findings of this paper concluded that; the proposed approach has the high prediction accuracy with clear and simple process for evaluating and ranking of building foundation alternatives and attributes. Some studies integrating WASPAS approach with other new utility approaches such as COPRAS, MOORA, MULTIMOORA and other old MCDM approaches such as AHP, entropy and TOPSIS (Staniūnas, Medineckienė, Zavadskas and Kalibatas [161]; Šiožinytė and Antuchevičienė [167]; Zavadskas, Antucheviciene, Saparauskas and Turskis [163]; Zavadskas, Antucheviciene, Šaparauskas and Turskis [162]; Karande, Zavadskas and Chakraborty [197]). In previous studies, there is a lack of attention to ecological factors in multi-dwelling house modernization. In this study three approaches, including WASPAS, COPRAS and TOPSIS were used for making an ecological-economic assessment of multi-dwelling house modernization. Results of this paper indicated that modernization can help to decrease missions around 30%. Šiožinytė and Antuchevičienė [167], used WASPAS, COPRAS, AHP and TOPSIS to solve the problem related to tradition continuity and daylighting in the reconstructed buildings. This study mentioned that; there are problems of tradition continuity and daylighting in a reconstructed vernacular building. In order to improve daylighting in the reconstructed building and preserve the features of its vernacular architecture, the AHP was used for weighting the evaluation criteria, and COPRAS, TOPSIS and WASPAS were applied to ranking the available alternative solutions. The results show that a rational solution to the problems of daylighting in a reconstructed building and preserving its traditional features of vernacular architecture could be implemented in new glass structures. Zavadskas, Antucheviciene, Šaparauskas and Turskis [162], employed the WASPAS, WPM, WSM and MOORA for evaluating facades, this study argued that; for commercial or building's facades, need to select the best design solution, outcomes of this paper indicated that, four building facades' alternatives for public or commercial buildings were evaluated considering a set of twelve criteria in the presented case study. Karande, Zavadskas and Chakraborty [197], used six different MCDM approaches for selection of real time industrial robot, findings of this paper found that the MOORA was most robust approach with compare to other six approaches. Other information about this section presented in Table A1.

4.3. Distribution of papers based on SWARA approach

Table A2 in Appendix A presents the studies, where the SWARA approach was used. Based on the results presented in this table, a total of 22 studies used SWARA in various application areas such as ERP, buildings' retrofit, building structures, machine tools selection, energy system sustainability, selecting the architect, supplier selection, high tech industries selection, dispute resolution, personal selection, mining industry selection, manufacturing systems and corporate social responsibility. Some of these studies integrating SWARA and COPRAS as another new MCDM utility approach (Volvačiovas, Turskis, Aviža and Mikštienė [206]; Hashemkhani Zolfani and Zavadskas [22]; Hasan Aghdaie, Hashemkhani Zolfani and Zavadskas [186]; Hashemkhani Zolfani and Bahrami [187]), Volvačiovas, Turskis, Aviža and Mikštienė [206] applied SWARA for selecting the strategy of public buildings' retrofit, this paper applied MADM techniques for solving this problem, the results obtained in this paper shown that, the best retrofitting strategy is to perform the construction work at the same stage, using the greatest possible number of workers. Hashemkhani Zolfani and Zavadskas [22], used the SWARA and COPRAS for developing of the building structures. Results of this study revealed that the area with local climate is optimal for Iranian traditional systems. Hasan Aghdaie, Hashemkhani Zolfani and Zavadskas [186], employed SWARA for selecting machine tools, this paper argued that; SWARA and COPRAS-G are more useful for evaluating the alternatives with compare to other techniques, the results of this paper with respect to conflicting criteria, show that the presented approach is most practical for machine tool ranking. Hashemkhani Zolfani and Bahrami [187], ranked the high tech industries by employing SWARA, in this paper SWARA was used for evaluating and weighting the criteria, although; the results yielded by COPRAS method show that Nano Technology and Biotechnology were the first and second high tech in Iran. Some studies integrated SWARA and ARAS for solving MCDM problems (Keršulienė and Turskis [181]; Karabasevic, Zavadskas, Turskis and Stanujkic [207]; Karabasevic, Paunkovic and Stanujkic [208]). Keršulienė and Turskis [181], integrated SWARA with ARAS-F for selecting the architect. Karabasevic, Zavadskas, Turskis and Stanujkic [207], used SWARA and ARAS approaches for personal selection, findings of this paper found that; the proposed model for selection of personal is easy to use and able to solving problems in this field. Karabasevic, Paunkovic and Stanujkic [208], assessed and rank the indicators of corporate social responsibility by using two MCDM approaches including SWARA and ARAS, results of this paper found that, contribution to economic development had the highest weight among other CSR sub-criteria. In addition; some studies integrated SWARA and MULTIMOORA (Karabasevic, Stanujkic, Urosevic and Maksimovic [209]), Karabasevic, Stanujkic, Urosevic and Maksimovic [209] used SWARA for determine weights of criteria and MULTIMOORA for ranking the alternatives, results of this paper found the proposed model can be used for solving problems related to personal selection and recruitment. Moreover; SWARA approach integrated with old MCDM techniques such as VIKOR, TOPSIS and PROMOTHEE. (Hashemkhani Zolfani, Esfahani, Bitarafan, Zavadskas and Arefi [182]; Alimardani, Hashemkhani Zolfani, Aghdaie and Tamošaitienė [180]; Stanujkic, Karabasevic and Zavadskas [210]; Shukla, Mishra, Jain and Yadav [211];). Hashemkhani Zolfani, Esfahani, Bitarafan, Zavadskas and Arefi [182], employed SWARA for selecting mechanical longitudinal ventilation, in this paper to identify and evaluate more effective criteria, the authors used the SWARA method, meanwhile, VIKOR was applied to evaluate and rank the alternatives. Results showed that jet fans with spot extraction by axial fans make the best choice. Alimardani, Hashemkhani Zolfani, Aghdaie and Tamošaitienė [180], indicated that; due to a large number of factors, supplier selection process is a difficult task for every company, therefore, two MADM methods, including SWARA and VIKOR were applied to decision-making process, results of this article show that the presented method is most practical for supplier alternatives' ranking with respect to the multi-conflicting criteria in agile environment. Stanujkic, Karabasevic and Zavadskas [210], used SWARA approach and group decision making to select the best packaging design to meet customers' requirements, findings of this paper found that the proposed model, decrease the number of pairwise comparisons in previous MCDM methods such as AHP. Shukla, Mishra, Jain and Yadav [211], argued that ERP system selection is the important task in the enterprises due to changing the current environments, in this regard, this study used SWARA and PROMETHEE approaches to select the best ERP system and competent in company, the results of this paper found that good technical capability, system vendors and service support were the significant factor in selection of ERP system. Aghdaie, Hashemkhani Zolfani and Zavadskas [212], used two MADM approaches including SWARA and VIKOR to finding synergies of MADM and data mining, this study demonstrated that; need to identify the interaction of MADM and data mining for supplier ranking and clustering. The details of selected papers based on SWARA approach presented in Table A2.

