VIKOR Technique: A Systematic Review of the State of the Art Literature on Methodologies and Applications

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Abstract: The main objective of this paper is to present a systematic review of the VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) method in several application areas such as sustainability and renewable energy. This study reviewed a total of 176 papers, published in 2004 to 2015, from 83 high-ranking journals; most of which were related to Operational Research, Management Sciences, decision making, sustainability and renewable energy and were extracted from the "Web of Science and Scopus" databases. Papers were classified into 15 main application areas. Furthermore, papers were categorized based on the nationalities of authors, dates of publications, techniques and methods, type of studies, the names of the journals and studies purposes. The results of this study indicated that more papers on VIKOR technique were published in 2013 than in any other year. In addition, 13 papers were published about sustainability and renewable energy fields. Furthermore, VIKOR and fuzzy VIKOR methods, had the first rank in use. Additionally, the Journal of Expert Systems with Applications was the most significant journal in this study, with 27 publications on the topic. Finally, Taiwan had the first rank from 22 nationalities which used VIKOR technique.

Keywords: decision making; energy; VIKOR; sustainability; multiple criteria decision making (MCDM); renewable

1. Introduction

The Multiple criteria decision making (MCDM) techniques such as VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) are usually used to evaluate and compare the sustainability of various energy plans or renewable energy technologies with the goal to present decision support for selecting the significant sustainable and appropriate options. Several of previous studies have used VIKOR technique in sustainability and renewable energy fields. Sustainability and renewable energy fields cover several specific sub-areas, including life cycle sustainability assessment, energy resources, environmental management, and environmental evaluation. As the product of an intentionally vague definition, sustainability has been applied to mean everything from environmental protection, social cohesion, economic growth, neighborhood design, alternative energy, green building design, and more [1]. The modern understanding of sustainability is characterized by the struggle to define and

quantify sustainability and its goals. The term sustainability has its roots in long-held "sustainable" beliefs and principles, but that term has changed significantly during the emergence of the concept of sustainable development, and modern-day interpretation and discussion. Without a firm hold on the defining principles, any initiative to move closer to sustainable development will likely fail. In recent years, use of the sustainable and renewable energy has increased in real world.

Several of previous studies focused on sustainable and renewable energy in various perspectives with different approaches of MCDM such as VIKOR method. Recently; Mardani *et al.* [2] selected, summarized and reviewed 54 papers which were related to renewable and sustainable energy and decision making techniques, these 54 papers published from 2003 to 2015, Vučijak *et al.* [3] evaluated of sustainable hydropower by applied the VIKOR, Quijano H *et al.* [4] used VIKOR for development of renewable sustainable energy plans, Tzeng *et al.* [5], used VIKOR and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for identify improvement strategies to residents satisfaction by define the people response to environmental quality. Results of this study indicated that; noise pollution and air quality were the important criteria of environmental quality in Taipei. Martin-Utrillas, *et al.* [6] integrated the VIKOR, fuzzy Delphi and Analytic Hierarchy Process (AHP) for selection of best infrastructure related to sustainable economy, Yazdani-Chamzini *et al.* [7] used the VIKOR, Simple Additive Weighting (SAW), Additive Ratio Assessment (ARAS), TOPSIS and Multi-Objective Optimization by Ratio Analysis (MOORA) for selection of the best renewable energy sources, Ren *et al.* [8] combined the VIKOR and AHP for assessment of life cycle sustainability, Civic and Vucijak [9] utilized VIKOR for insulation options for warmth of buildings to increase energy efficiency, Kim and Chung [10] evaluated the vulnerability of the water supply to variability and climate change.

MADM methods provide simple and intuitive tools for making decisions on problems that involve uncertain and subjective information. Since the early 1970s, these methods have been developed into many forms. Among them, the simple MCDM methods cover a wide range of quite distinct approaches [11–13]. In recent years, numerous MCDM and fuzzy MCDM approaches have been suggested to select the best compromise options. These approaches have been suggested for different problems in real world which need to consider as multi criteria by decision makers for improving and solving in various fields of mathematical optimization, computer science and computer technology [14]. Several of previous studies related to MCDM techniques were developed during 1980s and early of 1990s. [15]. Köksalan, Wallenius and Zionts [15], presented a history of MCDM development methods in a book. Mardani *et al.* [16], reviewed 403 papers most related to fuzzy MCDM from 1994 to 2014. Mardani *et al.* [17], classified around 393 papers related to classical MCDM techniques in various application areas. Keeney *et al.* [18], developed the basics of decision with multiple objectives for improvement the body of knowledge regarding to decision making techniques. Hwang *et al.* [19], reviewed the development of Multi-Objective Decision Making (MODM) techniques and its applications. Later, Tzeng and Huang [20] reviewed and documented the Multi-attribute Decision Making (MADM) techniques such as The Linear Programming Technique for Multidimensional Analysis of Preference (LINMAP), ELimination and Choice Expressing REality (ELECTRE), TOPSIS and SAW. In addition, recently; Mardani *et al.* [21] reviewed and classified fuzzy MCDM and classical MCDM techniques based on the service quality. In recent years; very few studies reviewed and summarized role of VIKOR method and its application in various fields of sciences. Therefore, this review paper aimed to document the role of VIKOR technique and its applications in various fields of science.

The AHP and Analytic Network Process (ANP) methods developed by Saaty [22]. In addition; problem of compromise theory provided in a book by Zeleny and Cochrane [23], Hwang and Lin [24], published an article related to multi-criteria group decision making. Roy [25], proposed and developed some information on ELECTRE group techniques. In addition, same previous scholars published some papers about seminal techniques Belton and Stewart [26]; (Gal *et al.* [27], Miettinen [28]). Furthermore; in recent years; based on Brauers [29] were created MOORA. There are some other

well-known techniques such as ANP [30], VIKOR [31,32], TOPSIS [33], SAW [34], AHP [35,36], Decision-Making Trial and Evaluation Laboratory (DEMATEL) [37], Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) [38], Data Envelopment Analysis (DEA) [39,40], ELECTRE [41–44]. Additionally, some new MCDM techniques developed in recent years, these techniques are; generalized regression with intensities of preference (GRIP) [45], Complex Proportional Assessment Method (COPRAS) [46–48], ARAS [48–50], MOORA [51], and MOORA plus the full multiplicative form (MULTIMOORA) [52], Step-Wise Weight Assessment Ratio Analysis (SWARA) [53], Weighted Aggregated Sum Product Assessment (WASPAS) [54].

The primary study of VIKOR was developed by Opricovic in a PhD dissertation in 1979 and also then by an application in 1980. This paper attempted to offer a comprehensive review of literature on VIKOR technique applications and methodologies. For this goal a reference database has been created according to classification scheme including 176 previous papers which published in 83 international journals since 2004 from two popular databases, *i.e.*, Web of Science and Scopus. Moreover, papers are classified based on author (s) and years on publications, technique and approach, type of study, nationality of author (s), application area and scope, study purpose and name of journal.

The rest of the paper is organized as follows: Section 2 explained the important role of VIKOR technique in literature and previous studies, and the steps for implementation of the VIKOR. Section 3 describes methodology of this paper for papers classification. Section 4 conducts reviewed papers based on application areas, which is organized into 15 application areas, frequently of integrated techniques with VIKOR, journals names, publication year and nationality of authors. Finally, the conclusion of the paper is offered in Section 5.

2. Chronology of VIKOR Technique

Opricovic [31], introduced the VIKOR method as well-known MCDM technique which emphasized on select and rank of alternatives sets of conflicting criteria, in recent years this technique more evolved by scholars. Opricovic and Tzeng [55], proposed new model based on VIKOR method and TOPSIS for defuzzification within the multiple criteria decision making model with combined fuzzy criteria and set of crisp. Opricovic and Tzeng [32], proposed and integrate VIKOR technique with triangular fuzzy numbers (TFNs) for analysis of the planning strategies. Opricovic and Tzeng [56], developed fuzzy VIKOR with incomplete information for analyze of land-use strategies for decrease the economic and social costs with potential natural hazards. Opricovic and Tzeng [57], indicated that, the TOPSIS defines solution with the farthest distance from the negative ideal solution and shortest distance from the ideal solution, but it does not consider the relative importance of these distances. Tzeng *et al.* [58], used VIKOR, AHP and TOPSIS techniques to determining of the best fuel alternatives in the technological development of buses. Opricovic [59], applied and extended fuzzy VIKOR technique for solving problems in environmental issues. Opricovic and Tzeng [60], extended VIKOR technique for solving MCDM problems, results of this extended VIKOR compared with three different MCDM techniques including PROMETHEE, TOPSIS and ELECTRE. Chen and Wang [61], presented a systematic and rational process to develop the optimal compromise solution and alternative under criteria selection by using VIKOR method and fuzzy set. Finding of this study suggested new solution for fuzzy MCDM problems. Opricovic [62], indicated that; comparison of game theory and MCDM is a challenging topic, choosing and combining opinions can improve new approaches for developing conflict resolution, then; Opricovic [62], employed VIKOR method and game theory for conflict resolution, in this study, five approaches are considered based on conflict resolution. Huang *et al.* [63], developed a VIKOR model for MCDM which was used to determine the preference ranking from a set of alternatives in the presence of conflicting criteria. Moeinzadeh and Hajfathaliha [64], presented a supply chain risk assessment model based on ANP and VIKOR methods with integrated fuzzy set theory where the subjectivity and vagueness were handled with linguistic terms parameterized by TFNs. Sayadi, *et al.* [65], proposed the VIKOR technique for decision making problems with the interval number where ranking is achieved by

