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Review

A bibliometric-based survey on AHP and TOPSIS techniques

Shaher H. Zyoud*, Daniela Fuchs-Hanusch

Institute of Urban Water Management and Landscape Water Engineering, Graz University of Technology, Graz, Austria

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ABSTRACT

In recent years, the employment of multiple criteria decision analysis (MCDA) techniques in solving complex real-world problems has increased exponentially. The willingness to build advanced decision models, with higher capabilities to support decision making in a wide range of applications, promotes the integration of MCDA techniques with efficient systems such as intelligence and expert systems, geographic information systems, etc. Amongst the most applied MCDA techniques are Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The development of a comprehensive perspective on research activities associated with the applications of these methods provides insights into the contributions of countries, institutes, authors and journals towards the advancements of these methods. Furthermore, it helps in identifying the status and trends of research. This in turn will help researchers in shaping up and improving future research activities and investments. To meet these aims, a bibliometric analysis based on data harvested from Scopus database was carried out to identify a set of bibliometric performance indicators (i.e. quantitative indicators such as productivity, and qualitative indicators such as citations and Hirsch index (*h*-index)). Additionally, bibliometric visualization maps were employed to identify the hot spots of research. The total research output was 10,188 documents for AHP and 2412 documents for TOPSIS. China took a leading position in AHP research (3513 documents; 34.5%). It was also the leading country in TOPSIS research (846 documents; 35.1%). The most collaborated country in AHP research was the United States, while in case of TOPSIS it was China. The United States had gained the highest h-index (78) in AHP research, while in TOPSIS it was Taiwan with h-index of 46. Expert Systems with Applications journal was the most productive journal in AHP (204; 2.0%) and TOPSIS research (125; 5.2%), simultaneously. University of Tehran, Iran and Islamic Azad University, Iran were the most productive institutions in AHP (173; 1.7%) and TOPSIS (115; 4.8%) research, simultaneously. The major hot topics that utilized AHP and will continue to be active include different applications of geographic information systems, risk modeling and supply chain management. While for TOPSIS, they are supply chain management and sustainability research. Overall, this analysis has shown increasing recognition of powerful of MCDA techniques to support strategic decisions. The efficacy of these methods in the previous context promotes their progress and advancements.

1. Introduction

Multiple criteria decision analysis (MCDA) is a full-grown branch and a useful resource within operations research and management sciences (Behzadian, Otaghsara, Yazdani, & Ignatius, 2012; Govindan & Jepsen, 2016). It is appropriate for addressing complex decision problems which are featuring conflicting objectives, diverse forms of data, multi interests and high uncertainties (Wang, Jing, Zhang, & Zhao, 2009). In practice, it is concerned with the evaluation of a collection of possible courses of action or options and this evaluation could be in the form of selecting a most preferred option, ranking options from the best one to the worst one or sorting the options into ordered classes (Durbach & Stewart, 2012). It can be perceived as a procedure which is valid to evaluate real-world cases based on diverse quantitative and/or qualitative criteria in environments characterized by certain/uncertain/risky decision making in order to find a convenient course of policy/strategy/action/choice among several obtainable options (Kumar, 2010). In everyday practices, the application of MCDA is crucial in allocating the finite resources between competing alternatives and interests (Diaby, Campbell, & Goeree, 2013). It is very useful in cases, there is a need to integrate hard data with subjective preferences, to do trade-offs between desired outcomes and to include multiple decision makers (Dolan, 2010). Through designing computational and mathematical tools, it is having a high potential to assist in the subjective evaluation of performance

* Corresponding author.
E-mail addresses: Shaher.h.zyoud@gmail.com (S.H. Zyoud), fuchs-hanusch@tugraz.at (D. Fuchs-Hanusch).

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criteria which have to be done by decision makers (Mardani, Jusoh, & Zavadskas, 2015). The employed knowledge in MCDA could be from different fields such as mathematics, information systems, economics, computer technology, behavioral decision theory and software engineering (Behzadian et al., 2012). As pointed out by Roy (2016), this discipline of research has produced since 60s and is continuing to produce in an active manner a huge number of theoretical and applied books and papers.

There is a large number of methods that have been developed to solve MCDA problems, and this development is an ongoing process. This growth is motivated by the diversity of real-life problems which are requiring the consideration of multiple and conflicting criteria and the willingness of decision makers and practitioners to offer enhanced and consolidated decision-making tools utilizing recent promotions in scientific computing, mathematical optimization and computer technology (Wiecek, Matthias, Fadel, & Rui Figueira, 2008). Furthermore, this growth is guided by the intense need to develop theories and methodologies that can treat complex problems encountered in business, management, engineering, science and other fields of human activities (Behzadian, Kazemzadeh, Albadvi, & Aghdasi, 2010). Typically, MCDA process realizes the objectives, selects the criteria to measure the objectives, allocates the alternatives, converts the scales of criterion into commensurable units, specifies criteria weights which reflect the relative importance of criteria, nominates and applies mathematical algorithms to rank the alternatives, and elects an alternative (Ananda & Herath, 2009). The common view in all MCDA methods is the possibility to improve most of decisions through a process of decomposing the overall evaluation of alternatives or options into a set of evaluations with respect to a number of usually conflicting criteria that are relevant to the decision problem. They are distinct from each other by means of evaluating the performance of options on each attribute and the aggregation of evaluations across attributes to reach at an overall evaluation (Durbach & Stewart, 2012). The performance matrix represents in general the basis of any analysis that using multiple decision criteria. This matrix is comprised of rows and columns; where the rows represent alternatives to be classified or rated, and the columns represent the evaluation criteria which to be used in assessing the performance of alternatives being compared (Diaby et al., 2013). The aggregation of information drawn from the performance matrix represents basic differences between MCDA methods (Diaby et al., 2013). Furthermore, MCDA methods involve different protocols to elicit the inputs, different structures to illustrate them, various algorithms to combine them, and several processes to demonstrate and use the formal results in decision making contexts (Huang, Keisler, & Linkov, 2011).