4.4. Distribution of paper based on integration of SWARA and WASPAS approaches

Table A3 in Appendix A presents some studies which integrated the WASPAS and SWARA techniques. Based on the results presented in this table, a total six studies integrated WASPAS and SWARA techniques in various application areas such as high technology (Ghorshi Nezhad, Hashemkhani Zolfani, Moztarzadeh, Zavadskas and Bahrami [220]), personnel selection (Karabašević, Stanujkić, Urošević and Maksimović [221]), renewable energies (Heidarzade, Varzandeh, Rahbari, Zavadskas and Vafaeipour [222]; Vafaeipour, Hashemkhani Zolfani and Morshed Varzandeh, Derakhti and Keshavarz Eshkalag [223]). Ghorshi Nezhad, Hashemkhani Zolfani, Moztarzadeh, Zavadskas and Bahrami [220] used SWARA for evaluating and ranking the high technology selection, this study indicated that; planning for future in every level of organization is important task because of exists of various criteria, in this regard; this paper used SWARA to find the weights of criteria and applied WASPAS for ranking the alternatives, the findings of this paper found that; the attractiveness was the first ranked and research and technology potential had the first rank in sub-criteria in ranking of high tech industry. Karabašević, Stanujkić, Urošević and Maksimović [221], integrated SWARA and WASPAS approaches for personnel selection, this study found personnel selection and recruitment process is important role in the human resource management in every organization, they used SWARA for evaluate weights of criteria and WASPAS for assessing of the alternatives, the findings of this paper found that interview preparedness had the first rank among other criteria. Heidarzade, Varzandeh, Rahbari, Zavadskas and Vafaeipour [222], used SWARA and WASPAS approaches for selection of best site regarding wind energy, this paper mentioned that, finding the best location site for wind energy is the critical issue in Iran, therefore; this paper applied SWARA approach to evaluate weight of criteria and used WASPAS for assessing the alternatives, the finding of this study is useful for decision maker related to wind energy. Vafaeipour, Hashemkhani Zolfani, Morshed Varzandeh, Derakhti and Keshavarz Eshkalag [223], integrated SWARA and WASPAS approaches to implement solar projects, this study mentioned there is lack of attention to solar power plants in Middle East countries, such as Iran, based on experts' opinions and literature, this paper found, there are 29 quantitative and qualitative criteria are important for implementation of solar power pants, this paper ranked the solar projects in 25 cities of Iran and found Yazd was ranked as the first city and economical perspective was ranked as the first criteria. Table A3 provides the information of all papers which integrated the both SWARA and WASPAS approaches.

4.5. Relationship and comparison analysis on the results of SWARA and WASPAS methods

There have been several MADM methods, such as the AHP, ANP, and entropy in dealing with the multiple criteria problems. In all of the above-mentioned methods, SWARA method has priorities in comparing to the classical AHP and other methods as follows, SWARA was developed for group decision-making establishment of criteria weights. Despite this, it can be successfully used by a single decision-maker; in addition; the number of comparisons is equal to $n-1$, when criteria are ranked according to the importance in descending order, while in AHP method it equals to $n(n-1)$; the calculation algorithm of this method is very simple and very close to common human's thinking, and thus it is understandable as for novice users and as well for experienced users; furthermore; in SWARA method no needs to check consistency of judgments, because it is ensured when criteria are ranked in descending order; moreover; SWARA method is flexible and not needs any comparative scale (for example 9 points Saaty's scale, which express relative importance of pair of criteria in numbers). In case of WASPAS method, there are a number of multi-attribute utility function forms. Most of them are additive form which are used in SAW, SMART, and similar MADM methods. Another popular utility form is multiplicative form. In most cases of assessment, decision-makers should select between these two forms. WASPAS method integrates both forms of utility function to one and allows to decision-maker to take decision in more comfortable way. WASPAS improves the chance of more consistent and best values and SWARA is an appropriate technique for the issues with priorities which identified earlier, based on conditions. SWARA is able to predict opinions of experts based on the importance ratio of each criterion. SWARA is helpful for experts in the evaluating of weights and criteria. Some previous scholars integrated SWARA and WASPAS as a new hybrid MADM approach to evaluate the criteria and rank the alternatives.

4.6. Distribution of papers by approaches and application fields

In recent decades, research on MCDM has continued and many areas for its application have been found. MCDM provides effective decision making methods in the domains, where the selection of the best alternative is very complicated. The current study reviews the main streams of considering the MCDM theory and practice in detail. The main purpose is to identify two MCDM utility determining approaches in various application areas, and to suggest approaches which could be used most robustly and effectively to identify the best alternatives. The MCDM approach has been applied to many domains of science. The MCDM approach helps to select the best alternatives in the presence of multiple criteria, while the best one can be obtained by analyzing different scopes and weights of the criteria and the selection of the optimum ones is performed by using any MCDM utility determining approach. This survey shows the development of two MCDM utility determining approaches and their applications in various areas. In total, 55 papers were classified into six areas: construction management, manufacturing and operation management, computing and operation research, sustainable and renewable energy, human resource management and other areas. Regarding the MCDM utility determining approaches, the results given in Fig. 10 show that previous scholars published more papers in the fields related to construction management than in other application areas. In addition; Fig. 10 shows the frequently of SWARA, WASPAS and integrating of these two approaches in six application areas. The information of other application areas and approaches is provided in Fig. 10.