interval numbers comparison. Opricovic [66], applied the VIKOR technique for solving decision problems in water resource management. In this paper some criteria such as environmental, social, economic and cultural features have been considered for developing reservoir system of the Mlava River. Chang [67], proposed a modified VIKOR method to solve MCDM problems with contradicting and non-commensurable criteria. Heydari *et al.* [68], extended VIKOR technique for solving problem based on multi-objective large-scale non-linear programming (MOLSNLP) problems and integrated with block angular structure. Sanayei *et al.* [69], applied the VIKOR technique under fuzzy set and group decision making (DM) process for selection of suppliers. Vahdani *et al.* [70], presented a novel method for solving MCDM problems based on the interval-valued fuzzy VIKOR in which the weights of criteria are unequal, using interval-valued fuzzy set concepts. Devi [71], extended VIKOR method into fuzzy environment in order to solve Multi criteria Decision Making in which weights of criteria and alternatives are taken as triangular fuzzy set. Kuo and Liang [72], integrated VIKOR with gray relational analysis (GRA) for evaluation of problems related to service quality. Park *et al.* [73], extended the VIKOR method for multi-criteria group decision making (MAGDM) in interval-valued intuitionistic fuzzy (IVIF) environment which preference information is presented by DMs as IVIF decision matrices. Liu and Wang [74], extended VIKOR technique for solving problems in MAGDM by generalized IVTF numbers, in which the attribute values and weights are given. Du and Liu [75], extended VIKOR technique for solving decision making problems based on ITF numbers. Su [76], proposed a new hybrid fuzzy method by a modified VIKOR method modified GRA method, to the negative ideal alternative and the positive ideal alternative. Liu and Wu [77], applied the VIKOR method and entropy to evaluate human resources managers' competency. Liu *et al.* [78], integrated and proposed the induced aggregation operators into the VIKOR for tackling multiple-criteria problems. Liao and Xu [79], extended and presented the VIKOR technique by employing the hesitant normalized Manhattan distance to accommodate the hesitant fuzzy circumstances. Wan *et al.* [80], extended the VIKOR technique for solving multi-criteria group decision making problems with triangular intuitionistic fuzzy numbers (TIFNs). Zhao *et al.* [81], presented an extended VIKOR technique for solving problems in multi-criteria group decision making based on cross-entropy in the IVIFs. Tan and Chen [82], proposed a decision-making method by integrating VIKOR technique and Choquet integral for solving problems of MCDM techniques with IVIFs. Vinodh *et al.* [83], presented the application of fuzzy VIKOR for concept selection in the context of agile systems. The best concept design was identified in the context of agility. The results derived from fuzzy VIKOR were compared with fuzzy TOPSIS. Ju and Wang [84], proposed a new method to solving MCGDM related to criteria weights and criteria values take the form of linguistic information based on the traditional idea of VIKOR method. Zhang and Wei [85], developed the extended VIKOR and TOPSIS to solve the multiple attribute decision marking problems with hesitant fuzzy set information. Liao and Xu [79], extended the classical VIKOR method to provide of hesitant fuzzy circumstances and improved the hesitant normalized Manhattan Lp—metric, the hesitant fuzzy individual regret measure, the hesitant fuzzy group utility measure and the hesitant fuzzy compromise measure for present a new hesitant fuzzy VIKOR. Park *et al.* [86], extended the VIKOR technique for dynamic intuitionistic fuzzy MADM. This study presented two new aggregation operators which called dynamic intuitionistic fuzzy weighted geometric (DIFWG) and uncertain dynamic intuitionistic fuzzy weighted geometric (UDIFWG) operator for solving problems of dynamic intuitionistic fuzzy MADM. Wei and Zhang [87], developed and presented a multi-criteria hesitant fuzzy decision-making by using of the Shapley value and VIKOR technique. Hajiagha *et al.* [88], presented a fuzzy multi-objective linear programming based on VIKOR method to find fuzzy efficient solution by minimizing its combinational distance from an ideal and nadir solution. Pai *et al.* [89], presented a novel decision making technique based on four kinds of MCDM techniques (VIKOR, PROMETHEE, ELECTRE and TOPSIS), intersection concepts and linguistic information. Keshavarz Ghorabaee [90], extended the VIKOR method for selection of project with interval type-2 fuzzy environment. You *et al.* [91], extended the VIKOR for supplier selection based on interval 2-tuple linguistic. Li and Zhao [92], proposed new VIKOR according to prospect

theory with grey number. Qin *et al.* [93], extended VIKOR for MADM based on interval type-2 fuzzy environment by propose a new distance measure for interval type-2 fuzzy set (IT2FS) and decision model integrating VIKOR and theory of prospect. Zhu *et al.* [94], combined the VIKOR and AHP to evaluate the design concept in development of new product. Keshavarz Ghorabaee [95], extended the VIKOR method with interval type-2 fuzzy sets for selection of robots. Bausys and Zavadskas [96], extended VIKOR technique for solving multi criteria decision making based in interval neutrosophic set environment. Figure 1 shows diagram of modified VIKOR technique presented by [97].
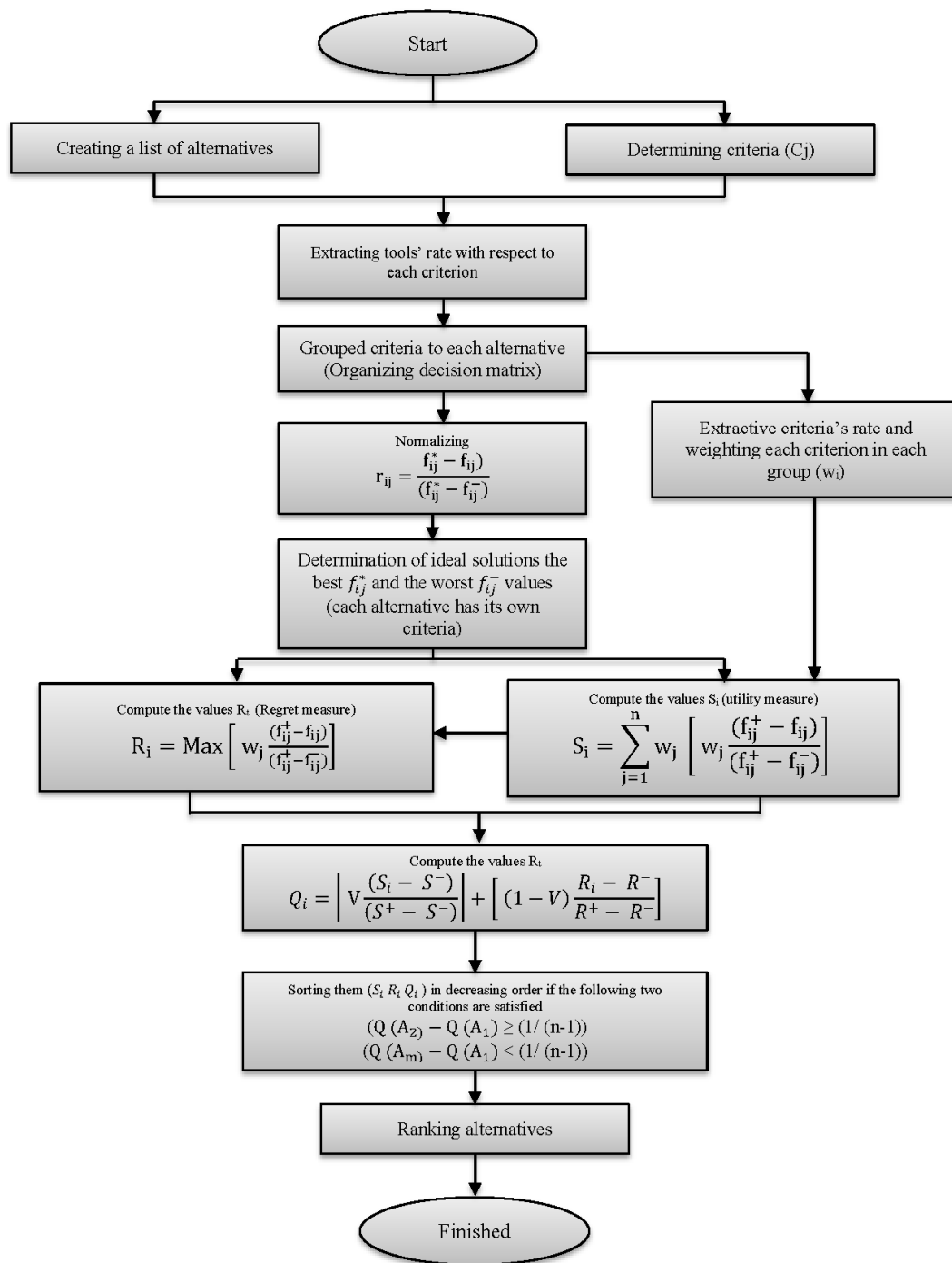

Figure 1. Diagram of modified VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) technique adopted from [97].

3. Research Methodology

This review paper attempted to review the published papers in various application areas related to the VIKOR technique. Therefore; this review paper searched to identify the papers related to VIKOR technique in various parts of published papers such as keywords, title, research method, results, conclusions and discussions. In relation to classification scheme, a reference repository has been established, which included a total of 176 papers in 83 international scholarly journals from 2004 to 2015. The papers were categorized based on the application areas, year of publication, name of the journal, study purpose, type of study (utilized, proposed, integrated, modified or extended types) and VIKOR technique and integrated with other techniques. This present review paper, first, classified of the articles into 15 fields (Manufacturing, Construction Management, Material Selection, Performance Evaluation, Health-Care, Supply Chain, Tourism Management, Service Quality, Sustainability and Renewable Energy, Water Resources Planning, Marketing, Risk and Financial management, Operation Management, Human Resource Management, other application areas) and second, examine of the type of study (utilized, proposed, integrated, modified or extended types), and third, articles reviewed based on research purpose and goal.

The target databases for this review paper were "Scopus and Web of Science" as two important databases which cover the extensive range of scopes of journals. Items such as textbooks, doctoral dissertations, unpublished papers and master's theses, were excluded in our review. In this review paper, we attempted to use the comprehensive list of journals indexed by two databases.

In recent years, scholars presented, extended and applied the VIKOR technique in various fields of sciences which are different in kind of questions, theoretical background, and the kind of achieved results. Various criteria and keywords should be considered for identifying and selecting published papers related to VIKOR technique. Figure 2 presented the systematic review of analysis and procedure. In this review paper we conduct a systematic review, a rigorous review methodology originally developed mainly within medical research and first outlined for the field of organization and management studies by [98]. Systematic reviews exhibit significant advantages compared to traditional narrative approaches of literature reviews. Those traditional reviews generally do not follow a formal methodology, thus resulting in lacking transparency and replicability by others. Researchers can focus on "preferred" literature sources and base their review on a personal, purposive selection of materials they believe to be important. Systematic reviews help to reduce those implicit researcher biases [99]. Through the adoption of search strategies, predefined search strings as well as inclusion/exclusion criteria, systematic reviews effectively force researchers to search for all relevant studies beyond their own horizon of experience. Furthermore, the application and extensive documentation of a clear review protocol improves the methodological transparency of the review and enables future replication by other researchers. As the motivation and research questions of the review have already been outlined in the introduction, the remainder of this part emphasis on how the this review paper is conducted and describe in detail the search strategy, selection criteria and synthesis criteria applied in this paper. Our search strategy consisted of looking for relevant studies within scientific literature sources, represented by academic studies published in peer-reviewed journals. We searched online databases to identify all articles published on the VIKOR technique between 2004 and 2015.
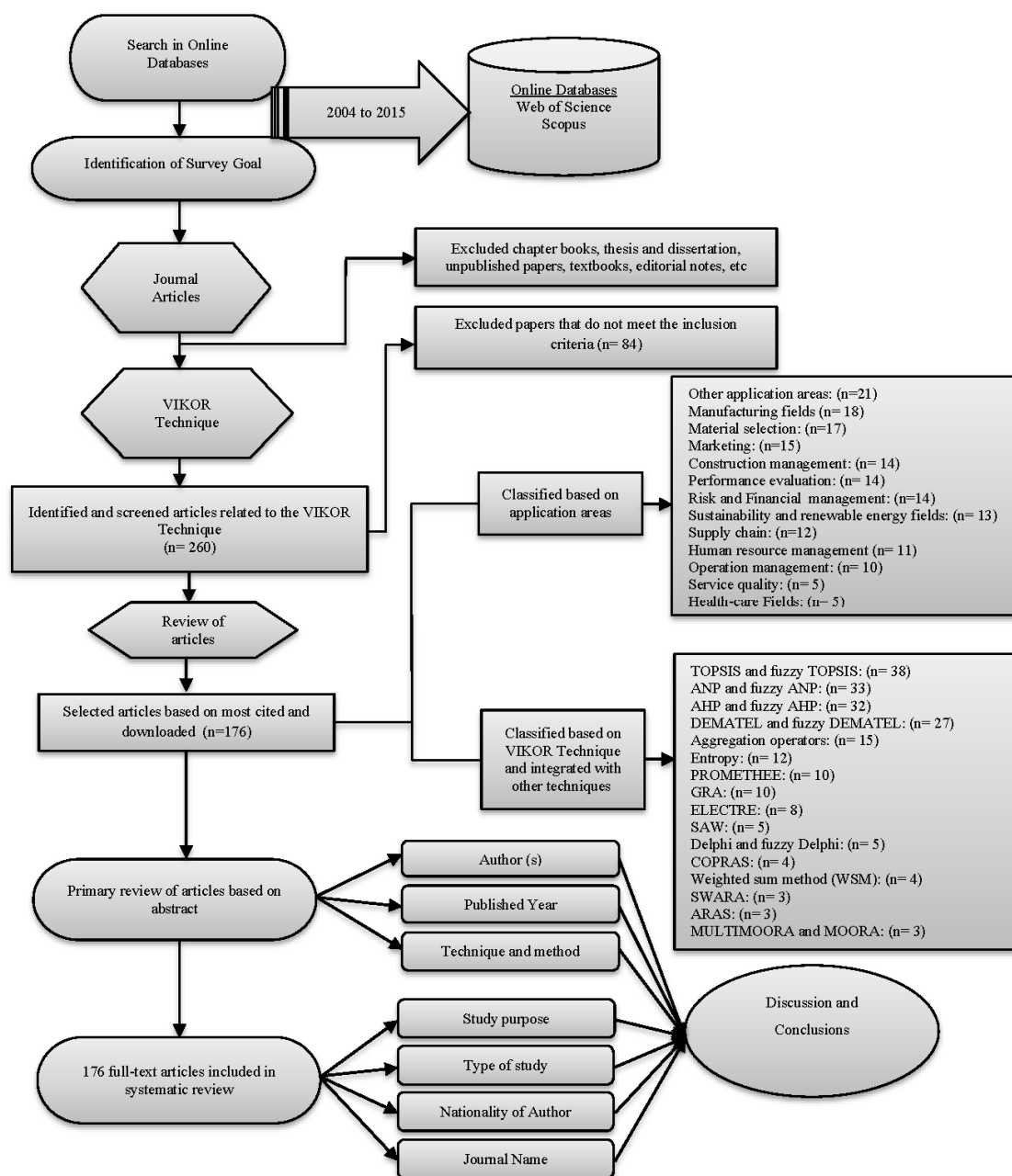
Figure 2. Summary of Analysis and Procedure of Study.