Among the most common MCDA methods, there are: analytic hierarchy process (AHP), multi-attribute utility theory (MAUT), simple multi-attribute rating technique (SMART), fuzzy set theory (FST), data envelopment analysis (DEA), case-based reasoning (CBR), simple additive weighting (SAW), elimination et choice translating reality (ELECTRE), technique for order of preference by similarity to ideal solution (TOPSIS), preference ranking and organization method for enrichment evaluation (PROMETHEE), and goal programming (GP) (Velasquez & Hester, 2013; Wang, Zhu, & Wang, 2016). MCDA frameworks have been employed and successfully applied to solve decision problems in many areas, including information and communication technologies (Cid-López, Hornos, Carrasco, & Herrera-Viedma, 2016), business intelligence (Pape, 2016), environmental risk analysis (Linkov & Seager, 2011; Mansour, Al-Hindi, Saad, & Salam, 2016), environmental impact assessment and environmental sciences (Huang et al., 2011; Ruiz-Padillo, Torija, Ramos-Ridao, & Ruiz, 2016), water resources management (Shen, Lu, Zhang, Song, & He, 2016), solid waste management (Maimoun, Madani, & Reinhart, 2016), remote sensing (Potić, Golić, & Joksimović, 2016), flood risk management (Azarnivand & Malekian, 2016), health technology assessment (Schmitz, McCullagh, Adams, Barry, & Walsh, 2016), health care (Mühlbacher & Kaczynski, 2016; Thokala et al., 2016), transportation (Karlson, Karlsson, Mörtberg, Olofsson, & Balfors, 2016), nanotechnology research (Linkov, Bates, Canis, Seager, & Keisler, 2011), climate change (Kim & Chung, 2013), energy (Franco, Bojesen, Hougaard, & Nielsen, 2015), and international politics and laws (Linkov, Trump, Jin, Mazurczak, & Schreurs, 2014).

Given the growing number of MCDA applications, the great deal of attentions that have been paid to these methods from practitioners and researchers and to develop a better recognition of the status of MCDA research at global level, it will be interesting to conduct a comprehensive analysis to estimate the global research productivity and to document the growing interest in these methods. We have chosen two MCDA methods, precisely AHP and TOPSIS methods for this investigation. The two MCDA methods, AHP and TOPSIS, are highly active fields of research among the MCDA methods and they are a good representative example of the diverse applications of MCDA methods in conjunction with other disciplines. To achieve this purpose, we suggest the employment of bibliometric techniques which are frequently used to measure the performance of science and technology at national and/or international levels within a given discipline or body of literature (Yataganbaba & Kurtbaş, 2016). Bibliometric techniques that fundamentally employ quantitative analyses and statistical indices to assess research output of individuals, institutions, journals, regions or countries are valuable instruments in measuring and evaluating the scientific research output (Wallin, 2005). It is possible to utilize these techniques to create pronouncements about qualitative indicators of scientific activities (Wallin, 2005), in addition to their high potential in performing systematic analyses (van Raan, 2005). A good information and useful knowledge related to the status of research activities within a particular discipline, which could help scholars and researchers in identifying and conducting new streamlines of research, can be drawn from the bibliometric outcomes and measurements (De Battisti & Salini, 2013).

These techniques are common tools in tracking research activities in different disciplines such as operation management (Shang, Saladin, Fry, & Donohue, 2015), medicine (Fan et al., 2016; Zyoud, Al-Jabi, & Sweileh, 2015), health and health care (Skvoretz et al., 2016), environment (Daughton, 2016; Zyoud, Fuchs-Hanusch, Zyoud, Al-Rawajfeh, & Shaheen, 2016), wastewater research (Zheng et al., 2015; Zyoud, Al-Rawajfeh, Shaheen, & Fuchs-Hanusch, 2016; Zyoud, Zyoud, Al-Jabi, Sweileh, & Awang, 2016), desalination research (Zyoud & Fuchs-Hanusch, 2015), drinking water (Fu, Wang, & Ho, 2013), groundwater research (Zyoud & Fuchs-Hanusch, 2016), computer science (Heradio, Perez-Morago, Fernandez-Amoros, Javier Cabrerizo, & Herrera-Viedma, 2016), geographic information systems (Liu, Lin, Wang, Peng, & Hong, 2016), landslides research (Wu, Chen, Zhan, & Hong, 2015). As well noted, these techniques can be applied to track research activities in specific topic or field of research at international, national, geographic area or country levels. In fields of MCDA research, there was a focus on conducting bibliometric analyses to evaluate the applications of MCDA methods in health care such a study done by Adunlin, Diaby, and Xiao (2015) in which they aimed to identify systematically the applications of MCDA methods in fields of research related to health care, and to report the publication trends. A review by Diaby et al. (2013) was devoted also to report the applications of MCDA methods in health care. Otherwise, there was a study which addressed the applications of MCDA methods in solving corporate finance problems by conducting a bibliometric analysis (Guerrero-Baena, Gómez-Limón, Cardozo, & J., 2014), a study which addressed the applications of AHP method in supply chain management (Tramarico, Mizuno, Salomon, & Marins, 2015) and a book chapter which tackled the issue of the growth of multi-attribute utility theory methods based on bibliometric techniques (Bragge, Korhonen, Wallenius, & Wallenius, 2010).

Up to the authors' knowledge and based on surveying the obtainable literature, this analysis has not been attempted before. It is the first of its nature in addressing this topic with aims to examine relative growth rates, leading countries and regions among the global, most prolific journals, institutions, and authors, collaboration patterns and citations rates in fields of research associated with the applications of AHP and TOPSIS methods. This work is partly motivated by the reality that AHP and TOPSIS research covers a large different body of literature, contributed from different disciplines. As an informative analysis, it will produce a detailed and new perspective on the status of research in these two vital topics and will help in recognizing the most significant contributors whether they were countries, journals, institutions or authors who played important roles in the growth and advancement of this field of research. The remainder of the paper is organized as follows. Section 2 provides a brief literature overview on the selected MCDA methods, AHP and TOPSIS methods. Section 3 describes the proposed methodology and the used techniques. Section 4 provides the results of the study with a comprehensive analysis and a discussion. Section 5 presents the implications, while Section 6 presents the strengths and limitations. Finally, Section 7 presents the conclusion remarks.

2. Literature overview

2.1. Analytic hierarchy process (AHP)

AHP is a multi-criteria decision making method which has been widely applied in wide variety of areas (Subramanian & Ramanathan, 2012). As pointed out by Ishizaka and Labib (2011) in their review on the main developments in the analytic hierarchy process, the oldest reference on this topic that they have found dates from 1972 (Saaty, 1972). There has been a steady-state increase in its usage since its introduction which is certainly due to its ease of application. A large body of research concerning with AHP applications in different disciplines can be found in literature such as but not limited to: sustainable and renewable energy (Singh & Nachtnebel, 2016; Štreimikiene, Šliogeriene, & Turskis, 2016), water resources management (Gdoura, Anane, & Jellali, 2015; Kavurmaci & Üstün, 2016), agriculture (Abdollahzadeh, Damalas, Sharifzadeh, & Ahmadi-Gorgi, 2016), health (Nguyen & Nahavandi, 2016), nuclear power (Erdoıan & Kaya, 2016), climate change (Chen et al., 2015), presidential elections (Zammori, 2010) and so on. The AHP is relied on three principles: decomposition, comparative judgments and synthesis of priorities (Ossadnik, Schinke, & Kaspar, 2016) and these principles can be achieved by performing the following steps: decision problem modelling or structuring, valuation and aggregation of weights and sensitivity analysis (Ishizaka & Labib, 2011).