4.7. Distribution of papers by publication year and approach

Distribution of papers based on publication year and MCDM utility approaches is shown in Fig. 11. In general, regarding SWARA approach, the first paper was published in 2010 and in field of rational dispute resolution and has an upward trend between 2010 and 2016, where it reached to the peak of seven papers in 2013 and 2015 in various application areas. Regarding the WASPAS approach, the first paper was published in 2012 in field of operation research and computing and has upward trend between 2012 and 2016, which it reached to the peak of six papers in 2013, 2014, 2015 and 2016 in various application areas. In case of integrated SWARA and WASPAS approaches, they have been used since 2013 in area of shopping mall location and area has an upward trend between 2013 and 2016, where it reached to the peak of two papers in 2014 and 2016 in various application areas. The information of other publication years and approaches is provided in Fig. 11.

4.8. Distribution of papers by journal

Scholarly papers have been chosen from a total of 33 international journals and conferences. The results presented in Table 3 give more than 33 scientific journals and conference publications using the considered two MCDM utility determining approaches. Based on the results, Journal of Civil Engineering and Management and Journal Engineering Economics had the first rank among the journals presented in this table, while Procedia Engineering journal was ranked second, and Technological and Economic Development of Economy and Journal of Business Economics and Management were ranked third among 33 journals considered in the work. The information about other journals is presented in Table 3.

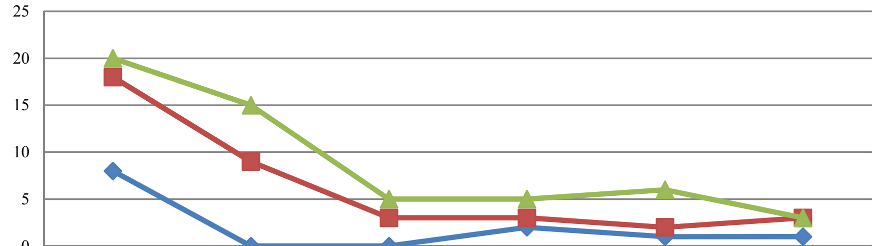
5. Conclusion

This review paper presents a comprehensive overview of the theory and applications with recent fuzzy developments of WASPAS and SWARA as two new MCDM utility determining approaches. Because of the ability of WASPAS and SWARA approaches to evaluate the criteria, rank the alternatives and comparative analysis, recently, WASPAS and SWARA related papers have increased in several MCDM problems. These selected papers were categorized into six application areas. In addition, all papers were classified by authors, the year of publication, journals and conferences names, the technique and method used, research objectives, research gap and problem, solution and modeling, and finally results and findings. Moreover; this study reviews the published papers in period of 2010–2016 in popular international journals and conferences accessible in three important databases such as Web of Science, Scopus and Google Scholar. To this end, we carefully selected 55 studies about WASPAS and SWARA based on the title, abstract, introduction, research method, and conclusion.

A number of important points with respect to WASPAS and SWARA applications extracted from this literature review article. The extensive of the selected studies were published in 2013 and 2015. In total, papers were classified into six areas including construction management, manufacturing and operation management, computing and operation research, sustainable and renewable energy, human resource management and other areas. In this regard, construction management was the most important application area with 20 papers used WASPAS and SWARA. Additionally, 33 international journals and conferences were considered in the current review paper. Journal of Civil Engineering and Management was ranked first among the considered journals in terms of using WASPAS and SWARA approaches.

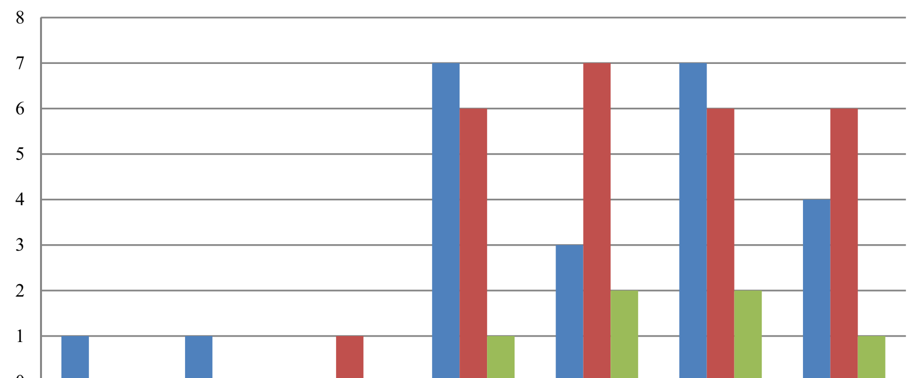
WASPAS method integrated with fuzzy set theory, interval type-2 fuzzy environment. The researchers have shown that there are a great number of MCDM utility determining approaches with fuzzy sets theory, and that several of these approaches had been used to solve problems related to various application areas. Moreover, this study confirms that the MCDM utility determining approaches can help decision makers and stakeholders to overcome some inherent uncertainties of various application areas decision making. The processes of evaluation and calculation in different fields of decision making are usually based on using the MCDM utility determining approaches. It is necessary to apply different approaches to obtain the rankings of the alternatives referring to different areas and to ensure the validity of MCDM utility determination. It is believed that the results obtained by various mathematical methods are more rational, and more mathematical methods can contribute to solving the various areas problems in the future. As long as the criteria and weights are used, MCDM approaches are appropriate to solving specific decision making problems in other application areas, and the MCDM utility determining approaches can be viewed as a powerful tool for solving the problems in different fields of science.