4. Results

4.1. Classifications and Observations

In recent decades, research related to VIKOR technique has continued, and many new areas to which it can be applied have been found. VIKOR technique provides effective decision-making method in domains in which selection of the best alternative is highly complex environment. This survey reviews the main considerations of VIKOR technique in various fields based on theory and practice. The VIKOR technique aids in identifying the best alternatives *in situ*ations with multiple criteria; the best choice can be obtained by analyzing different scopes and weights of the criteria. This survey comprehensively shows the development of VIKOR technique and its applications in the 15 various topics. This survey is based on a literature review and classification of international journal articles from 2004–2015.

All selected papers were classified in 15 different application areas such as Manufacturing Fields, Construction Management, Material Selection, Performance Evaluation, Health-Care, Supply Chain, Tourism Management, Service Quality, Sustainability and Renewable Energy fields, Water Resources Planning, Marketing, Risk and Financial management, Operation Management, Human Resource Management, other application areas. Table 1 presented the distribution papers based on application fields.

Table 1. Distribution papers based on application fields.

Application Fields	Number of Paper	Percentage (%)
Manufacturing fields	18	10.23%
Material selection	17	9.66%
Marketing	15	8.52%
Construction management	14	7.95%
Performance evaluation	14	7.95%
Risk and Financial management	14	7.95%
Sustainability and renewable energy fields	13	7.39%
Supply chain	12	6.82%
Human resource management	11	6.25%
Operation management	10	5.68%
Service quality	5	2.84%
Health-care Fields	5	2.84%
Tourism management	4	2.27%
Water resources planning	3	1.70%
Other application areas	21	11.93%
Total	**176**	**100.00%**

4.2. Field of Category

Several application areas applied the VIKOR technique in the real world; there is a strong motivation to categorize these techniques across several areas and particular sub-areas. The studies that have used the VIKOR technique are categorized into four groups: utilizing research (the study exclusively used VIKOR as a single technique), integrated research (VIKOR is integrated with other techniques), proposed research (VIKOR was proposed to be applied in the study), and modified research (modified VIKOR technique was applied in the study). To identify the differences and similarities, the 176 papers were categorized into 15 fields: (1) Manufacturing, (2) Construction management, (3) Material Selection, (4) Performance Evaluation, (5) Health-care, (6) Supply Chain, (7) Tourism Management, (8) Service Quality, (9) Sustainability and Renewable Energy, (10) Water Resources Planning, (11) Marketing, (12) Risk and Financial Management, (13) Operation Management, (14) Human Resource Management, (15) Other application areas. Similarly, study by Behzadian, *et al.* [100] have categorized TOPSIS papers based on various application areas such as, environmental science, manufacturing systems, supply chain issue, human resource management (HRM), energy and safety, business and management and so on. It is interesting to note that while the technique is originally used in water resources research [66], it has increasingly been applied by authors from both applied and social sciences. The next sections provide a review of the 176 papers categorized into 15 application areas.

4.2.1. Manufacturing Fields

Manufacturing fields cover several specific sub-areas including robot selection, product design, manufacturing strategy, product development, machine tools, and manufacturing systems. Keshavarz Ghorabaee [95], extended the VIKOR method with interval type-2 fuzzy sets for selection of robots. Liu *et al.* [101], proposed new method for failure mode and effects analysis based on the fuzzy VIKOR, fuzzy AHP and entropy. Peng *et al.* [102], combined the VIKOR technique, intuitionistic fuzzy sets (IFSs) and Taguchi to optimize quality problems solving. Zhu, Hu, Qi, Gu and Peng [94] integrated

AHP and the VIKOR to evaluate design concept in development of new product, Anvari, Zulkifli and Arghish [97], modified VIKOR for lean tools selection in manufacturing systems problems. Tzeng and Huang [103] combined the VIKOR, ANP and DEMATEL for selection of the best global manufacturing strategy selection, Mousavi, *et al.* [104] proposed a novel fuzzy VIKOR for selection of new products for manufacturing companies success, Büyüközkan and Görener [105] applied the VIKOR and AHP to evaluate product development partners. Table 2, presented the VIKOR papers addressed within manufacturing fields based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. In total, 18 past papers used the VIKOR technique in fields of manufacturing.

Table 2. Distribution of papers in manufacturing fields.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Vinodh *et al.* [106]	VIKOR	Utilized	Manufacturing environment	Selection of fit concept in the modern manufacturing environment.
Chatterjee *et al.* [107]	VIKOR and ELECTRE	Integrated	Robot selection	Integrated VIKOR and ELECTRE for selection of industrial robots.
Keshavarz Ghorabaee [95]	VIKOR and Interval type-2 fuzzy sets	Extended	Robot selection	Extended VIKOR for selection of robots.
Devi [71]	Fuzzy VIKOR	Extended	Robot selection	Extended VIKOR for robot selection in intuitionistic fuzzy environment.
Zhu, Hu, Qi, Gu and Peng [94]	VIKOR and AHP	Integrated	Product design	Evaluation of design concept for combine VIKOR and AHP.
Parameshwaran *et al.* [108]	Fuzzy VIKOR, fuzzy TOPSIS, fuzzy AHP and fuzzy Delphi	Integrated	Robot selection	Combined Fuzzy VIKOR, fuzzy TOPSIS, fuzzy AHP and fuzzy Delphi for selection of robot.
Liu, You, You and Shan [101]	Fuzzy VIKOR, fuzzy AHP and entropy	Integrated	FMEA	Presented a new method for FMEA by apply fuzzy VIKOR, fuzzy AHP and entropy.
Peng, Yeh, Lai and Hsu [102]	VIKOR and IFSs	Integrated	Taguchi	Mixed VIKOR and Taguchi for optimization of multi-response problems in IF environments.
Bairagi *et al.* [109]	Fuzzy VIKOR, fuzzy AHP, fuzzy TOPSIS and COPRAS-G	Integrated	Robot selection	Applied Fuzzy VIKOR, fuzzy AHP, fuzzy TOPSIS and COPRAS-G for selection of robot.
Wang and Wu [110]	VIKOR	Utilized	Product varieties	Utilized VIKOR and KANO model for combine customer preferences and perceptions.
Feng *et al.* [111]	VIKOR and PROMETHEE II	Proposed	Equilibrium design	Proposed model based on VIKOR and PROMETHEE II for equilibrium design.
Anvari, Zulkifli and Arghish [97]	VIKOR	Modified	Lean tool	Modified VIKOR for selection of lean tool.
Tzeng and Huang [103]	VIKOR, ANP and DEMATEL	Integrated	Global manufacturing strategy	Combined VIKOR, ANP and DEMATEL for selection of the best global manufacturing strategy selection.
Mousavi, Torabi and Tavakkoli-Moghaddam [104]	Fuzzy VIKOR	Proposed	Product Selection	Proposed a novel fuzzy VIKOR for selection of new products.
Büyüközkan and Görener [105]	VIKOR and AHP	Utilized	Product development	Evaluated of product development by applied VIKOR and AHP.
Zhang and Xu [112]	VIKOR	Utilized	Machine tools	Employed VIKOR for transmission system accuracy best allocation for multi-axis machine tools.
Chaturvedi and Singh [113]	VIKOR	Utilized	Manufacturing Systems	Applied VIKOR for analysis of control parameters in abrasive water jet machining.
Vinodh *et al.* [114]	Fuzzy VIKOR	Utilized	Rapid prototyping technology	Used fuzzy VIKOR for selection of the best rapid prototyping technologies in agile environment.

4.2.2. Construction Management

Construction Management covers several specific sub-areas including project manager selection, tunneling, building fields, transportation systems. Table 3, presented the VIKOR papers addressed within Construction Management based on author (s) and year, technique and approach, type of study,

application area and scope and study purpose. Peng [115] combined VIKOR, TOPSIS, ELECTRE III, GRA, PROMETHEE II, and weighted sum model (WSM) for assessment of earthquake vulnerability, Zolfani *et al.* [116] combined the VIKOR and SWARA for selection of mechanical longitudinal ventilation of tunnel pollutants, Ginevičius *et al.* [117] combined the VIKOR and TOPSIS for assessment of alternatives of wall insulation, Zavadskas and Antuchevičiene [118] integrated the VIKOR and TOPSIS for ranking of building redevelopment, Mela *et al.* [119] integrated VIKOR with weighted product method, TOPSIS and PROMETHEE II, weighted sum method for evaluation of building design, Pamučar and Ćirović [120] presented new model based on DEMATEL–Multi-Attributive Border Approximation area Comparison (MABAC) for decision assessment on the acquisition of manipulative transport. Ebrahimnejad *et al.* [121], integrated a modified ANP with the VIKOR for selection construction project. Totally, 14 articles used the VIKOR technique in the fields of Construction Management (Table 3).