For the decision problem modelling step, AHP has a strong potential in structuring the decision problem in the form of hierarchical structure. In its general form, the hierarchy structure takes a tree shape where the root represents the overall goal and the nodes that are descending from the goal represent the criteria. The criteria could branching out into other clusters of evaluation criteria which can be found in the intermediate levels of the structure. The complexity of the decision problem controls the number of levels of main criteria and evaluation criteria. The last level of the structure is kept for the set of options. This decomposition of the decision problem enables decision makers to analyze the options with respect to single subsets of criteria/evaluation criteria at different levels of generality (Del Vasto-Terrientes, Valls, Slowinski, & Zielniewicz, 2015). The AHP uses the pairwise comparisons at each node of the structure and allows consistency and cross checking between the different pairwise comparisons by using a ratio scale (Kainulainen, Leskinen, Korhonen, Haara, & Hujala, 2009).The pairwise comparison is reliable in decreasing the effect of subjective point-of-views associated with eliciting the weights directly (Dede, Kamalakis, & Sphicopoulos, 2016). In AHP, it is possible to evaluate quantitative as well as qualitative criteria and alternatives on the same preference scale of nine levels where the verbal comparisons should be converted into numerical values (Ishizaka & Labib, 2009). Derivation of priorities in AHP requires the calculations of the maximum Eigen value, consistency index (CI), consistency ratio (CR), and normalized values for each criteria/alternative and if the previous outcomes were satisfactory, the decision can be taken based on the normalized values; otherwise the procedure will be repeated until these values fall well in a desired range (Vaidya & Kumar, 2006). The consistency verification in AHP, which is perceived as one of the most significant strengths of AHP and incorporated to evaluate the degree of consistency among pairwise comparisons, is vital because it acts as a feedback for decision makers to review and revise their evaluations and judgments (Ho, 2008).

To determine the global priorities of options in the last level of the hierarchy structure, the local priorities across all levels of the hierarchy structure can be synthesized based on additive aggregation with normalization of the sum of the local priorities to unity (Ishizaka, Balkenborg, & Kaplan, 2011). It is possible in AHP, with the aim to examine the impact of modified the inputs on the outputs, to conduct a sensitivity analysis. This allows the production of different scenarios and if there were no changes in the rankings, it is possible to say the results were robust, else they will be sensitive (Ishizaka & Labib, 2011). The application of AHP in group decision making can be adopted. This is required in cases where complex decisions need to be considered involving high risks and in this case it is more preferable to base the decisions on combined judgments and opinions of several decision makers rather than to simply depend on skills of an individual decision maker (Dede et al., 2016). The two dominant synthesizing procedures in group decision making are: computing the geometric mean of individual evaluations in the pair-wise matrices and then priorities can be derived while in the second procedure, the priorities are firstly computed and then aggregated by using the weighted arithmetic mean method (Pedrycz & Song, 2011). To deal with uncertainty in human judgments and real evaluation problems, fuzzy extensions based on fuzzy sets theory, which has been introduced by L.A. Zadeh as the generalization of classical set theory in 1965 has been integrated with AHP (Nayagam, Jeevaraj, & Sivaraman, 2016). A review conducted by Mardani et al. (2015) on fuzzy multiple criteria decision-making techniques and applications showed that the technique of Fuzzy Analytic Hierarchy process (Fuzzy AHP), which integrates fuzzy set theory with traditional AHP was the most used one among MCDA techniques that employed fuzzy decision making tools and approaches. This approach has found large applications in recent years, and proved to be an efficient methodology for decision making in fuzzy environments (Wang & Chin, 2011).

One of the main keys to this success in the AHP applications is the user friendly supporting software, Expert Choice, which is of potential to incorporate intuitive graphical user interfaces, calculations of priority weights, assessment of consistency and diverse approaches to perform the sensitivity analysis (Ishizaka & Labib, 2009). The integration of AHP with other techniques like fuzzy set theory, mathematical programming, data envelopment analysis, artificial neural networks and genetic algorithms produces more realistic decisions than the stand-alone AHP method (Ho, 2008). As mentioned by Ishizaka and Labib (2011) in their comprehensive review on the main developments in AHP methods, the AHP will be more frequently adopted in different applications without no doubt despite its suffer from some theoretical disputes such as rank reversal which is still not perfectly solved, and the assumption of criteria independence which could be sometimes a limitation of using AHP method and the analytic network process (ANP) is proposed as a solution to this issue.

2.2. Technique for order of preference by similarity to ideal solution (TOPSIS)

It is a well-known and one of the major classical MCDA methods that was originally developed by Hwang and Yoon in 1981 (Yoon & Hwang, 1995). As pointed out by Zavadskas, Mardani, Turskis, Jusoh, and Nor (2016), the TOPSIS method is the second most popular method among multi criteria decision making techniques. A full use of attribute information is possible by employing this method which provides a cardinal ranking of options and does not require the independency of the attribute preferences (Chen & Hwang, 1992; Yoon & Hwang, 1995). In its basics, the alternatives are ranking according to their distances from positive and negative ideal solutions, i.e. the best alternative will be the one who has the shortest distance from the positive ideal solution and simultaneously the farthest distance from the negative ideal solution (Roghanian, Rahimi, & Ansari, 2010). This method considers simultaneously the distances to both positive and negative ideal solutions, and a preference order is ranked based on their relative closeness and the combination of these two distance measures (Yue, 2011). The concept of distance measures which is the pillar of TOPSIS method and the most straightforward technique in multi attribute decision making conduce to consider this method an important branch of decision making (Shih, Shyur, & Lee, 2007). For the positive ideal solution, it is recognized with a "hypothetical alternative" that has the best assessments for all considered criteria while for the case of the negative ideal solution the "hypothetical alternative" has the worst criteria values (Roghanian et al., 2010; Yue, 2011). The application of this method requires: all values of attributes must be numeric, to be increasing or decreasing monotonically and all attributes should have commensurable units (Behzadian et al., 2012).

This method has been successfully applied in diverse applications and it continues to work satisfactorily (Behzadian et al., 2012). Its implementation in real-world applications includes, for example but not limited to, e-commerce (Kang, Jang, & Park, 2016), industry (Shaverdi, Ramezani, Tahmasebi, & Rostamy, 2016), health (Viyanchi, Ghatari, Rasekh, & Safikhani, 2016), solid waste management (Aghajani Mir et al., 2016), supplier selection (Wood, 2016), cloud computing (Liu, Chan, & Ran, 2016), risk management (Mahdevari, Shahriar, & Esfahanipour, 2014), renewable energy (Şengül, Eren, Eslamian Shiraz, Gezder, & Sengül, 2015), water resources management (Zyoud, Kaufmann, Shaheen, Samhan, & Fuchs-Hanusch, 2016), climate change (Kim & Chung, 2013), sustainability assessment (Mulliner, Malys, & Maliene, 2016). Fuzzy extensions of TOPSIS method have been proposed by researchers to grasp the vagueness and to alleviate uncertainties that are inherent in the assessment values and human judgments (Roghanian et al., 2010). Among MCDA techniques that employed fuzzy decision making approaches, Fuzzy TOPSIS occupied the third position as pointed out in a review on fuzzy multiple criteria decision-making techniques and applications (Mardani et al., 2015). Fuzzy TOPSIS has been used widely in fields of research related to engineering and computer sciences (Kahraman, Onar, & Oztaysi, 2015). Furthermore, it has also been connected to group decision making and multi-objective decision making based on its high flexibility which in turn leads to make better choices (Hwang & Lin, 2012).