This review paper has some limitations, which can be considered as an object of future studies. First, this review is focused on the use of the MCDM utility determining approaches rather than the old MCDM techniques. WASPAS and SWARA methods [225] can be adapted to the development of hybrid MCDM meth-



	Construction management	Manufacturing and operation management	Computing and operation research	Sustainable and renewable energy	Human resource management	Other areas
Integrating of SWARA and WASPAS	2	6	2	2	4	0
WASPAS	10	9	3	1	1	2
SWARA	8	0	0	2	1	1

Fig. 10. The distribution of papers based on application areas and approaches.



	2010	2011	2012	2013	2014	2015	2016
SWARA	1	1	0	7	3	7	4
WASPAS			1	6	7	6	6
Intrgrated WASPAS and SWARA				1	2	2	1

Fig. 11. The distribution of papers by publication year and approach.

ods such as ARAS, EDAS [226–229], Investment Value Assessments along with Recommendations (INVAR) [230], CODAS [231,232], Fuzzy Ranking and Aggregated Weights (AFRAW) [233], MULTIMOORA and MOORA [234–238]. The concept of the neutrosophic set developed by Smarandache is a set model which generalizes the classic set, fuzzy set, interval fuzzy set, intuitionistic fuzzy set and interval valued intuitionistic fuzzy set. In contrast to intuitionistic fuzzy sets and also interval valued intuitionistic fuzzy sets, indeterminacy degree of an element in a universe of discourse is expressed explicitly in the neutrosophic set. There are three membership functions such that truth membership, indeterminacy membership and falsity membership in a neutrosophic set, and they are independent. In this require, due to nature of SWARA method, we can suggest that, it is appropriate in the future to apply intuitionistic or neutrosophic sets with method. This paper reviewed and classifies two MCDM utility determining methods including SWARA and WASPAS with fuzzy theory sets. There are other MCDM utility determining methods such as COPRAS, ARAS [207], and MULTIMOORA [239] with their fuzzy extensions and Grey number, for example fuzzy ARAS, Grey ARAS, MULTIMOORA with integrating with interval-valued triangular fuzzy numbers, MULTIMOORA with fuzzy set theory, fuzzy MULTIMOORA with interval-valued intuitionistic, COPRAS method with Grey [240] and fuzzy set theory, COPRAS with interval-valued intuitionistic. Therefore future studies can review and classification of these techniques with their fuzzy extensions and Grey number. In addition; this study addressed to the significant role of fuzzy set theory and Grey number with WASPAS method for example; combined WASPAS method with interval type-2 fuzzy sets, combined WASPAS method based on interval-valued intuitionistic fuzzy numbers, combined WASPAS method with single-valued neutrosophic set and WASPAS method with Grey number. In this regard, future papers can focus on the integrating WASPAS and SWARA methods with other types of fuzzy theory sets, fuzzy integrals and aggregation operators such as; hesitant fuzzy Choquet integral, in addition, generalized hesitant fuzzy Choquet ordered averaging (GHFCOA), hesitant fuzzy Choquet geometric Bonferroni mean (HFCGBM), the hesitant fuzzy weighted averaging (HFWA), hesitant fuzzy ordered weighted distance (GHFOWD) and the generalized hesitant fuzzy hybrid weighted distance (GHFHWD) and some types of distance measures related to dual hesitant fuzzy sets based on Archimedean t-conorm and t-norm for dual hesitant fuzzy information. Moreover; future studies can combine these two techniques with qualitative information and quantitative data based on hesitant fuzzy linguistic term sets, discrete fitting aggregation and simplified optimal discrete fitting aggregation, fuzzy Choquet integral operator 2-tuple linguistic, ordered weighted averaging operator, 2-tuple linguistic weighted averaging operator, interval-valued 2-tuple linguistic, 2-tuple averaging operator, 2-tuple linguistic power average operator, 2-tuple OWA operator, 2-tuple weighted average (2TWA) operator. In case of interval-valued intuitionistic fuzzy, future scholars can use MCDM utility determining methods for integrating with Interval-valued intuitionistic fuzzy weighted arithmetic aggregation, the interval-valued intuitionistic fuzzy ordered weighted aggregation, interval-valued intuitionistic fuzzy hybrid aggregation operators. Furthermore, future studies

Table 3
Distribution of papers based on the journals of their publication.

Number	Name of journal	N	%
1	Journal of Civil Engineering and Management	5	9.09%
2	Inzinerine Ekonomika-Engineering Economics	5	9.09%
3	Procedia Engineering	4	7.27%
4	Technological and Economic Development of Economy	3	5.45%
5	Journal of Business Economics and Management	3	5.45%
6	Archives of Civil and Mechanical Engineering	3	5.45%
7	Informatica	2	3.64%
8	Economic Computation and Economic Cybernetics Studies and Research	2	3.64%
9	Economic Research-Ekonomska Istraživanja	2	3.64%
10	Acta Montanistica Slovaca	2	3.64%
11	International Journal of Strategic Property Management	2	3.64%
12	CATENA	1	1.82%
13	Expert Systems with Applications	1	1.82%
14	World Sustainability Forum	1	1.82%
15	Buletin Teknologi Tanaman	1	1.82%
16	Serbian Journal of Management	1	1.82%
17	Journal of Economics, Management and Informatics	1	1.82%
18	International Journal of Industrial Engineering Computations	1	1.82%
19	Sustainability	1	1.82%
20	Journal of Cleaner Production	1	1.82%
21	Journal of Production Engineering	1	1.82%
22	Proceedings of the 6th International ICT Conference	1	1.82%
23	Procedia – Social and Behavioral Sciences	1	1.82%
24	International Journal of Intelligent Enterprise	1	1.82%
25	Computer-Aided Civil and Infrastructure Engineering	1	1.82%
26	International Journal of Computers Communications & Control	1	1.82%
27	Energy Conversion and Management	1	1.82%
28	International Journal of Business and Systems Research	1	1.82%
29	Elektronika ir Elektrotechnika	1	1.82%
30	Applied Soft Computing	1	1.82%
31	Information Technology and Control	1	1.82%
32	Studies in Informatics and Control	1	1.82%
33	Transport	1	1.82%

can combine the MCDM utility determining methods with fuzzy ordered weighted operators like induced interval-valued intuitionistic fuzzy ordered weighted geometric, fuzzy ordered weighted averaging (FOWA) operator, the fuzzy hybrid harmonic mean (FHHM) operator, the intuitionistic fuzzy hybrid geometric (IFHG) operator, the intuitionistic fuzzy hybrid averaging (IFHA) operator and the dynamic intuitionistic fuzzy weighted geometric (DIFWG) operator.