Table 3. Distribution of papers in Construction Management.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Ginevičius, Podvezko and Raslanas [117]	VIKOR and TOPSIS	Integrated	Wall insulation	Combined VIKOR and TOPSIS for assessment of alternatives of wall insulation;
Abbasianjahromi *et al.* [122]	VIKOR	Utilized	Subcontractor selection	Used VIKOR for selection of subcontractor.
Mohammadi, *et al.* [123]	VIKOR and ANP	Integrated	Project manager selection	Integrated VIKOR CANP for selection of project manager.
Lanjewar *et al.* [124]	VIKOR, TOPSIS and AHP	Integrated	Fuels transportation	Employed for evaluation of fuels for transportation.
Peng [115]	VIKOR, TOPSIS, ELECTRE III, GRA, PROMETHEE II, and WSM	Utilized	Earthquake vulnerability	Combined VIKOR, TOPSIS, ELECTRE III, GRA, PROMETHEE II, and WSM for assessment of earthquake vulnerability.
Zolfani, Esfahani, Bitarafan, Zavadskas and Arefi [116]	VIKOR and SWARA	Integrated	Tunneling	Combined VIKOR and SWARA for selection of mechanical longitudinal ventilation of tunnel pollutants.
Zavadskas and Antuchevičiene [118]	VIKOR and TOPSIS	Integrated	Buildings' redevelopment	Integrated VIKOR and TOPSIS for ranking of building redevelopment.
Vučijak, *et al.* [125]	VIKOR, PVIKOR and PROMETHEE	Integrated	Highway Tunnel Doors	Mixed VIKOR, PVIKOR and PROMETHEE for selection optimal choice of highway tunnel doors.
Mela, Tiainen and Heinisuo [119]	VIKOR, weighted product method, TOPSIS and PROMETHEE II, weighted sum method	Integrated	Building design	Integrated of VIKOR, weighted product method, TOPSIS and PROMETHEE II, weighted sum method for evaluation of building design.
Tošić, *et al.* [126]	VIKOR	Utilized	Concrete production	Applied VIKOR for selecting the transport scenario and aggregate type in concrete production.
Pamučar and Ćirović [120]	VIKOR, DEMATEL MABAC, SAW, MOORA COPRAS and TOPSIS	Proposed	Manipulative transport	Presented new model based on DEMATEL–MABAC for decision assessment on the acquisition of manipulative transport.
Vahdani, *et al.* [127]	VIKOR	Proposed	Contractor selection	Proposed new model based on VIKOR method for contractor selection.
Ebrahimnejad, Mousavi, Tavakkoli-Moghaddam, Hashemi and Vahdani [121]	fuzzy VIKOR and fuzzy ANP	Integrated	Construction project selection	Integrated a modified ANP with VIKOR for selection construction project.
Bashiri, *et al.* [128]	Fuzzy VIKOR	Utilized	Transportation systems	Applied fuzzy VIKOR for solve of hub location problem.

4.2.3. Material Selection

Table 4, presented the VIKOR papers addressed within Material Selection based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Liu, Mao, Zhang and Li [78] integrated and proposed the induced aggregation operators into the VIKOR for tackling multiple-criteria problems, Hsu *et al.* [129] integrated VIKOR, DEMATEL and ANP for vendor selection based on recycled materials, Chatterjee *et al.* [130] used the VIKOR method and ELECTRE for material selection, Chauhan and Vaish [131] used the VIKOR method and TOPSIS for magnetic material selection, Çalışkan *et al.* [132] applied VIKOR, PROMETHEE II, AHP, entropy and TOPSIS for material selection, Çalışkan [133] applied the VIKOR method, PROMETHEE II and TOPSIS for material selection. Yazdani and Payam [134] applied the VIKOR method and TOPSIS to develop MEMS technology, Anojkumar *et al.* [135] combined the VIKOR method with fuzzy AHP TOPSIS, ELECTRE and PROMETHEE for selection of pipe material. Totally, 17 past papers used the VIKOR technique in the fields of Material Selection which presented in Table 4.

Table 4. Distribution of papers in Material Selection.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Liu, Mao, Zhang and Li [78]	IOWA-VIKOR	Integration	Material selection	Integrated and proposed the induced aggregation operators into VIKOR for tackling multicriteria problems.
Hsu, Wang and Tzeng [129]	VIKOR, DEMATEL and ANP	Integrated	Recycled material	Integrated VIKOR, DEMATEL and ANP for vendor selection based on recycled materials.
Chatterjee, Athawale and Chakraborty [130]	VIKOR and ELECTRE	Integration	Material selection	Used VIKOR and ELECTRE for material selection.
Jahan *et al.* [136]	VIKOR	Utilized	Material selection	Applied VIKOR for material selection.
Bahraminasab and Jahan [137]	VIKOR	Utilized	Material selection	Employed VIKOR for material selection.
Chauhan and Vaish [131]	VIKOR and TOPSIS	Integration	Material selection	Magnetic material selection by used VIKOR and TOPSIS.
Girubha and Vinodh [138]	Fuzzy VIKOR	Utilized	Material selection	Utilized fuzzy VIKOR for material selection.
Çalışkan, Kurşuncu, Kurbanoğlu and Güven [132]	VIKOR, PROMETHEE II, AHP, Entropy and TOPSIS	Integration	Material selection	Applied VIKOR, PROMETHEE II, AHP, Entropy and TOPSIS for material selection.
Cavallini *et al.* [139]	VIKOR	Utilized	Material selection	Applied VIKOR for material selection.
Jahan and Edwards [140]	VIKOR	Utilized	Material selection	Employed VIKOR for material selection.
Çalışkan [133]	VIKOR, PROMETHEE II and TOPSIS	Integration	Material selection	Applied VIKOR, PROMETHEE II and TOPSIS for material selection.
Liu *et al.* [141]	VIKOR, DEMATEL and ANP	Integration	Material selection	Material selection by integrated of VIKOR, DEMATEL and ANP.
Yazdani and Payam [134]	VIKOR and TOPSIS	Integration	Material selection	Applied VIKOR and TOPSIS for develop of MEMS technology
Ray [142]	VIKOR and AHP	Integrated	Material selection	Integrated VIKOR and AHP for selection cutting fluid.
Chauhan *et al.* [143]	VIKOR	Utilized	Material selection	Used VIKOR for selection of Piezoelectric material.
Anojkumar, Ilangkumaran and Sasirekha [135]	VIKOR, Fuzzy AHP TOPSIS, ELECTRE and PROMETHEE	Integrated	Pipe material selection	Combined VIKOR, Fuzzy AHP TOPSIS, ELECTRE and PROMETHEE for selection of pipe material.
Vats and Vaish [144]	Fuzzy VIKOR	Utilized	Piezoelectric material selection	Used fuzzy VIKOR for selection of piezoelectric material in transducer application.

4.2.4. Performance Evaluation

Performance Evaluation covers several specific sub-areas including universities evaluation performance, banking performance, business performance, and engineering departments performance. Table 5, presented the VIKOR papers addressed within Performance Evaluation based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Rezaie *et al.* [145] integrated fuzzy AHP and the VIKOR method for evaluation of performance in cement firms, Wu *et al.* [146] evaluated performance based on BSC and applied the VIKOR method, DEMATEL and ANP, Wu *et al.* [147] used the VIKOR method, fuzzy AHP and TOPSIS to evaluate banking performance based on BSC, Chen and Chen [148] integrated VIKOR and fuzzy AHP for innovation systems in airline industry based on AIS, Zolfani and Ghadikolaei [149] mixed the VIKOR method with DEMATEL and ANP for evaluation of universities performance, Hsu [150] applied the VIKOR method, GRA and entropy for evaluation of business performance, Hsu [151] applied the VIKOR method, IGRA and entropy to evaluate efficiency and operating performance, Tsai and Chang [152] integrated the VIKOR method, GRA, TOPSIS and AHP for evaluation of performance of Tablet PCs. Totally, 14 past papers used the VIKOR technique in the fields of Performance Evaluation which presented in Table 5.

Table 5. Distribution papers on Performance Evaluation.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Rezaie, Ramiyani, Nazari-Shirkouhi and Badizadeh [145]	VIKOR and fuzzy AHP	Integration	Performance evaluation	Integrated fuzzy AHP and VIKOR for evaluation of performance in cement firms.
Wu, Lin and Chang [146]	VIKOR, DEMATEL and ANP	Integration	Education centers in universities	Evaluated performance based on BSC and applied VIKOR, DEMATEL and ANP.
Wu, *et al.* [153]	VIKOR and AHP	Integration	Performance evaluation	Evaluated of performance based on VIKOR and AHP for ranking universities.
Wu, Tzeng and Chen [147]	VIKOR, FAHP and TOPSIS	Integrated	Performance evaluation	Used VIKOR, FAHP and TOPSIS to evaluating banking performance based on BSC.
Chen and Chen [148]	VIKOR and fuzzy AHP	Integrated	Airline operation performance	Integrated VIKOR and fuzzy AHP for innovation operations in airlines industry based on AIS.
Kuo and Liang [154]	VIKOR and interval-valued fuzzy sets	Proposed	Performance evaluation	Proposed new method for performance evaluation.
Zolfani and Ghadikolaei [149]	VIKOR, DEMATEL and ANP	Integrated	Performance evaluation	Mixed VIKOR, DEMATEL and ANP for evaluation of universities performance.
Hsu [150]	VIKOR, GRA and entropy	Integrated	Performance evaluation	Applied VIKOR, GRA and entropy for evaluation of business performance.
Hsu [151]	VIKOR, IGRA and entropy	Integrated	Evaluate efficiency and operating performance	Applied VIKOR, IGRA and entropy for evaluate efficiency and operating performance.
Chou *et al.* [155]	VIKOR and entropy	Utilized	Women performance in science and technology	Employed VIKOR and entropy to evaluating of women in science and technology.
Ranjan *et al.* [156]	VIKOR, DEMATEL and Entropy	Integrated	Performance evaluation	Used VIKOR, DEMATEL and Entropy for evaluation of performance in engineering departments.
Dincer and Hacioglu [157]	Fuzzy VIKOR and AHP	Utilized	Performance evaluation	Used fuzzy VIKOR and AHP for evaluation of performance based on customer satisfaction.
Lee and Pai [158]	VIKOR and DEA	Utilized	Operation Performance	Improve DEA and VIKOR for evaluation of dynamic operation performances.
Tsai and Chang [152]	VIKOR, GRA, TOPSIS and AHP	Integrated	Performance evaluation	Integrated VIKOR, GRA, TOPSIS and AHP for evaluation of performance of Tablet PCs.

4.2.5. Health-Care Fields

Health-Care Fields covers several specific sub-areas including health-care waste disposal, and healthcare management. Table 6, presented the VIKOR papers addressed within Health-Care Fields based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Liu *et al.* [159] assessed the health-care waste disposal based on fuzzy VIKOR and Ordered Weighted Averaging (OWA), Chang [160] evaluated hospital service by employing the fuzzy VIKOR, Lu *et al.* [161] improved and assessed of RFID adoption based on VIKOR, DEMATEL and ANP, Liu *et al.* [162] combined the fuzzy VIKOR, fuzzy TOPSIS, 2-tuple DEMATEL and MULTIMOORA for evaluation of health-care waste. In total, five past papers used the VIKOR technique in fields of Health-Care Fields which presented in Table 6.