The steps of performing TOPSIS procedure based on (Hwang & Yoon, 1981) methodology comprise the forming of the decision matrix, followed by decision matrix normalization and weighted normalized decision matrix. After that, a step of calculating the positive and negative ideal solutions, and determining of separation measures for each alternative is to be done. The last step is dedicated to calculate the relative closeness coefficients and to rank the alternatives in descending order based on the associated values of closeness coefficients (Behzadian et al., 2012). Many various developments, improvements and extensions of the traditional TOPSIS method have been developed and recently many developments of hybrid methods that integrate TOPSIS methods with other methods such as AHP, PROMETHEE, ELECTRE, DEA, etc. are becoming increasingly apparent (Zavadskas et al., 2016).

3. Materials and methods

3.1. Search strategy

Typically, bibliometric analyses are carried out based on employing one of four widely popular databases which include Web of Knowledge, Scopus, Google Scholar and PubMed (Falagas, Pitsouni, Malietzis, & Pappas, 2008). We used Scopus database to retrieve documents related to AHP and TOPSIS methods because it is deemed the largest database which indexes the largest number of journals than other scientific research databases (Falagas et al., 2008; Kulkarni, Aziz, Shams, & Busse, 2009). As the largest abstract and citation database of peer-reviewed literature, it includes more than 60 million records, and covers over 21,500 peer–reviewed journals (Elsevier, 2016). Scopus database grants the most flexible overview of the global research productivity in all domains of science (Yataganbaba & Kurtbaş, 2016). All subject areas within Scopus database which include: social, health, physical and life sciences were looked for during the data search and gathering. The document types (article, article in press, review) were considered in the search while the other document types such as book, conference papers, erratum, etc. were eliminated. Beyond the year 2015, the scientific research output was excluded from the analysis since the period after Dec. 31, 2015 is still open for new publications. No time restrictions were imposed in the search regarding the starting year. The search was applied one time interval (20th April 2016) to eliminate the bias which may emerge as a result of continuous updating of Scopus database.

Scopus database was searched for each of the two MCDA methods separately. For the AHP method, the following search expressions in Scopus database advance search were used in the title, abstract and keywords to obtain the research output at global level: analytical hierarchy process, analytical hierarchical process, analytic hierarchy process, analytic hierarchical process, analytical hierarch process and analytical hierarch process. For the TOPSIS method, the used search expressions were: topsis and technique for order preference by similarity to the ideal solution.

By the use of Boolean operators "OR" and "AND", the following search queries were reached to evaluate the total number of publications related to each of the two MCDA methods at global level; for the AHP method, the query was as follows: (TITLE-ABS-KEY ("analytical hierarchy process*") OR TITLE-ABS-KEY ("analytical hierarchical process*") OR TITLE-ABS-KEY ("analytic hierarchy process*") OR TITLE-ABS-KEY ("analytic hierarchical process*") OR TITLE-ABS-KEY ("analytical hierarch process*") OR TITLE-ABS-KEY ("analytical hierarch process*")) AND PUBYEAR < 2016 AND ((EXCLUDE (DOCTYPE,"cp") OR EXCLUDE (DOCTYPE,"cr") OR EXCLUDE (DOCTYPE,"ch") OR EXCLUDE (DOCTYPE,"bk") OR EXCLUDE (DOCTYPE,"no") OR EXCLUDE (DOCTYPE,"er") OR EXCLUDE (DOCTYPE,"rp") OR EXCLUDE (DOCTYPE,"sh") OR EXCLUDE (DOCTYPE,"le") OR EXCLUDE (DOCTYPE,"Undefined")). For the TOPSIS query, it was: ((TITLE-ABS-KEY (topsis) OR TITLE-ABS-KEY (technique* order preference* similarity ideal solution*)) AND PUBYEAR < 2016 AND ((EXCLUDE (DOCTYPE,"cp") OR EXCLUDE (DOCTYPE,"cr") OR EXCLUDE (DOCTYPE,"ch") OR EXCLUDE

(DOCTYPE,"er") OR EXCLUDE (DOCTYPE,"le") OR EXCLUDE (DOCTYPE,"Undefined")).

We used the asterisk (*) in the search as a wild card character to make our search simpler and more comprehensive as it will track all possible forms of the used terms (i.e. it was more comprehensive, when "analytic hierarchy process*" search expression was used in comparison with the use of "analytic hierarchy process". The following symbols (cp: conference paper, cr: conference review, ch: book chapter, er: erratum, no: note, bk: book, rp: report, sh: short survey, le: letter) and undefined indicated to the excluded documents. The outputs of search from Scopus database can be displayed in the form of list with 20–200 items per page. Furthermore, the extracted documents can be exported to Excel spreadsheets. The results can be revised by the author name, affiliation, document type, source title, number of publications per year, and/or subject area, and a new search can be launched within the results (Falagas et al., 2008).

3.2. Statistical analysis and indices of research productivity

The output data was analyzed to create an informative framework and comprehensive perspective about several bibliometric indicators which were considered as quantitative and qualitative indicators such as: date and growth rates of published documents, journals names and their impact factors (IF), authorships, countries of origin, affiliations, number and evolution of citations, international collaboration patterns, document types and prevalent areas of interests. The Microsoft Excel 2013 was used for data collection and generation of figures, and the statistical package for social sciences (SPSS) program, version 20 was employed to perform the descriptive statistics calculations (i.e. frequency in count and percentage, mean, median and sum) and inter quartile range (Q1:Q3). The formula of standard competition ranking (SCR) was employed to rank the top 20 most productive countries, prolific authors, journals, institutions, most cited articles and areas of interests. They are ranked in descending order which means that the 1st is ranked as the highest and is considered as the most prolific. In a condition, two measurements are attracting the same ranking, a gap will be left for the followed ranking number.