Articles published at the end of 2016 and first of 2017 (if any) have not been included in the present paper because of the limited reporting time. The present review can be expanded for the future studies. Another limitation is that the data were collected from journals and conferences, while the examined documents did not include papers, textbooks, doctoral and master's theses and unpublished papers on the MCDM problems. Therefore, in the future study, the data can be collected from these sources, and the obtained results can be compared with the data obtained and reported in this study. One more limitation is that all the papers were extracted from the journals written in English, which implies that the scientific journals in other languages were not involved in the review. However, the researchers believe that this paper comprehensively reviewed most of the papers published by international journals and conferences. Moreover, the current review paper can provide future academic scholars with a better understanding of the MCDM utility determining approaches. This study can be used by academics and managers as a basis for further research. It can also help the practitioners make more appropriate decisions using these approaches and be a guide to scholars, improving the discussed methodologies. The authors of this paper carefully selected and summarized the available papers of several publishers in Web of Science, Scopus, and Google Scholar. However, a number of relevant outlets remained beyond the scope of the current study. Therefore, the future researchers will be able to review the papers, which are not considered in the current review. Another limitation is associated with the fact that the paper presents a review of numerous works on the problem of using the recently developed MCDM approaches published in various journals and conferences. However, this review does not cover recent methods discussed in the books.

Appendix A.

Table A1
Distribution of papers based on WASPAS technique.

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Karande, Zavadskas and Chakraborty [197]	WASPAS, WSM, WPM MOORA, reference point approach and MULTIMOORA	Used six different MCDM approaches for selection of real time industrial robot.	Due to inherent ability to judge diverse in selection of real time industrial robot, MCDM is the useful tool for solving problems in this regards.	Compared six MCDM approaches for choose the industrial robot.	Findings of this paper found that the MOORA was most robust approach compare to other six approaches.
Turskis, Zavadskas, Antucheviciene and Kosareva [194]	Fuzzy WASPAS	Proposed the new fuzzy multi-attribute performance measurement (MAPM) for selection of construction sites.	There are various quantitative and qualitative attributes conflicting in assessment of construction site alternatives.	Integrated fuzzy WASPAS and fuzzy AHP for selection of the best shopping centre construction site	The increasing competition cause a lot of construction site selection problems. Making decisions is a complex process that involves multiple, usually conflicting, objectives or attributes. They are ill-structured.
Madic, Antucheviciene, Radovanovic and Petkovic [198]	WASPAS, AHP and OCRA	Application the WASPAS approach to determine of manufacturing process conditions in laser cutting.	Need to determine the most appropriate manufacturing process criteria and need to consider a number of diverse and conflicting processes performance.	Integrated three MCDM approaches including WASPAS, AHP and OCRA for determine best condition of manufacturing process regarding laser cutting.	The findings of this paper found that; change in assist gas pressure, cutting speed and laser power was the most important factors.
Yazdani [199]	WASPAS	Used factor relationship (FARE) and WASPAS approaches for material selection.	Need to present the material selection model in order to reach the desired outputs with the minimum cost and specific applicability.	Used WASPAS for evaluating and ranking of alternative and FARE for elaborate the weights of criteria.	The results of this study found that; the proposed FARE-WASPAS model is useful methodology for material selection field.
Zavadskas, Turskis and Antucheviciene [29]	WASPAS-G	Proposed the WASPAS grey for choose and assess the right construction contractor.	Due to increase the competition in world market chooses the contractor for better performance is the significant issue for organizations.	Integrated the WASPAS with grey attributes for selecting the right contractor.	The findings of this paper demonstrated that; the proposed method able to development strategy ranking, management decisions and effective investment.
Chakraborty and Zavadskas [170]	WASPAS	Used WASPAS approach for solving decision making problem related to manufacturing.	Due to the number of conflicting selection criteria, there is need to the logical, simple and systematic approaches or mathematics tools for solving problems related to manufacturing.	Proposed WASPAS method to finding the appropriate assessment criteria of selecting the manufacturing problems.	Findings of this paper found that; the proposed method had accurately ranking capability for solving decision making problems related manufacturing.
Zavadskas, Chakraborty, Bhattacharyya and Antucheviciene [200]	WASPAS	Proposed WASPAS approach to explore the optimization parameters in non-traditional machining processes.	Need to improve machining performance of non-traditional machining processes because of several control parameters.	Used WASPAS approach for the parametric optimization of five famous non-traditional machining processes.	The outcomes of this paper found that; WASPAS approach can be used as efficient for multi and single responds optimization of the non-traditional machining processes.
Madić, Gecevska, Radovanović and Petković [201]	WASPAS	Used the WASPAS approach based on economic analysis of machining process.	There is need to consider the economic and technological criteria for selection of machining process. .	This study involved five economic criteria and eight different machining processes by using the WASPAS approach.	The outcomes of this paper found that; abrasive jet machining was the best machining processes.
Zavadskas, Turskis, Antucheviciene and Zakarevicius [37]	WASPAS	Proposed new approach to measure the latter approaches accuracy and increasing of alternatives ranking accuracy.	Due to the important of computer-aided multiple criteria decision support system this paper proposed new decision making approach as WASPAS.	Integrated WSM and WPM for create new approach as called WASPAS.	The results of this paper demonstrated that; the proposed WASPAS approach enable enables to attain the measurement high accuracy.
Madić, Vitković and Trifunović [202]	WASPAS	Applied WASPAS approach for selection the software.	Assessment and selection of software based on organization needs is difficult problem.	For solving this problem, authors of this paper employed WASPAS approach.	The findings of this paper indicated that; there was good correlation between results of this study with other previous studies for solving problem regarding software selection.