Table 6. Distribution of papers in Health-Care Fields.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Liu, Wu and Li [159]	Fuzzy VIKOR and OWA	Integration	Health-care	Evaluation of health-care waste disposal based on Fuzzy VIKOR and OWA.
Chang [160]	Fuzzy VIKOR	Utilized	Hospital service	Evaluated of hospital service by employ fuzzy VIKOR.
Lu, Lin and Tzeng [161]	VIKOR, DEMATEL and ANP	Integration	Healthcare	Improved and assessed of RFID adoption based on VIKOR, DEMATEL and ANP.
Liu, You, Lu and Chen [162]	Fuzzy VIKOR, Fuzzy TOPSIS, 2-tuple DEMATEL and MULTIMOORA	Integrated	Health-care waste	Combined fuzzy VIKOR, fuzzy TOPSIS, 2-tuple DEMATEL and MULTIMOORA for evaluation of health-care waste.
Zeng *et al.* [163]	VIKOR	Modified	Healthcare management	Improved VIKOR for enhance accuracy in healthcare management.

4.2.6. Supply Chain

Supply Chain covers several specific sub-areas including supplier selection, supply chain networks, and supply chain performance. Table 7, presented the VIKOR papers addressed within Supply Chain based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Rostamzadeh *et al.* [164] evaluated green supply chain by applying the fuzzy VIKOR, Akman [165] applied the VIKOR and fuzzy c-means for evaluation of green supplier development, Chen and Wang [61] employed the fuzzy VIKOR for assessing and evaluating of suppliers/vendors, Chithambaranathan *et al.* [166] evaluated performance of service supply chain by using the VIKOR and ELECTRE, Shemshadi *et al.* [167] extended the VIKOR for selection of supplier based on entropy measure, You, You, Liu and Zhen [91] extended the VIKOR for supplier selection based on interval 2-tuple linguistic, Alimardani *et al.* [168] combined the VIKOR and SWARA for selection of supplier in agile environment. In total, 12 articles used VIKOR technique in fields of Supply Chain which presented in Table 7.

Table 7. Distribution of papers in Supply Chain.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Rostamzadeh, Govindan, Esmaeili and Sabaghi [164]	Fuzzy VIKOR	Utilized	Green supply chain	Evaluated green supply chain by applied fuzzy VIKOR.
Akman [165]	VIKOR and fuzzy c-means	Utilized	Supply chain	Applied VIKOR and fuzzy c-means for evaluation of green supplier development.
Chen and Wang [61]	Fuzzy VIKOR	Utilized	IS/IT outsourcing	Employed fuzzy VIKOR for assessing and evaluating of suppliers/vendors.
Chithambaranathan, Subramanian, Gunasekaran and Palaniappan [166]	VIKOR and ELECTRE	Integrated	Supply chain	Evaluated performance of service supply chain by used VIKOR and ELECTRE.
Sanayei, Mousavi and Yazdankhah [69]	Fuzzy VIKOR	Utilized	Supplier selection	Employed fuzzy VIKOR for selection of supplier.
Shemshadi, Shirazi, Toreihi and Tarokh [167]	VIKOR and entropy	Extended	Supplier selection	Extended VIKOR for selection of supplier based on entropy measure.
You, You, Liu and Zhen [91]	VIKOR and interval 2-tuple linguistic	Extended	Supplier selection	Extended VIKOR for supplier selection based on interval 2-tuple linguistic.
Aghdaie *et al.* [169]	VIKOR and SWARA	Integrated	Supply chain	Combined VIKOR and SWARA for clustering and ranking of supplier.
Geng and Liu [170]	VIKOR	Utilized	Service supplier selection	Utilized VIKOR for selection of service supplier.
Wu and Liu [171]	VIKOR, entropy and fuzzy TOPSIS	Integrated	Supplier selection	Integrated VIKOR, entropy and fuzzy TOPSIS for supplier selection.
Alimardani, Hashemkhani Zolfani, Aghdaie and Tamošaitienė [168]	VIKOR and SWARA	Integrated	Supplier selection	Combined VIKOR and SWARA for selection of supplier in agile environment.
Sarrafha *et al.* [172]	VIKOR	Utilized	Supply chain networks	Used VIKOR to evaluate of supply chain networks.

4.2.7. Tourism Management

Tourism Management is considered as a next area in VIKOR applications. Tourism Management covers several specific sub-areas including tourism policy and tourism development. Table 8, presented the VIKOR papers addressed within Tourism Management based on author(s) and year, technique and approach, type of study, application area and scope and study purpose. Tzeng *et al.* [173], combined AHP technique with VIKOR algorithm for selection of restaurant location in Taipei. In this study, five aspects with 11 criteria were used to evaluate restaurant location. Liu *et al.* [174] integrated the VIKOR, DEMATEL and ANP for implementation of tourism policy, Tsai *et al.* [175] presented the effective model to evaluate of national park websites, Liu *et al.* [176] combined the VIKOR, ANP and DEMATEL for improvement of metro–airport connection service, Hsieh *et al.* [177] presented a model for efficiency and effectiveness of tourist hotel by applying the VIKOR and DEA. In total, 12 papers used the VIKOR technique in the fields of Tourism Management, which presented in Table 8.

Table 8. Distribution of papers in Tourism Management.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Liu, Tzeng and Lee [174]	VIKOR, DEMATEL and ANP	Integration	Tourism policy	Integrated VIKOR, DEMATEL and ANP for implementation of tourism policy.
Tsai, Chou and Lai [175]	VIKOR, DEMATEL and ANP	Integration	Tourism management	Presented the effective model to evaluating of national park websites.
Liu, Tzeng, Lee and Lee [176]	VIKOR, ANP and DEMATEL	Integrated	Tourism development	Combined VIKOR, ANP and DEMATEL for Improvement of metro–airport connection service.
Hsieh, Wang, Huang and Chen [177]	VIKOR and DEA	Integrated	Tourist	Presented a model for efficiency and effectiveness of tourist hotel by apply VIKOR and DEA.

4.2.8. Service Quality

Service Quality covers several specific sub-areas including electronic service quality, airline service quality and service quality improvement. Table 9, presented the VIKOR papers addressed within Service Quality based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Wu *et al.* [178] measured electronic service quality in social media by using the VIKOR and fuzzy AHP, Liou *et al.* [179] modified VIKOR for improvement of domestic airline service quality, Kuo [180] proposed a new method for service quality improvement by combining of the VIKOR method, IVFS and GRA, Wang and Pang [181] evaluated the service quality of online auction by applying the fuzzy VIKOR. In total, five past papers used VIKOR technique in the field of Service Quality (presented in Table 9).

Table 9. Distribution of papers in Service Quality.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Wu, Shen and Chang [178]	VIKOR and fuzzy AHP	Integration	Electronic service quality	Measured and evaluated of electronic service quality in social media by used VIKOR and fuzzy AHP.
Kuo and Liang [72]	Fuzzy VIKOR and GRA	Integrated	Service quality	Combined fuzzy VIKOR and GRA for evaluation of service quality.
Liou, Tsai, Lin and Tzeng [179]	VIKOR	Modified	Service quality	Modified VIKOR for improvement of domestic airline service quality.
Kuo [180]	VIKOR, IVFS and GRA	Proposed	Service quality	Proposed a new method for service quality improvement by combining of VIKOR, IVFS and GRA.
Wang and Pang [181]	Fuzzy VIKOR	Utilized	Online service quality	Evaluation the service quality of online auction by applied fuzzy VIKOR.

4.2.9. Sustainability and Renewable Energy Fields

Sustainability and renewable energy fields cover several specific sub-areas, including life cycle sustainability assessment, energy resources, environmental management, and environmentally evaluation. Table 10, presented the VIKOR papers addressed within sustainability and renewable energy fields based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Tzeng, Tsaur, Laiw and Opricovic [5], integrated VIKOR with TOPSIS to identify improvement strategies for residents satisfaction. Results of this study indicated that noise pollution and air quality were the important criteria of environmental quality in Taipei. Vučijak,

Kupusović, Midžić-Kurtagić and Ćerić [3] evaluated sustainable hydropower by applying the VIKOR, Quijano H, Botero B and Domínguez B [4] used VIKOR for development of renewable sustainable energy plans, Martin-Utrillas, Juan-Garcia, Canto-Perello and Curiel-Esparza [6] integrated the VIKOR, fuzzy Delphi and AHP for selection of best infrastructure related to sustainable economy, Ren, Manzardo, Mazzi, Zuliani and Scipioni [8] combined the VIKOR and AHP for assessment of life cycle sustainability, Yazdani-Chamzini, Fouladgar, Zavadskas and Moini [7] used the VIKOR, SAW, ARAS, TOPSIS and MOORA for selection of the best renewable energy sources, Civic and Vucijak [9] utilized VIKOR for insulation options for warmth of buildings to increase energy efficiency, Kim and Chung [10] evaluated the vulnerability of the water supply to variability and climate change. In total, 13 past papers used the VIKOR technique in the fields of sustainability and renewable energy, which presented in Table 10.

Table 10. Distribution on papers in Sustainability and Renewable Energy fields.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Vučijak, Kupusović, Midžić-Kurtagić and Ćerić [3]	VIKOR	Utilized	Energy	Evaluated of sustainable hydropower by applied VIKOR.
Quijano H, Botero B and Domínguez B [4]	VIKOR	Utilized	Renewable sustainable energy	Used VIKOR for development of renewable sustainable energ plans.
Martin-Utrillas, Juan-Garcia, Canto-Perello and Curiel-Esparza [6]	VIKOR, fuzzy Delphi and AHP	Integrated	Sustainable economy	Integrated VIKOR, fuzzy Delphi and AHP for selection of best infrastructure related to sustainable economy.
Vinodh *et al.* [182]	Fuzzy VIKOR	Utilized	Life cycle assessment	Applied VIKOR for assessment of life cycle and selection of sustainable concept.
Ren, Manzardo, Mazzi, Zuliani and Scipioni [8]	VIKOR and AHP	Integrated	Life cycle sustainability assessment	Combined VIKOR and AHP for assessment of life cycle sustainability.
Kaya and Kahraman [183]	VIKOR and AHP	Integration	Renewable energy	Integrated VIKOR and AHP for determine the optimal renewable energy alternatives.
Yazdani-Chamzini, Fouladgar, Zavadskas and Moini [7]	VIKOR, SAW, ARAS, TOPSIS and MOORA	Integrated	Renewable energy	Used VIKOR, SAW, ARAS, TOPSIS and MOORA for selection of the best renewable energy sources.
San Cristóbal [184]	VIKOR	Utilized	Renewable energy	Used VIKOR for selection of renewable energy project.
Civic and Vucijak [9]	VIKOR	Utilized	Energy	Utilized VIKOR for insulation options for warmth of buildings to increase energy efficiency.
Sharma *et al.* [185]	VIKOR, TOPSIS and entropy	Integrated	Energy resources	Used VIKOR, TOPSIS and entropy for selection the optimal energy resources.
Kim and Chung [10]	Fuzzy VIKOR	Utilized	Climate change and variability	Evaluated the vulnerability of the water supply to variability and climate change.
Chang and Hsu [186]	VIKOR	Utilized	Environmental Management	Applied VIKOR for ranking of land-use restraint strategies.
Venkata Rao [187]	VIKOR	Utilized	Environmentally evaluation	Applied VIKOR for evaluation of environmentally in manufacturing programs.