The total citations of the published research were analyzed based on Hirsch-index (*h*-index) which is an indicator that integrates measures of quantity (i.e. amount of publications) and quality (i.e. citation rates) (Egghe, 2006). It is defined as the number of publications that have a citation count higher or equal to *h*, and it is a representative index with potential to qualify scientific research productivity for researchers, countries, institutions, journals, etc. (Hirsch, 2005). It is of advantage to identify the importance, significance and broad impact of a researcher's accumulative research contributions (Hirsch, 2005), and to identify research performance in qualitative sight (Meho & Rogers, 2008). To demonstrate its concept when it is testing the country's scientific research productivity and impact, it is true to state that a specific country with *h*-index 10 has published 10 documents and each document has attracted at least 10 citations at the time of data analysis. The IF of each considered journal was extracted from the Journal Citation Reports (JCR) Ranking: 2015 edition released by Thomson Reuters. The countries and regions of the world, which were examined in this study, were categorized according to classification of SCImago Journal & Country Rank which is a portal that includes the countries and journals scientific indicators promoted by the information contained in Scopus database (SJR, 2016).

3.3. Content analysis

The analysis of the word frequency in published research is an effective tool to examine the content analysis of research (Wang, Zhao, Mao, Zuo, & Du, 2017). The author keywords have the potential to reflect the focus of research since the core words indicate the core literature within a specific field of research. This will help in identifying the central topics and hot spots which will continue to be vital in the examined field of research and could help in suggesting new directions for science in the future (Tan, Fu, & Ho, 2014). Accordingly, the analysis of co-occurrence of keywords of published research to examine the hot research areas will be conducted by benefiting from the capabilities of VOSviewer software. This software produces visualization maps relied on data of network and uses the "visualization of similarities" mapping and techniques of clustering. They are designed primarily to be used in the analysis of bibliometric networks (van Eck & Waltman, 2010; Zeraatkar, 2013).

4. Results and discussion

This study attempted to survey and examine the bibliometric performance indicators associated with the applications of two most widely used MCDA methods, AHP and TOPSIS. The followed approach of this analysis relied on Scopus database in sourcing publications and gathering systematic data, and utilizing bibliometric techniques that are frequently employed to survey the trends and the scientific research output in many disciplines of science. The research out performance indicators have been assessed in terms of the total amounts of published documents, while the research quality, it has been assessed by employing the *h*-index and citation rates. To present a roadmap related to scientific activities conducted on AHP and TOPSIS methods, the following dimensions and their outcomes in the below subsections have been considered and analyzed in details.

4.1. Analysis of growth rates and evolution of AHP and TOPSIS scientific publications

The resulting sample based on the analysis conducted over the Scopus database and related to AHP method comprises 16,712 documents including articles, conference papers, reviews, book, erratum, short survey, etc. By restricting the search to articles, articles in press and reviews, the net research output was 10,188 documents. The majority of these documents were made as articles (9957; 97.7%) and followed with large margin by the reviews (231; 2.27%). The yearly average was 255 documents/year. A gradual increase in the scientific research productivity was observed and a steep rise and breakthrough occurred after 2005. More than 83.0% of research was published during the period extended from 2006 to 2015. The first article as documented in Scopus database was published in 1976 by the developer of the method Saaty, T.L. as a first author and Rogers, P.C. as a second author (Saaty & Rogers, 1976). In this article, the authors discussed the application of the hierarchical framework with eigenvector weighting in field of planning in higher education in the United States.

For the TOPSIS method, the total number of documents was 3752. The limiting of search to articles, articles in press and reviews lead to a net total of 2412 documents where the number of articles was (2375; 98.5%) and the remaining (37; 1.50%) were classified as reviews. Its yearly average was about 60 documents/year. Since its inception in 1981, it grew at a modest rate and it has witnessed a dramatic rise since 2005 as more than 96% of research was published after this year. This result may owe to the increase of integrating the TOPSIS method with other MCDA methods, multi-objective and group decision making (Roghanian et al., 2010). The first work documented the application of TOPSIS method in Scopus database was in 1983 (McCahon, Hwang, & Tillman, 1983). In this work, the authors used five multi-attribute decision making techniques, the TOPSIS method was among them, to

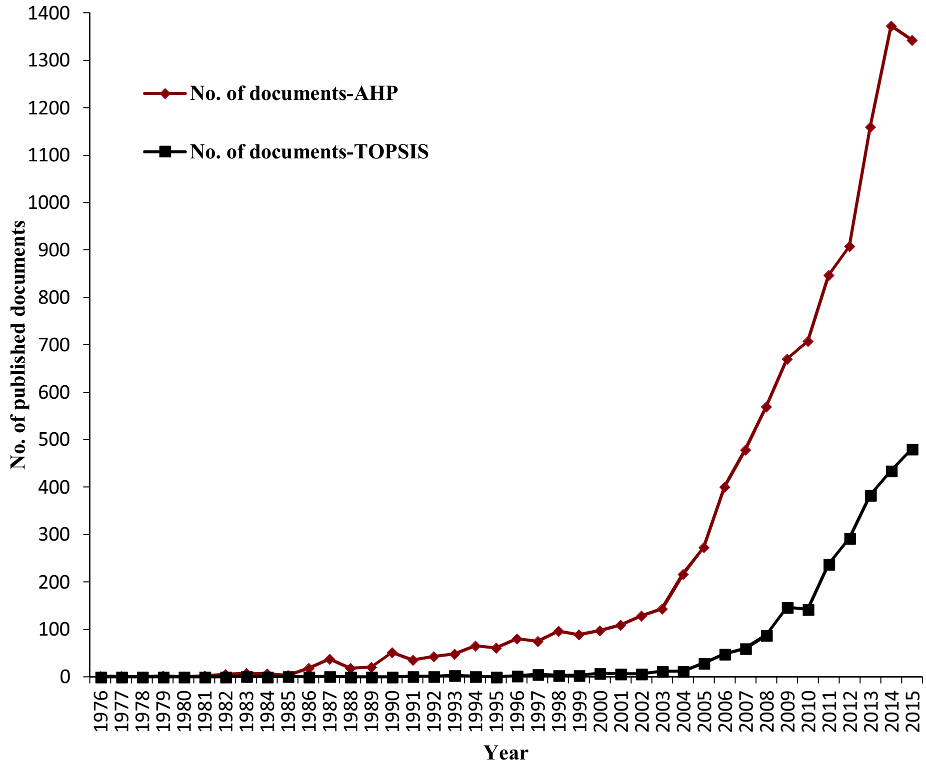

Fig. 1. No. of published articles and review articles from the global in AHP & TOPSIS methods.