Table A1 (*Continued*)

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Zavadskas, Antucheviciene, Razavi Hajiagha and Hashemi [1]	WASPAS-IVIF	Extended WASPAS approach for solving problems in area of decision making in uncertain environments.	There is need to improve the accuracy of WSM and WPM based on aggregation methods such as interval-valued intuitionistic fuzzy sets.	Integrated WASPAS approach with interval-valued intuitionistic fuzzy sets.	The results of this paper found that; the integrated proposed approach is the perfect method for solving strategy selection and management decision problems.
Chakraborty, Zavadskas and Antucheviciene [203]	WASPAS	Used WASPAS to valeted five problems related to real time manufacturing.	There is need to use the WASPAS method to validate problems related to real time manufacturing because of influenced by control parameter.	Integrated weighted product model (WPM) and weighted sum model (WSM) as WASPAS for solving problems in manufacturing fields.	The findings of this paper found that; WASPAS method is the validated method for solving real time manufacturing problems with compare with previous studies.
Zavadskas, Kalibatas and Kalibatiene [204]	WASPAS	Used WASPAS approach to select the optimal indoor environment.	There is need to evaluate the current dwelling houses and refurbish them to satisfy the humans' needs and energy efficient requirement.	Evaluated the indoor environment of six different apartments in the same brick house by utilizing of WASPAS approach.	The outcomes of this paper found that MADM-opt able to evaluate the options and their assessment based on best options.
Staniūnas, Medineckienė, Zavadskas and Kalibatas [161]	WASPAS, COPRAS and TOPSIS	Ecological–economic evaluation of dwelling house modernization by applying WASPAS, COPRAS and TOPSIS.	In previous studies, there is a lack of attention to ecological factors in multi-dwelling house modernization.	Three techniques, including WASPAS, COPRAS and TOPSIS, were used for making an ecological-economic assessment of multi-dwelling house modernization.	Results of this paper indicated that modernization can help decrease missions around 30%.
Zavadskas, Skibniewski and Antucheviciene [205]	WASPAS	The analysis of performance by applying WASPAS to journals of civil engineering.	A need for evaluating the progress of scientific journals, such as civil engineering journals.	Suggested WASPAS for evaluating a journal's progress.	Results of this paper indicated that the ranking order of journals was different when applying both approaches.
Zavadskas, Antucheviciene, Šaparauskas and Turskis [162]	WASPAS, WPM, WSM and MOORA	Employed WASPAS, WPM, WSM and MOORA for evaluating facades.	A need for choosing the best design solution for a commercial or public building's facades.	WASPAS, WPM, WSM and MOORA techniques were applied to selecting the best facades.	Four building facades' alternatives for public or commercial buildings were evaluated considering a set of twelve criteria in the presented case study.
Zavadskas, Baušys and Stanujkic [25]	WASPAS-SVNS	Proposed a new approach based on WASPAS and single valued neutrosophic sets for selection of lead-zinc flotation circuit design.	Due to important influence of processing costs and useful minerals, need to consider adequate circuit design of lead-zinc utilization.	For selection of lead-zinc flotation circuit design this paper integrated the WASPAS method and single valued neutrosophic sets.	Findings of this paper found that; the proposed approach is suitable approach for selection of lead-zinc flotation circuit design.
Bagočius, Zavadskas and Turskis [160]	WASPAS and entropy	Used a mixed WASPAS and entropy approach for deep-water port selection.	There is a need for developing a deep-water sea port in the Klaipeda region to satisfy the economic needs.	This paper proposes an integrated multi-criteria decision-making model to solve the problem.	According to the proposed model for resolving the problem the best alternative is the fourth alternative. The proposed model shows the performance ratio of each alternative to the optimal alternative.

Table A1 (*Continued*)