4.2.10. Water Resources Planning

Water Resources Planning is considered as a next area in VIKOR applications. This area of application focused on developing, planning, managing and distributing the optimal usage of water resources. Water Resources Planning can be as a part of water cycle management. Water Resources Planning covers some specific sub-areas such as watershed vulnerability. Opricovic [66], utilized

VIKOR technique for assessing of water resources planning. Opricovic [188], presented the fuzzy VIKOR technique to evaluating of water resources planning. Table 11, presented the VIKOR papers addressed within Water Resources Planning based on author(s) and year, technique and approach, type of study, application area and scope and study purpose. Totally, three past papers used VIKOR techniques in fields of Water Resources Planning fields which presented in Table 12. In total, three past papers used VIKOR techniques in fields of Water Resources Planning fields which presented in Table 11.

Table 11. Distribution of papers in Water Resources Planning.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and scope	Study Purpose
Opricovic [66]	VIKOR	Utilized	Water resources planning	Applied VIKOR for evaluation of water resources planning.
Opricovic [188]	Fuzzy VIKOR	Proposed	Water resources planning	Proposed fuzzy VIKOR for evaluation of water resources planning.
Chang and Hsu [189]	VIKOR	Modified	Watershed vulnerability	Modified VIKOR for classification of land subdivisions based on watershed vulnerability.

4.2.11. Marketing

Marketing covers several specific sub-areas, including brand marketing, portfolio selection, outsourcing providers, and strategy evaluation. Table 12, presented the VIKOR papers addressed within Marketing based on author(s) and year, technique and approach, type of study, application area and scope and study purpose. Tsai, Chou, and Leu [190] combined the VIKOR, ANP and DEMATEL for evaluation of effectiveness in web-based marketing, Wang and Tzeng [191] combined the VIKOR, ANP and DEMATEL for assess of interrelated relationships of brand marketing, Ginevičius, Bruzgė and Podvezko [192] used the VIKOR, SAW and TOPSIS for comparison the help to several businesses and to identify its influence on their development objectively, Chiu, Tzeng and Li [193] improved e-store business by combined the VIKOR, DEMATEL and ANP, Chang, Tsai and Chang [194] integrated the VIKOR, fuzzy AHP (FAHP), GRA and TOPSIS for building the business model, Azimi, Yazdani-Chamzini, Fooladgar and Basiri [195] used the VIKOR and ANP for assessment of strategies of mining sectors, Chen and Chen [196] applied VIKOR for selection of creativity strategy in higher education. In total, 15 past papers used the VIKOR technique in fields of Marketing fields which presented in Table 12.

Table 12. Distribution of papers in marketing.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Tsai *et al.* [190]	VIKOR, ANP and DEMATEL	Integrated	Web-based marketing	Combined VIKOR, ANP and DEMATEL for evaluation of effectiveness in web-based marketing.
Wang and Tzeng [191]	VIKOR, ANP and DEMATEL	Integrated	Brand marketing	Combined VIKOR, ANP and DEMATEL for assess of interrelated relationships of brand marketing.
Ginevičius, Bruzgė and Podvezko [192]	VIKOR, SAW and TOPSIS	Integrated	Market development	Used VIKOR, SAW and TOPSIS for comparison the help to several businesses and to identify its influence on their development objectively.
Chiu, Tzeng and Li [193]	VIKOR, DEMATEL and ANP	Integrated	e-store business	Improved e-store business by combined VIKOR, DEMATEL and ANP.

Table 12. *Cont.*

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Chang, Tsai and Chang [194]	VIKOR, FAHP, GRA and TOPSIS	Integrated	E-book business	Integrated VIKOR, FAHP, GRA and TOPSIS for building the business model.
Azimi, Yazdani-Chamzini, Fooladgar and Basiri [195]	VIKOR and ANP	Integrated	Strategy evaluation	Used VIKOR and ANP for assessment of strategies of mining sectors.
Chen and Chen [196]	VIKOR	Utilized	Creativity strategy selection	Applied VIKOR for selection of creativity strategy in higher education.
Liou and Chuang [197]	VIKOR, ANP and DEMATEL	Integrated	Outsourcing providers	Integrated VIKOR, ANP and DEMATEL for selection of outsourcing providers.
Ho *et al.* [198]	VIKOR, ANP and DEMATEL	Integrated	Portfolio selection	Combined VIKOR, ANP and DEMATEL for selection of portfolio.
Sachdeva *et al.* [199]	VIKOR	Utilized	Logistic outsourcing	Used VIKOR for analysis of logistic outsourcing problem
Vahdani, Hadipour, Sadaghiani and Amiri [70]	VIKOR	Extended	Maintenance strategy selection	Extended of VIKOR for selection of maintenance strategy.
Chen and Chen [200]	VIKOR	Utilized	Innovative development	Employed VIKOR for develop of innovative based on intellectual capital.
Lu *et al.* [201]	VIKOR, ANP and DEMATEL	Integrated	User behavior intention	Combined VIKOR, ANP and DEMATEL for examine user behavior intention.
Ahmadi *et al.* [202]	VIKOR, AHP and TOPSIS	Integrated	Maintenance strategy	Combined VIKOR, AHP and TOPSIS for selection of maintenance strategy.
Rostamzadeh *et al.* [203]	Fuzzy VIKOR	Utilized	Assisting business angels	Employed fuzzy VIKOR for evaluation of business angels.

4.2.12. Risk and Financial Management

Risk Economics, and Financial management covers specific sub-areas including risks evaluation, information security risk, financial assessment, and financial performance improvement. Table 13, presented the VIKOR papers addressed within Risk and Financial management based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Liu *et al.* [204] used the fuzzy VIKOR and TOPSIS for evaluation of risks based on FMEA, Shen and Tzeng [205] combined VIKOR, ANP and DEMATEL for improving financial performance, Lee and Yang [206] combined the VIKOR and ANP for selection of convertible bonds, Peng *et al.* [207] combined the VIKOR, TOPSIS and PROMETHEE for financial risk prediction, Kou *et al.* [208] ranked and selected popular clustering algorithms in analysis of financial risk, Mandal *et al.* [209] utilized the fuzzy VIKOR for identifying and ranking of human error and risk in overhead crane operations, Ginevičius and Podvezko [210] applied VIKOR to assess the financial problems in construction enterprises. There are14 past papers used the VIKOR technique in fields of Risk and Financial management fields which presented in Table 13.

Table 13. Distribution of papers in risk and financial management.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Liu, Chen, You and Li [204]	Fuzzy VIKOR and TOPSIS	Utilized	Risks evaluation	Used fuzzy VIKOR and TOPSIS for evaluation of risks based on FMEA.
Shen and Tzeng [205]	VIKOR, ANP and DEMATEL	Integrated	Financial performance improvement	Combined VIKOR, ANP and DEMATEL for improve of financial performance.
Lee and Yang [206]	VIKOR and ANP	Integrated	Convertible bonds	Combined VIKOR and ANP for selection of convertible bonds.
Peng, Wang, Kou and Shi [207]	VIKOR, TOPSIS and PROMETHEE	Integrated	Financial risk evaluation	Combined VIKOR, TOPSIS and PROMETHEE for evaluating of financial risk prediction.
Liu *et al.* [211]	Fuzzy VIKOR	Utilized	Risk evaluation	Applied fuzzy VIKOR for assessment of risk.
Kou, Peng and Wang [208]	VIKOR, TOPSIS and DEA	Integration	Financial risk	Ranked and selected of popular clustering algorithms in analysis of financial risk.
Safari *et al.* [212]	Fuzzy VIKOR	Utilized	Enterprise architecture risks	Applied fuzzy VIKOR for evaluation of enterprise architecture risks based on FMEA.
Ou Yang *et al.* [213]	VIKOR	Proposed	Information security risk	Modified VIKOR for improve information security risk.
Mandal, Singh, Behera, Sahu, Raj and Maiti [209]	Fuzzy VIKOR	Utilized	Human error identification and risk prioritization in overhead crane operations	Utilized fuzzy VIKOR for identify and ranking of human error and risk in overhead crane operations.
Ginevičius and Podvezko [210]	VIKOR	Utilized	Financial assessment	Applied VIKOR for assessment of financial in construction enterprises.
Emovon *et al.* [214]	VIKOR and entropy	Integrated	Marine machinery systems risk	Integrated for ranking of risk in marine machinery systems.
Yang *et al.* [215]	VIKOR, DEMATEL and ANP	Utilized	Information security management risk	Evaluated information security risk control by used VIKOR, DEMATEL and ANP.
Yalcin *et al.* [216]	VIKOR, fuzzy AHP and TOPSIS	Integrated	Performance evaluation	Evaluated financial performance by combined VIKOR, fuzzy AHP and TOPSIS.
Safaei Ghadikolaei *et al.* [217]	Fuzzy VIKOR, fuzzy AHP, ARAS-F, fuzzy COPRAS	Integrated	Financial performance evaluation	Combined Fuzzy VIKOR, fuzzy AHP, ARAS-F, fuzzy COPRAS for evaluation of financial performance.

4.2.13. Operation Management

Operation Management fieldcovers several specific sub-areas such as; knowledge management; city logistics; concept selection; benchmarking and process performance. Table 14, presented the VIKOR papers addressed within Operation Management based on author (s) and year, technique and approach, type of study, application area and scope and study purpose. Chu *et al.* [218] evaluated knowledge communities by integrating the VIKOR, TOPSIS and SAW, Bazzazi *et al.* [219] mixed the VIKOR, AHP and entropy for selection of surface mine equipment, Tadić *et al.* [220] combined the fuzzy VIKOR, fuzzy DEMATEL and fuzzy ANP for selection of city logistics, Leng *et al.* [221] proposed a combined decision support method for PMO using the fuzzy VIKOR, Fu, Chu, Chao, Lee, and Liao [222] combined the VIKOR and fuzzy AHP for benchmarking in hotel industry, Büyüközkan and Ruan [223] extended the fuzzy VIKOR for measurement of Enterprise Resource Planning (ERP) software performance. Totally, 10 past papers used VIKOR technique in fields of Operation Management presented in Table 14.