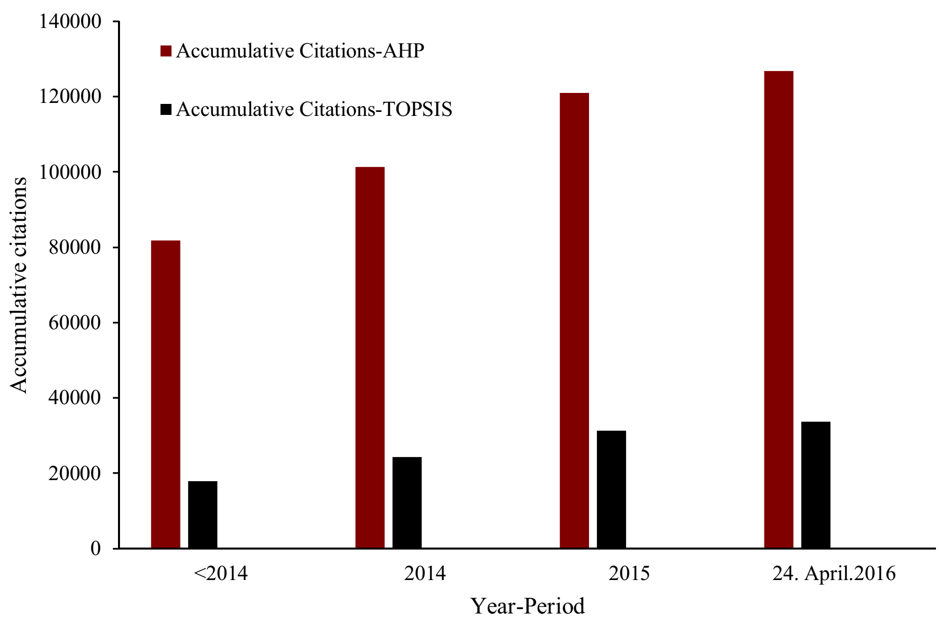

Fig. 2. Evolution of citations for the published articles and review articles from the global in AHP & TOPSIS methods.

evaluate the best estimation method among three Bayesian availability estimators. The evolution of distribution of the published research along the time for AHP and TOPSIS methods is shown graphically in Fig. 1.

In terms of citation rates, the total number of citations for published research in AHP was 126,804 citations, with a mean of 12.45 and a median (interquartile range) of 2 (0.0–10.0), while for the TOPSIS method, the total number of citations at the time of processing the analysis was 33,698, with a mean of 13.97 and a median (interquartile range) of 2 (0.0–10.0). Fig. 2 displays the evolution of citations for the published research in AHP and TOPSIS methods. From the above findings, it can be deduced that the performance of AHP method in the most of bibliometric indicators was predominant. This could be attributed to a number of facts such as, the AHP method has been developed early in comparison with the TOPSIS method, was the subject of much methodological research over the past three decades (Cabala, 2010), has been accepted by the international scientific community as a very useful tool for dealing with complex decision problems, for major policy decisions; many corporations and governments are routinely using

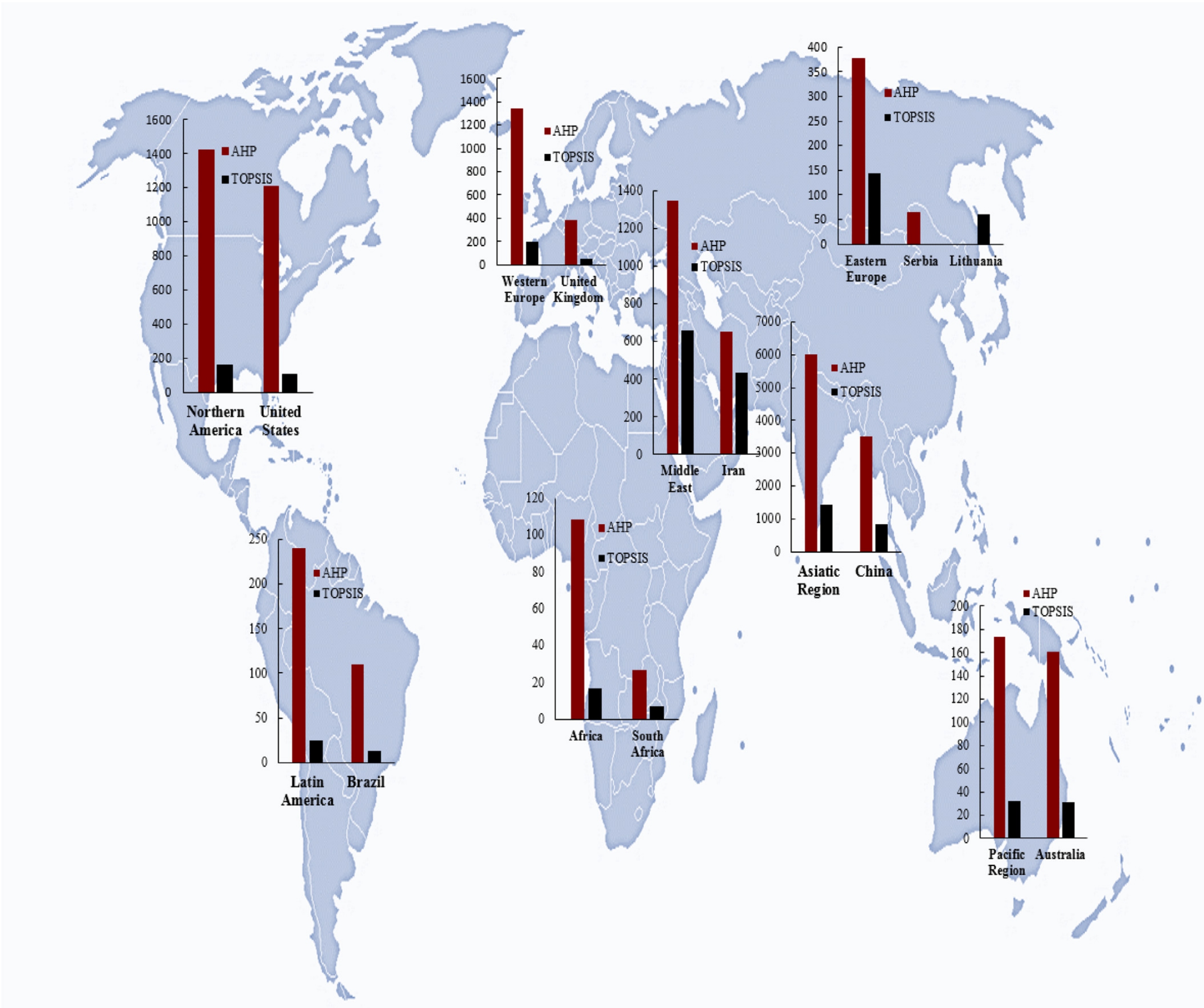

Fig. 3. Geographic distribution of scientific research productivity in AHP and TOPSIS research with the most productive country in each region.

the AHP (Golden, Wasil, & Harker, 1989) and the availability of a leading software, Expert Choice, which supports the AHP (Ishizaka & Labib, 2009).