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Dėjus and Antuchevičienė [165]	WASPAS	Employed WASPAS for evaluating health and safety on the construction site	It is emphasised that more investigations should be made to identify the options for improving education and training effectiveness of construction workers in the area of health and safety.	The use of the WASPAS technique for assessment and selection of appropriate solutions for occupational safety is suggested.	The investigation has revealed that typical solutions for occupational safety are used in the field of road construction; however, they are intended for protecting third persons from accessing dangerous zones next to a construction site rather than for ensuring health and safety of workers.
Šiožinytė and Antuchevičienė [167]	WASPAS, COPRAS; AHP and TOPSIS	Used WASPAS, COPRAS, AHP and TOPSIS for solving the problem of tradition continuity and daylighting in the reconstructed buildings	There are problems of tradition continuity and daylighting in a reconstructed vernacular building.	In order to improve daylighting in the reconstructed building and preserve the features of its vernacular architecture, the AHP was used for weighting the evaluation criteria, and COPRAS, TOPSIS and WASPAS were applied to ranking the available alternative solutions.	The results show that a rational solution to the problems of daylighting in a reconstructed building and preserving its traditional features of vernacular architecture could be implemented in new glass structures.
Bagočius, Zavadskas and Turskis [169]	WASPAS	Wind turbine selection by using WASPAS	The construction of wind farms is a challenge of crucial importance to Lithuania.	MCDM methods represent a robust and flexible tool investigating and assessing possible discrete alternatives evaluated applying the aggregated WSM and WPM method, WASPAS.	Calculations were made applying WASPAS method, which showed that the best type of the wind power plant suitable for any conditions is REpower M5 5.0 MW Wind Turbine.
Turskis, Daniūnas, Zavadskas and Medzvieckas [196]	WASPAS grey	Used WASPAS grey for or choosing the kind of foundation for dwelling house with a single-story.	Building construction selection is the important issue for stakeholders, contractors and owners.	Integrated WASPAS approach with grey number for dwelling house.	The findings of this paper concluded that; the proposed approach has the high prediction accuracy with clear process and simple for evaluating and ranking of building foundation alternatives and attributes.
Lashgari, Antuchevičienė, Delavari and Kheirkhah [171]	QSPM and WASPAS	Used WASPAS for selection of the best outsourcing development strategies.	There is need to analysis the various internal and external factors which influencing on the outsourcing of healthcare services in Tehran.	Employed WASPAS and Quantitative Strategic Planning Matrix (QSPM) for evaluating and selecting of the best outsourcing strategy.	The findings of this study indicated that; the first five best ranked strategic options coincide WASPAS and QSPM.
Kazimieras Zavadskas, Baušys and Lazauskas [177]	WASPAS-SVNS	Used WASPAS approach for plant construction site for incineration of non-hazardous wastes.	There is need to consider all factors regarding sustainability for the waste incineration plant.	Integrated WASPAS with single-valued neutrosophic set for evaluating of sites for the construction of a Waste Incineration Plant.	Results of this paper concluded that; this territory is appropriate for the project implementation in the construction of a waste incineration plant.
Zavadskas, Antucheviciene, Saparauskas and Turskis [163]	WASPAS, MOORA and MULTIMOORA	Applied WASPAS, MOORA and MULTIMOORA for evaluating the robustness of methods.	There is a need for verifying the robustness of methods in assessing the alternative solutions.	The paper employs the innovative, newly developed WASPAS method and the reputed MOORA method, consisting of the Ratio System and the Reference Point approach as well as the Full Multiplicative Form and MULTIMOORA.	Based on the results of the research, the conclusion that newly developed WASPAS method seems to be robust can be confirmed. The validation of the method for real life applications can also be made.
Keshavarz Ghorabaee, Zavadskas, Amiri and Esmaeili [175]	WASPAS and IT2FSs	Proposed a novel approach by combining WASPAS approach and Interval type-2 fuzzy sets (IT2FSs) for green supplier selection.	There is need to find the best solution by integration of objective and subjective weights for solving problems related to green supplier selection by using MCDM techniques.	For solving green supplier selection this paper extended the WASPAS approach with interval type-2 fuzzy environment.	The findings of this study found that; the proposed approach is able to solve problems regarding green supplier selection.

Table A2
Distribution of papers based on SWARA approach.

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Hashemkhani Zolfani and Bahrami [187]	SWARA-COPRAS	Ranked high tech industries by employing SWARA.	A need for focusing on the priority of investment in high tech industries in Iran.	SWARA was used for evaluating and weighting the criteria, while COPRAS was employed for evaluating and ranking the alternatives.	The results yielded by COPRAS method show that Nano Technology is the best high tech industry to develop in Iran, while Biotechnology is at the second place of importance. Then follows BioMEMS, and Biomedical engineering is the last according to the priority order.
Keršuliene, Zavadskas and Turskis [66]	SWARA	Applied SWARA to evaluating and selecting a rational method of dispute resolution	In order to assess dispute resolution methods from economic, social and other perspectives, it is necessary to apply methods to assessing solutions based on multiple attributes.	SWARA method could be applied to practical implementation of specialised decision support systems and alternative dispute resolution in a virtual environment.	It has been proved that successful selection of a rational method for dispute resolution is based on the attribute weight determination by using SWARA method and the initial decision-making matrix normalised by applying linear normalisation method.
Karabasevic, Zavadskas, Turskis and Stanujkic [207]	SWARA and ARAS	Used SWARA for selection of personal.	Using decision making tools in hiring organizations are not common, therefore; need to suggest the new framework for choose the candidates in process of recruitment.	Integrated SWARA and ARAS approaches for personal selection.	Findings of this paper found that; the proposed model for selection of personal is easy to use and able to solving problems in this field.
Nakhaei, Lale Arefi, Bitarafan and Kapliński [214]	SWARA and SMART	Used SWARA to ranked and weighted of index and sub-index.	Need to assessment of building regarding of vulnerability to explosion.	Integrated SWARA and SMART for evaluating and calculating weights of index and sub-index.	The results of this paper found that; capability to decrease blast effect, remembering that location underground was the criterial factor of blast.

Table A2 (*Continued*)

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Karabasevic, Stanujkic, Urosevic and Maksimovic [209]	SWARA and MULTIMOORA	Used SWARA approach for personal selection in mining industry.	The recruitment and personal selection is the important part of human resource management and need to consider decision making approach in this field.	Used SWARA for determined weights of criteria and MULTIMOORA for ranking the alternatives.	Results of this paper found the proposed model can be used for solving problems related to personal selection and recruitment.
Jamali, Farrokhnejad and Mohammadi [215]	SWARA and COPRAS_G	Assess and analysis of advance manufacturing systems by integration of SWARA and COPRAS grey approaches.	Due to important and complexity of manufacturing systems decision process a new decision making is required.	Integrated SWARA and COPRAS grey to evaluate and analysis five kinds of manufacturing systems.	The findings of this study found that; operating cost was the important criterion in group of stability criteria.
Dehnavi, Aghdam, Pradhan and Morshed Varzandeh [216]	SWARA	Proposed new hybrid approach by integrated SWARA technique and ANFIS to assess landslide susceptible areas by applied geographical information system.	Due to important of landslides which the important concern for rural and urban areas and also infrastructures in Iran, there is need to evaluated landslides.	For solving problems in area of landslides, this paper integrated three techniques including SWARA, ANFIS and GIS.	The results of this study found that proposed approach better can predict to assess of landslides hazard in Iran.
Karabasevic, Paunkovic and Stanujkic [208]	SWARA and ARAS	Assessed and rank the indicators of corporate social responsibility by using two MCDM approaches including SWARA and ARAS.	Need to find the corporate social responsibility indicators due to increasing of company image and responsibility toward society.	Integrated SWARA and ARAS approaches for evaluation of CSR indicators and ranking companies.	Results of this paper found that; contribution to economic development had the highest weight among other CSR sub-criteria.
Stanujkic, Karabasevic and Zavadskas [210]	SWARA and group decision making	Used SWARA approach and group decision making to select the best packaging design to meet customers' requirements.	Identify the best and ideal solution for packaging design is the complex process and needs to use decision making approaches.	Integrated the SWARA approach and group decision making method for choose the best packaging design.	The findings of this paper found that the proposed model decrease is number of pairwise comparisons in previous MCDM methods such as AHP.
Hashemkhani Zolfani, Salimi, Maknoon and Kildiene [217]	SWARA	Proposed SWARA for evaluation the new framework for R&D projects based on technology foresight.	Due to significant the role of technology foresight in developing the country economy, need to consider it as the most important government sections.	Used SWARA approach as the efficient MADM approach for evaluation of technology foresight criteria in high level of decision making.	The outcomes of this study found that, the technological merit factor was the important factors.