Table 14. Distribution of papers in operation management.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Chu, Shyu, Tzeng and Khosla [218]	VIKOR, TOPSIS and SAW	Integrated	Knowledge management	Evaluated of knowledge communities by integrated of VIKOR, TOPSIS and SAW.
Bazzazi, Osanloo and Karimi [219]	VIKOR, AHP and entropy	Integrated	Equipment selection	Mixed VIKOR, AHP and entropy for selection of surface mine equipment.
Tadić, Zečević and Krstić [220]	fuzzy VIKOR, fuzzy DEMATEL and fuzzy ANP	Integrated	City logistics concept selection	Combined fuzzy VIKOR, fuzzy DEMATEL and fuzzy ANP for selection of city logistics.
Leng, Jiang and Ding [221]	Fuzzy VIKOR	Proposed	Parts machining outsourcing	Proposed a combined decision support method for PMO using fuzzy VIKOR.
Fallahpour and Moghassem [224]	VIKOR	Utilized	Spinning preparation parameters selection	Employed VIKOR for selection of spinning preparation parameters.
Hadi-Vencheh and Mohamadghasemi [225]	Fuzzy VIKOR, FWA and fuzzy TOPSIS	Integrated	Material handling equipment selection	Combined Fuzzy VIKOR, FWA and fuzzy TOPSIS for selection of material handling equipment.
Fu *et al.* [222]	VIKOR and fuzzy AHP	Integrated	Benchmarking	Combined VIKOR and fuzzy AHP for analysis of benchmarking in hotel industry.
Büyüközkan *et al.* [226]	Fuzzy VIKOR and fuzzy Delphi	Utilized	Knowledge management	Employed fuzzy VIKOR and fuzzy Delphi method for evaluation of KM tools.
Büyüközkan and Ruan [223]	Fuzzy VIKOR and Fuzzy Delphi	Extended	ERP	Extended Fuzzy VIKOR for measurement of ERP software performance.
Gauri and Pal [227]	VIKOR and GRA	Utilized	Process performance	Used VIKOR and GRA to optimize of process performance.

4.2.14. Human Resource Management (HRM)

The technique is also applied in Human Resource Management (HRM). HRM fieldcovers different specific sub-areas including corporate social responsibility, HRM evaluation, intellectual capital and customer satisfaction. Table 15, presented the VIKOR papers addressed within HRM based on author(s) and year, technique and approach, type of study, application area and scope and study purpose. Chen *et al.* [228] combined VIKOR, ANP, and DEMATEL to evaluate companies' web site by considering of corporate social responsibility, Tsai *et al.* [229] mixed the VIKOR and ANP for evaluation of entrepreneurship policies, Mazdeh *et al.* [230] applied the VIKOR and ANP for evaluation of the entrepreneurship intensity, Peng and Tzeng [231] combined the VIKOR, DEMATEL and ANP for solving problem in economics and business, Liu and Wu [77] applied VIKOR and entropy for evaluation of human resources managers' competency, Wu *et al.* [232] integrated VIKOR and fuzzy AHP for evaluation of Innovation capital in universities, Celik *et al.* [233] integrated the fuzzy VIKOR and fuzzy AHP for modelling of trust. The VIKOR technique is applied in 11 papers in the field of HRM as which presented in Table 15.

Table 15. Distribution of papers in human resource management (HRM).

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Chen, Tzeng and Chang [228]	VIKOR, ANP, and DEMATEL	Integrated	Corporate social responsibility	Combined VIKOR, ANP, and DEMATEL to evaluate companies' web site by considering of corporate social responsibility.
Tsai, Lee, Shen and Hwang [229]	VIKOR and ANP	Integrated	Entrepreneurship policies evaluation	Mixed VIKOR and ANP for evaluation of entrepreneurship policies.
Mazdeh, Razavi, Hesamamiri, Zahedi and Elahi [230]	VIKOR and ANP	Integrated	Entrepreneurship intensity	Applied VIKOR and ANP for evaluation of the entrepreneurship intensity.
Peng and Tzeng [231]	VIKOR, DEMATEL and ANP	Integrated	Economics and business improvement	Combined VIKOR, DEMATEL and ANP for improve problem in economics and business.
Baležentis *et al.* [234]	VIKOR, TOPSIS and ARAS	Integrated	Economic assessment	Integrated VIKOR, TOPSIS and ARAS for evaluation of economic sector of Lithuania.
Liu and Wu [77]	VIKOR and entropy	Utilized	HRM evaluation	Applied VIKOR and entropy for evaluation of human resources managers' competency.
Chen and Tzeng [235]	VIKOR, ANP and DEMATEL	Integrated	Teaching materials evaluation	Combined VIKOR, ANP and DEMATEL for evaluation of aspired intelligent for teaching materials.
Wu, Chen and Chen [232]	VIKOR and fuzzy AHP	Integrated	Intellectual capital	Integrated VIKOR and fuzzy AHP for evaluation of Innovation capital in universities.
Mohanty and Mahapatra [236]	VIKOR	Utilized	Customer satisfaction	Applied VIKOR for selection of ergonomically designed office chair.
Celik, Aydin and Gumus [233]	VIKOR and interval type-2 fuzzy sets	Integration	Customer satisfaction	Evaluated customer satisfaction based on SERVQUAL by used VIKOR and interval type-2 fuzzy sets.
Ashtiani and Azgomi [237]	Fuzzy VIKOR and fuzzy AHP	Integrated	Trust modelling	Integrated fuzzy VIKOR and fuzzy AHP for modelling of trust.

4.2.15. Other Application Areas

The technique is also applied in other areas such as network selection, process of leachate treatment, flood management, and so on. Table 16, presented the VIKOR papers addressed within Mehbodniya *et al.* [238] extended fuzzy VIKOR for selection of network, Lee [239] combined VIKOR, DEMATEL and ANP for evaluation of merger and acquisition, Arunachalam *et al.* [240] used fuzzy VIKOR and AHP for selection of compliant polishing tool, Martin-Utrillas *et al.* [241] applied VIKOR and Delphi for process of leachate treatment selection, Mousavi *et al.* [242] extended VIKOR for improve the selection problems, Chitsaz and Banihabib [243] used VIKOR, SAW, TOPSIS M-TOPSIS, AHP, ELECTRE I and ELECTRE III for ranking in-flood management, Milosevic and Naunovic [244] applied VIKOR and fuzzy AHP for selection of sanitary landfill facility location, Pourebrahim *et al.* [245] combined VIKOR and fuzzy AHP for conservation development in a coastal area, Lee and Tu [246] applied VIKOR, ANP and DEMATEL for evaluation of company value, Lin [247] integrated for VIKOR, DEMATEL and ANP determining product position.

Table 16. Distribution of papers in other application areas.

Author (s) and Year	Technique and Approach	Type of Study	Application Area and Scope	Study Purpose
Mehbodniya, Kaleem, Yen and Adachi [238]	Fuzzy VIKOR	Extended	Network selection	Extended fuzzy VIKOR for selection of network.
Lee [239]	VIKOR, DEMATEL and ANP	Integrated	Merger and acquisition	Combined VIKOR, DEMATEL and ANP for evaluation of merger and acquisition.
Tong *et al.* [248]	VIKOR	Utilized	Multi-response process	Applied VIKOR for optimization of multi-response process.
Arunachalam, Idapalapati and Subbiah [240]	Fuzzy VIKOR an AHP	Utilized	Compliant polishing tool	Used fuzzy VIKOR and AHP for selection of compliant polishing tool.
Martin-Utrillas, Reyes-Medina, Curiel-Esparza and Canto-Perello [241]	VIKOR and Delphi method	Utilized	Process of leachate treatment	Applied VIKOR and Delphi for process of leachate treatment selection.
Mousavi, Jolai and Tavakkoli-Moghaddam [242]	VIKOR	Proposed	Selection problems	Extended VIKOR for improve the selection problems.
Hsu and Pai [249]	VIKOR	Utilized	Feature selection mechanism	Used VIKOR for selection of feature in data mining.
Chitsaz and Banihabib [243]	VIKOR, SAW, TOPSIS M-TOPSIS, AHP, ELECTRE I and ELECTRE III	Utilized	Flood Management	Used VIKOR, SAW, TOPSIS M-TOPSIS, AHP, ELECTRE I and ELECTRE III for ranking of flood management.
Fallahpour and Moghassem [250]	VIKOR	Utilized	Rotor Spinning	Employed VIKOR for improve and selection of spinning machine parameters.
BONDOR *et al.* [251]	VIKOR	Utilized	Diabetic Nephropathy Risk	Applied VIKOR for analysis of risk in diabetic nephropathy.
Lee [252]	VIKOR, ANP, and DEMATEL	Integrated	Location selection	Integrated VIKOR, ANP, and DEMATEL for location selection.
Milosevic and Naunovic [244]	VIKOR and fuzzy AHP	Utilized	Landfill facility selection	Applied VIKOR and fuzzy AHP for selection of sanitary landfill facility location.
Kosareva and Krylovas [253]	VIKOR, COPRAS and TOPSIS	Integrated	Accuracy	Utilized VIKOR, COPRAS and TOPSIS for compare of accuracy in ranking alternatives.
Pourebrahim, Hadipour, Mokhtar and Taghavi [245]	VIKOR and fuzzy AHP	Integrated	Coastal assessment	Combined VIKOR and fuzzy AHP for conservation development in a coastal area.
Sun *et al.* [254]	VIKOR	Extended	Power system restoration	Extended VIKOR to presenting of compromise solutions considering hybrid attributes.
Hu *et al.* [255]	VIKOR, ANP and DEMATEL	Integrated	Smart phone improvements	Improves smart phone for combine VIKOR, ANP and DEMATEL
Yücenur and Demirel [256]	Fuzzy VIKOR	Integrated	Insurance company selection	Extended fuzzy VIKOR for selection of insurance company.
[257]	VIKOR and AHP	Integrated	Forestation areas selection	Combined VIKOR and AHP for selection of forestation areas.
Lee and Tu [246]	VIKOR, ANP and DEMATEL	Integrated	Company value	Applied VIKOR, ANP and DEMATEL for evaluation of company value.
Peng *et al.* [258]	VIKOR, TOPSIS, PROMETHEE and WSM	Integration	Multiclass classification	Used VIKOR, TOPSIS, PROMETHEE and WSM for ranking of multiclass classification.
Lin [247]	VIKOR, DEMATEL and ANP	Integration	Information and communications technology	Integrated for VIKOR, DEMATEL and ANP determining product position.

4.3. Distribution Paper Based on VIKOR and Combined with Other Techniques

This section provides number of papers which applied the VIKOR technique and integrated with other techniques in several application areas. While some of the papers applied exclusively VIKOR or fuzzy VIKOR techniques (34%), most of the papers attempted to integrate or compare the techniques with other techniques such as TOPSIS, ANP, DEMATEL, AHP, GRA, ELECTRE, SWARA, MOORA, fuzzy set theory and so on. Table 17 showed the frequency of VIKOR integrated with other techniques. Results of this table showed that, previous scholars integrated TOPSIS and fuzzy TOPSIS with VIKOR technique more than other techniques.

Table 17. Distribution papers based on techniques integrated or compared with VIKOR.