4.2. Analysis of publications distributions by countries and regions

The geographic distribution of scientific research productivity for the AHP method is given in Fig. 3. At the level of global regions, the Asiatic region was the most productive region with a total of 6011 documents (59.0%), followed by Northern America (1420; 13.9%), Middle East region (1349; 13.2%), Western Europe (1339; 13.1%), Eastern Europe (377; 3.7%), Latin America (240; 2.3%), Pacific region (173; 1.7%) and Africa region (108; 1.1%). The total number of countries that have contributions towards research on AHP method was 111 countries. These countries are distributed over the regions of the world as follows: 20 countries in Asiatic region, 19 countries for each of Western and Eastern Europe, 17 countries for Africa, 16 for Latin America, 15 for Middle East, 3 for Pacific region and 2 for Northern America.

At country level, Table 1 displays the results of the analysis of bibliometric performance indicators for the top twenty most productive countries that published research related to AHP method. The analysis tracked the performance of each country in terms of number of published documents, *h*-index of the published research, overall citations, average and median of citations, number of collaborated countries and the research productivity resulted from collaboration, most collaborated country and the most used journal. As it is shown from Table 1, the country with the highest scientific research output in the global was China (3513; 34.4%), After China, the countries found to have the highest research output are the United States (1209; 11.85), Taiwan (866; 8.5%), India (701; 6.8%), Iran (649; 6.3%), Turkey (464; 4.5%), etc. The highest *h*-index was 78 and has been recorded by the United States, followed by 62 for Turkey, 60 for Taiwan, 55 for the United Kingdom and 51 for China. The highest rate of citations at time of data analysis was recorded for published research from the United States (29,430), followed by China (16,811), Taiwan (14,463) and Turkey (11,478). The highest average of citations (40.14) and the highest median (interquartile range) 21 (5–46.75) were recorded by Hong Kong.

According to the analysis of collaboration among countries as shown in Table 1, the United States was the dominant country in

Table 1
Ranking of top twenty most productive countries - AHP research.

SRC[a]	Country	No. of documents (%)	*h*-index	No. of citations	Average citation	Median citation (Q1-Q3)	Collaboration with foreign countries	No. of documents form collaboration (%)[b]	Most collaborated country	No. of documents with most collaborated country (%)	Most used journal	No. of documents in the most used journal (%)
1st	China	3513 (34.5)	51	16,811	4.79	1 (0–4)	39	331 (9.4)	United States	113 (3.22)	Biotechnology an Indian Journal	95 (2.70)
2nd	United States	1209 (11.9)	78	29,430	24.34	9 (2–25)	60	452 (37.4)	China	113 (9.35)	European Journal of Operational Research	76 (6.29)
3rd	Taiwan	866 (8.5)	60	14,463	16.7	4 (1–16)	22	97 (11.2)	United States	31 (3.58)	Expert Systems with Applications	58 (6.70)
4th	India	701 (6.9)	39	8355	11.92	3 (0–10)	32	92 (13.1)	United States	20 (2.85)	International Journal of Production Research	24 (3.42)
5th	Iran	649 (6.4)	29	4806	7.41	2 (0–7)	31	132 (20.3)	United States	38 (5.86)	Journal of Environmental Studies	19 (2.93)
6th	Turkey	464 (4.6)	62	11,478	24.74	6 (1–23)	24	57 (12.3)	United States	22 (4.74)	Expert Systems with Applications	36 (7.76)
7th	United Kingdom	388 (3.8)	55	10,496	27.05	8.5 (2–27)	53	120 (30.9)	China	41 (10.57)	International Journal of Production Economics	17 (4.38)
8th	South Korea	282 (2.8)	29	3320	11.77	4 (1–15)	19	90 (31.9)	United States	50 (17.73)	Expert Systems with Applications	16 (5.67)
9th	Canada	242 (2.4)	37	3940	16.28	6.5 (2–20)	28	96 (39.7)	United States	30 (12.4)	European Journal of Operational Research	12 (4.96)
10th	Malaysia	213 (2.1)	16	1133	5.32	1 (0–5)	27	57 (26.8)	Iran	26 (12.21)	Jurnal Teknologi	11 (5.16)
11th	Spain	194 (1.9)	28	2691	13.87	4.5 (1–17)	32	58 (29.9)	United Kingdom	11 (5.67)	European Journal of Operational Research	6 (3.10)
11th	Italy	194 (1.9)	29	2994	15.43	6 (1–17)	30	63 (32.5)	United Kingdom	15 (7.73)	Reliability Engineering and System Safety	6 (3.10)
13th	Japan	190 (1.8)	22	1998	10.52	2 (0–10)	25	63 (33.2)	China	15 (7.89)	Journal of the Operations Research Society of Japan	11 (5.79)
14th	Hong Kong	176 (1.7)	45	7064	40.14	21 (5–46.7)	15	102 (58.0)	China	54 (30.68)	-Expert Systems with Applications -European Journal of Operational Research -International Journal of Production Research	9 (5.11) 9 (5.11) 9 (5.11)
15th	Australia	161 (1.6)	31	4482	27.84	7 (1–23.5)	33	87 (54.0)	China	28 (17.39)	Environmental Modelling and Software	8 (4.97)
16th	Brazil	110 (1.1)	11	411	3.74	1 (0–4)	9	12 (10.9)	United States	4 (3.64)	Producao	8 (7.27)
17th	Germany	102 (1.0)	22	1461	14.32	5 (1–18.75)	32	57 (55.9)	United States	16 (15.69)	European Journal of Operational Research	6 (5.88)
18th	Finland	98 (1.0)	28	2270	23.16	10 (2.75–31.75)	17	30 (30.6)	Italy	9 (9.18)	International Journal of Production Economics	10 (10.20)
19th	Netherlands	94 (0.9)	21	1248	13.28	9.5 (2–19.25)	34	51 (54.3)	United States	13 (13.83)	European Journal of Operational Research	9 (9.57)
20th	Greece	93 (0.9)	21	1595	17.15	6 (2–26.5)	12	14 (15.1)	China; Cyprus; Italy; Spain; United Kingdom	2 (2.15) 2 (2.15) 2 (2.15) 2 (2.15) 2 (2.15)	Energy Policy	7 (7.53)

Abbreviations: SCR = Standard Competition Ranking; Q1–Q3 = lower quartile–upper quartile
[a] Equal countries have the same ranking number, and then a gap is left in the ranking numbers
[b] Proportion of published documents with international authors from the total documents published by each country.

terms of joint publications with other countries (i.e. number of collaborated countries and number of documents resulted from collaboration). The most collaborated country with the United States was China. China was the second in terms of collaboration with other countries and the volume of produced research from collaboration. The high rates of contributions of Chinese scholars could be justified generally by the population size of China and admittedly, the research productivity depends on population size, socio economic or overall scientific activity of the country (Miró, Montori, Ramos, Galicia, & Nogué, 2009). Furthermore, China has become a powerhouse in research and development spending (Sun & Cao, 2014), and its research capacity has grown dramatically in the past decade (Yang, 2013). According to the Nature Index database started in 2012, China's total contribution in global research has risen to become the second largest in the world and surpassed only by the United States (Zhou, 2015). Regarding China's contributions to AHP research, Liu and Xu (1987) concluded in their study about the applications of AHP in China, that the AHP method have such a strong appeal to many Chinese scholars. They have paid a great attention to the theoretical and mathematical foundations of the AHP, the test of judgments consistency, fuzzy extensions of the method, dynamic, absolute and impact priorities and so on. From these findings, the authors deduced that in the subsequent periods, the AHP will become a key factor in the thinking of the Chinese people, and further fast developments in its research and applications fields will become apparent (Liu & Xu, 1987).