Table A2 (*Continued*)

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Shukla, Mishra, Jain and Yadav [211]	SWARA and PROMETHEE	Used SWARA and PROMETHEE approaches to select the best ERP system and competent in company.	ERP system selection is the important task in the enterprises due to changing the current environments.	For chose the suitable component and ERP system this study integrated the SWARA and PROMETHEE approaches.	The results of this paper found that good technical capability, system vendors and service support were the significant factors in selection of ERP system.
Hashemkhani Zolfani, Zavadskas and Turskis [184]	SWARA and YYB theory	Used SWARA approach for ranking the important criteria in producing and designing products.	producing and designing products is the very criterial issue	Integrated SWARA method and Yin-Yang balance (YYB) theory for product producing and designing.	The outcomes of this study indicated that; the important criterion in producing and designing products was considering important general features of each product and applications.
Nakhaei, Lale Arefi, Bitarafan and Kildienė [218]	SWARA and COPRAS	Integrated SWARA and COPRAS to assess the light supply in the public underground safe spaces.	Need to consider the resources management light supply possess is very important issue underground safe spaces.	Used SWARA for determine the best index among various indexes and COPRAS approach for select the best strategy.	Findings of this paper found that; lamp with battery source was the light supply for the city shelters.
Kouchaksaraei, Hashemkhani Zolfani and Golabchi [219]	SWARA and COPRAS	Integrated SWARA and COPRAS for glasshouse locating.	Need to consider the glasshouse as the important factors in the prevalent greenhouses.	Applied SWARA to evaluating the criteria of glasshouse locating and used COPRAS for assessing the alternatives.	The findings of this propose approach able to solving problems related to locating and other issues.
Aghdaie, Hashemkhani Zolfani and Zavadskas [212,213]	SWARA and VIKOR	Used two MADM approaches including SWARA and VIKOR to finding synergies of MADM and data mining.	Need to identify the interaction of MADM and data mining for supplier ranking and clustering.	Suggested the new hybrid approach based on DM-MADM for clustering and ranking of supplier.	The results of this paper found that; the hybrid model presents the systematically analytic approach for raking and clustering in the real problems with a integrating of decision making and MCDM methods.

Table A3
Distribution of papers based on integration of SWARA and WASPAS approaches.

Author	Technique and method	Research Objective	Research gap and problem	Solution and modeling	Results and findings
Hashemkhani Zolfani, Maknoon and Zavadskas [224]	SWARA and WASPAS	Evaluated Nash equilibrium strategies by applying SWARA and WASPAS	When there are at least two Nash equilibriums, what do researchers do? Why did they not evaluate Nash equilibriums?	Strategy evaluation based on MCDM methodology is considered for decision making, when there are more than two Nash equilibriums.	The study shows how this new framework can be effective in policy-makers' future decisions with respect to critical issues, when at least two different Nash equilibriums exist.
Ghorshi Nezhad, Hashemkhani Zolfani, Moztarzadeh, Zavadskas and Bahrami [220]	SWARA-WASPAS	Used SWARA for evaluating and ranking high technology selection.	Planning for future in every level of organization is important duty because of exist of various criteria.	Integrated SWARA for finding the weights of criteria and applied WASPAS for ranking the alternatives.	The findings of this paper found that; the attractiveness as aspect was the first ranked and research and technology potential had the first rank in sub-criteria in ranking of high tech industry.
Karabašević, Stanujkić, Urošević and Maksimović [221]	SWARA and WASPAS	Integrated SWARA and WASPAS for personnel selection.	Personnel selection and recruitment process is important role in the human resource management in every organization.	Used SWARA for evaluate weights of criteria and WASPAS for assessing of the alternatives.	Findings of this paper found that interview preparedness had the first rank among other criteria.
Heidarzade, Varzandeh, Rahbari, Zavadskas and Vafaeipour [222]	SWARA and WASPAS	Used SWARA and WASPAS for selection of best site regarding wind energy.	Finding the best location site for wind energy is the critical issue in Iran.	Applied SWARA for evaluate weight of criteria and used WASPAS for assessing the alternatives.	The finding of this study is useful for decision maker related to wind energy.
Vafaeipour, Hashemkhani Zolfani, Morshed Varzandeh, Derakhti and Keshavarz Eshkalag [223]	SWARA and WASPAS	To implement solar projects by applying SWARA and WASPAS techniques.	Lack of attention to solar power plants in Middle East countries, such as Iran.	Finding 29 quantitative and qualitative criteria based on experts' opinions and literature.	Ranking of solar projects in 25 cities of Iran, in which Yazd was ranked first and economical perspective, was ranked first in criteria.
Hashemkhani Zolfani, Aghdaie, Derakhti, Zavadskas and Morshed Varzandeh [166]	SWARA and WASPAS	The authors applied SWARA to selecting the shopping mall location.	There is a lack of previous studies considering all criteria for selecting the mall location.	The authors of this paper believe that SWARA and WASPAS are powerful techniques for solving these kinds of problems.	The results of this study demonstrated that decision criteria can be significant for selecting the shopping mall location.

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