Techniques Integrated or Compared	N	%	Techniques Integrated or Compared	N	%
TOPSIS and fuzzy TOPSIS	38	17.67%	SAW	5	2.33%
ANP and fuzzy ANP	33	15.35%	Delphi and fuzzy Delphi	5	2.33%
AHP and fuzzy AHP	32	14.88%	COPRAS	4	1.86%
DEMATEL and fuzzy DEMATEL	27	12.56%	weighted sum method (WSM)	4	1.86%
Aggregation operators	15	6.98%	SWARA	3	1.40%
Entropy	12	5.58%	ARAS	3	1.40%
PROMETHEE	10	4.65%	MULTIMOORA and MOORA	3	1.40%
GRA	10	4.65%	DEA	3	1.40%
ELECTRE	8	3.72%	Individual VIKOR and fuzzy VIKOR	67	33.88%

4.4. Distribution Paper Based on Journals Name

Table 18 presents information about journal distribution which is used for this review paper. The selected papers related to the VIKOR technique were found from 83 international scholarly journals most related to MCDM issue extracted from Scopus and Web of Science. From a total 83 journals, journal of Expert Systems with Applications had the first rank with 27 papers. According to this finding; we can revealed that this journal is the most important journal as far as VIKOR technique is concerned. It published more papers related to the VIKOR technique and its application. Journal of Materials and Design is the second with 12 papers; Journal of Technological and Economic Development of Economy was in the third rank with 10 papers, while Journal of Applied Mathematical Modelling with seven papers is in the fourth rank. Journal of The International Journal of Advanced Manufacturing Technology, and International Journal of Applied Soft Computing with six and five papers are in the fifth and sixth rank respectively, while Journal of Quality and Quantity and Journal of Business Economics and Management is in the seventh rank with four papers. The frequency of other published journals is shown in Table 18.

Table 18. Distribution of papers based on the name of journals.

Name of Journal	N	%
Expert Systems with Applications	27	15.34%
Materials and Design	12	6.82%
Technological and Economic Development of Economy	10	5.68%
Applied Mathematical Modelling	7	3.98%
The International Journal of Advanced Manufacturing Technology	6	3.41%
Applied Soft Computing	5	2.84%
Quality and Quantity	4	2.27%
Journal of Business Economics and Management	4	2.27%
Journal of civil engineering and management	3	1.70%
International Journal of Management Science and Engineering Management	3	1.70%
Water resources management	3	1.70%
Information sciences	3	1.70%
International Journal of Information Technology and Decision Making	3	1.70%
The Service Industries Journal	3	1.70%

Table 18. *Cont.*

Name of Journal	N	%
Journal of the Chinese Institute of Engineers	3	1.70%
Soft Computing	2	1.14%
Kybernetes	2	1.14%
Robotics and Computer-Integrated Manufacturing	2	1.14%
International Journal of Production Economics	2	1.14%
Procedia Engineering	2	1.14%
International Journal of Computer Integrated Manufacturing	2	1.14%
International Journal of Production Research	2	1.14%
Tourism Management	2	1.14%
Journal of Intelligent Manufacturing	2	1.14%
Renewable and Sustainable Energy Reviews	2	1.14%
Physical Communication	2	1.14%
Waste Management and Research	2	1.14%
Procedia-Social and Behavioral Sciences	1	0.57%
International Journal of Reliability, Quality and Safety Engineering	1	0.57%
Computers and Industrial Engineering	1	0.57%
Applied Medical Informatics	1	0.57%
International Journal of Computational Intelligence Systems	1	0.57%
Mathematics and Computers in Simulation	1	0.57%
Transport Policy	1	0.57%
Journal of Environmental Management	1	0.57%
Journal of Advanced Manufacturing Systems	1	0.57%
Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials Design and Applications	1	0.57%
Knowledge-Based Systems	1	0.57%
Ocean Engineering	1	0.57%
Fibers and Polymers	1	0.57%
Journal of the Textile Institute	1	0.57%
Advances in Mechanical Engineering	1	0.57%
Resources, Conservation and Recycling	1	0.57%
Energy	1	0.57%
Transportation Research Part E: Logistics and Transportation Review	1	0.57%
Applied Financial Economics	1	0.57%
Asia-Pacific Journal of Operational Research	1	0.57%
Energy Systems	1	0.57%
Journal of Air Transport Management	1	0.57%
Waste Management	1	0.57%
Decision Support Systems	1	0.57%
Service business	1	0.57%
International Journal of Sustainable Development and World Ecology	1	0.57%
Tourism Management Perspectives	1	0.57%
Clean Technologies and Environmental Policy	1	0.57%
Higher education	1	0.57%
Advanced Engineering Informatics	1	0.57%
Procedia Materials Science	1	0.57%
Group Decision and Negotiation	1	0.57%
Arabian Journal for Science and Engineering	1	0.57%
Annals of Operations Research	1	0.57%
Omega	1	0.57%
Ocean and Coastal Management	1	0.57%
OPSEARCH	1	0.57%
The International Journal of Life Cycle Assessment	1	0.57%
Ecological Indicators	1	0.57%

Table 18. *Cont.*

Name of Journal	N	%
Engineering Applications of Artificial Intelligence	1	0.57%
Journal of Advanced Ceramics	1	0.57%
Rapid Prototyping Journal	1	0.57%
Applied Energy	1	0.57%
IJCSET	1	0.57%
Journal of Industrial and Production Engineering	1	0.57%
Measurement	1	0.57%
Evaluation and Program Planning	1	0.57%
Computers in Human Behavior	1	0.57%
International Journal of Strategic Property Management	1	0.57%
Journal of Medical Systems	1	0.57%
Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science	1	0.57%
Transport	1	0.57%
Total	**176**	**100.00%**

4.5. Distribution Paper Based on Publication Year

We found the considerable growth in the number of papers published related to VIKOR technique from 2004 to 2015. From a single article in 2004, the yearly paper published increased to seven papers in 2009. It further increased to 11 and 14 articles in 2010 and 2011 respectively. There is almost 20-fold increase of VIKOR paper published during 2004–2015 period. We may expect that the numbers of published papers related to VIKOR technique will increase in coming years. Cumulative numbers of VIKOR paper published in each year are shown in Figure 3.
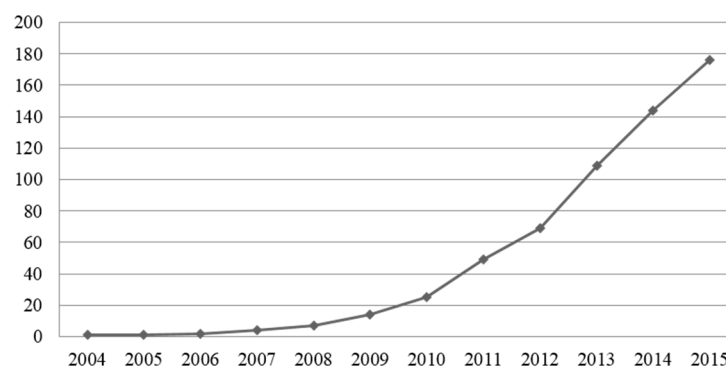
Figure 3. Distribution papers based on year of publication (cumulative).

4.6. Distribution of Papers Based on Nationality of Authors

Table 19 provides that; 22 countries and nationalities used VIKOR technique in the several application areas. The technique seems to be more popular in developing and newly industrialised countries. Results in this table indicated that; Taiwan was the first country which published 48 papers (27.27%) related to VIKOR technique. Furthermore, results of this table found that, Iran, China and India have published papers regarding several application areas by using VIKOR technique with 30, 26 and 21 publications respectively. Table 19 presents details regarding the nationality of authors.

Table 19. Distribution of papers based on the authors' nationality.

Name of Country	Number	Percentage (%)	Name of Country	Number	Percentage (%)
Taiwan	48	27.27%	Serbia	2	1.14%
Iran	30	17.05%	Italy	2	1.14%
China	26	14.77%	Yugoslavia	1	0.57%
India	21	11.93%	Serbia and Montenegro	1	0.57%
Turkey	12	6.82%	USA	1	0.57%
Lithuania	7	3.98%	Colombia	1	0.57%
Japan	4	2.27%	Finland	1	0.57%
South Korea	4	2.27%	Singapore	1	0.57%
Malaysia	4	2.27%	Ireland	1	0.57%
Spain	4	2.27%	Romania	1	0.57%
Bosnia and Herzegovina	3	1.70%	UK	1	0.57%

5. Concluding Remarks

VIKOR method is one of popular MCDM technique which has increasingly applied by researchers for solving problems in the real worlds. In recent years; several of previous scholars reviewed the MCDM techniques in various fields such as service quality [21], transportation [259], economic [260], MADM/MCDM [21], however; very few studies [261] reviewed and summarized role of VIKOR method and its application in various fields of sciences. Therefore; this review paper aimed to document the role of VIKOR technique and its applications in various fields of science. This review study attempted to review, classify and summarize papers which employed the VIKOR technique in various application areas which published from 2004 to 2015 in 83 international journals accessible in Web of Science and Scopus. In addition, this review paper aimed to classified these published papers into 15 application areas: (1) Manufacturing, (2) Construction Management, (3) Material Selection, (4) Performance Evaluation, (5) Health-Care, (6) Supply Chain, (7) Tourism Management, (8) Service Quality, (9) Sustainability and Renewable Energy, (10) Water Resources Planning, (11) Marketing, (12) Risk and Financial Management, (13) Operation Management, (14) Human Resource Management, (15) Other application areas. In the field of manufacturing, finding indicated that 18 studies have VIKOR technique. Additionally, in the field of material selection, 17 papers have implemented VIKOR technique. Furthermore, in the field of marketing, results showed that 15 researchers have used VIKOR technique. Additionally, in the area of construction management, findings showed that 14 papers have used VIKOR technique. Moreover, from 176 papers, 22 papers were reviewed and classified as other areas, other information related to this classification presented in Table 1.

Based on review findings, 38 studies have integrated VIKOR, TOPSIS and fuzzy TOPSIS in different applications areas, 33 articles combined VIKOR, ANP and fuzzy ANP, in addition, 27 papers mixed VIKOR, DEMATEL and fuzzy DEMATEL In the distribution of journals, the Expert Systems with Applications journal was the first ranked journal among 83 journals with 27 published papers related to the VIKOR technique and its application areas. In the nationality-based classification, it was shown that 22 nationalities and countries applied VIKOR technique in 15 different application areas. Finally, Taiwan was shown to have the highest contribution to the publication of VIKOR technique papers in the 15 application areas.

The current review paper has some implications and limitations for future researches. This paper attempted to classified published paper in 15 different application areas, therefore; we can suggest future work to classify and summarize paper in different fields and sub-fields. As another limitation, this review paper just focused on English international scholarly journal, there are some journals with other languages which were not considered into our paper, although, we believed that current paper presented a comprehensive review paper and included the majority of published papers related to MCDM field. Future study may include other database apart from Scopus and WOS.

The MCDM methods are developed to assist decision making in either ranking a known set of alternatives for a problem or making a choice among this set while considering the conflicting criteria. The preferences of the decision making are elicited either before or during the evaluation

of the alternatives and the criteria. The alternatives are compared against each other based on how they perform relative to each criterion. Similarly, some methods require comparison of the criteria to determine the relative importance of each criterion. MCDM methods will then utilize this information to assign ranks to the alternatives. The alternative with the highest rank is selected as the best compromise solution. Furthermore; results of this review found that; VIKOR method was developed for multi-criteria optimization for complex systems, to find a compromise priority ranking of alternatives according to the selected criteria. Compromise solutions for a problem with conflicting criteria can help decision makers identify an acceptable answer. The VIKOR method solves MCDM problems with conflicting or non-commensurable criteria. This method assumes that compromising is acceptable for conflicting resolution. Although the VIKOR method is a popular method applied in multi-criteria analysis, it has some problems when solving MCDM problems. In this regards; our paper attempted to represent some examples about extended, improved, and proposed of this technique for solving MCDM techniques.

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