The AHP method is widely used by researchers from the United States as it represents the American school in MCDA field which is contrasted to the French school (Lootsma, 1990). Prof. Thomas Saaty, who is internationally recognized for this decision making process is working at University of Pittsburgh in the United States. The qualitative indicators of published research, number of citations and *h*-index, related to AHP method shows the superiority of the United States which in general heads the list of nations in the volume of publications and citations and the share of top 1% cited papers in all fields of scientific research (King, 2004). In the context of collaborations, the United States sustains as a major contributor in scientific collaboration due to its large productivity in scientific research and it is playing an important role in networking international research collaboration (Gazni, Sugimoto, & Didegah, 2012).

For the TOPSIS method, the geographic distribution of scientific output is given in Fig. 3 which shows also the most productive country in each region. Asiatic region was the most productive region (1417; 58.7%), followed by Middle East (656; 27.2%), Western Europe (197; 8.2%), Northern America (157; 6.5%), Eastern Europe (143; 5.9%), Pacific region (32; 1.3%), Latin America (24; 1.0%), and Africa region (17; 0.7%). The number of countries that have contributions in TOPSIS research was 71 countries, and they are distributed as follows: 17 countries from Western Europe, 16 form Eastern Europe, 16 from Asiatic region, 8 from Africa, 7 from the Middle East, 3 from Latin America and 2 from each of Northern America and Pacific region. As can be seen, the most productive region was Asiatic region where TOPSIS has been deemed as one of the major used decision making techniques (Roghanian et al., 2010)

Table 2 displays the analysis of outputs of performance indicators for the top twenty most productive countries that have contributions related to TOPSIS research. China was the country with the highest research output (846; 35.0%), followed by Iran (434; 18.0%), India (238; 9.9%), Taiwan (217; 9.0%), Turkey (197; 8.2%), United States (105; 4.4%), etc. Taiwan registered the high *h*-index (46) with high number of citations (9544), followed by China, Turkey and Iran. Taiwan also registered the highest average of citations (44.0). Collaboration patterns show that China was the most collaborated country, and mostly collaborated with the United States. Iran and the United States followed China in terms of number of collaborated countries and number of documents resulted from collaboration. It is well noted that 16 countries in the list of top twenty most productive countries in TOPSIS method were the same as in the list of the AHP method.

4.3. Analysis of the leading journals that contributed to the AHP and TOPSIS literature

Identifying the journals that publish AHP or TOPSIS research is important for scholars and practitioners who have interests in these fields of research and it is of advantage to decide which journals to consider in performing a literature review as pointed out by Rey-Martí, Ribeiro-Soriano, and Palacios-Marqués (2016). In AHP field of research, there was 150 journals that contributed to AHP literature. In this study as shown in Table 3, the Expert Systems with Applications journal was the most comprehensive source of AHP research (204; 2.0%) with an average of 8.5 research papers per year. It was mostly used by researchers from Taiwan (58; 28.4%). It was followed by European Journal of Operational Research (199; 1.95%) with an average of 5.9 research papers per year, and was mostly used by researchers from the United States (76; 38.2%), International Journal of Production Research (100; 0.98%) with an average of 4.1 documents per year, and was mostly used by researchers from India (24; 24.0%), etc. The high rate of citations was documented to the benefit of European Journal of Operational Research (14,027) which attracted also the high *h*-index (58). It was followed by Expert Systems with Applications journal which registered (7430) citations, and attracted an *h*-index of 50 for the published research related to AHP methods, International Journal of Production Economics which registered (4374) citations and attracted an *h*-index of 35, and International Journal of Production Research with 2872 citations and *h*-index of 29. There was twelve journals out of twenty one journals in the list of top twenty most productive journals that have contributions towards AHP research and have impact factors according to Journal Citation Reports (JCR) Ranking: 2015 edition released by Thomson Reuters.

Table 4 displays the top twenty most productive journals out of 144 journals contributed to TOPSIS literature. As in case of AHP research, the Expert Systems with Applications journal was the most productive journal (125; 5.2%) with an average of 12.5 documents per year and was mostly utilized by scholars from Turkey (27; 22.0%), China (17.05), Taiwan (19; 15.0%) and Iran (16; 13.0%). Applied Soft Computing Journal was the second with (45 documents; 1.9%), an average of 5.0 documents per year and mostly used by researchers from Iran (14; 31.0%), China (9; 20.0%) and Taiwan (7; 16.0%). It was followed by International Journal of Advanced Manufacturing Technology (40; 1.7%), International Journal of Production Research (36; 1.5%), Journal of Intelligent and Fuzzy Systems (30; 1.2%), etc. Expert Systems with Applications journal gained the high rates of citations (6422) and the high *h*-index (46). In terms of citations, it was followed by Mathematical and Computer Modelling Journal (1463), International Journal of Advanced Manufacturing Technology (1138) and Applied Soft Computing (1124). Sixteen journals out of twenty two journals in the list of most productive journal have impact factors.

4.4. Analysis of the used languages

For the AHP research, the most commonly used language was English (8014 documents; 79.0%), followed by Chinese language (1998 documents; 19.6%). The rest of the most popular world's languages was poorly represented such as Japanese (44; 0.43%), Portuguese (44; 0.43%), Spanish (44; 0.43%), Persian (31; 0.30%), Croatian (21; 0.21%), Turkish (20; 0.19%), German (18; 0.18%), Polish (18;

Table 2
Ranking of top twenty most productive countries - TOPSIS research.

SRC[a]	Country	No. of documents (%)	*h*-index	No. of citations	Average citations	Median citation (Q1-Q3)	Collaboration with foreign countries	No. of documents form collaboration (%)[b]	Most collaborated country	No. of documents with most collaborated country (%)	Most used journal	No. of documents in the most used journal (%)
1st	China	846 (35.1)	39	5972	7.06	1 (0–5)	26	98 (11.58)	United States	36 (36.73)	Expert Systems with Applications	21 (2.48)
2nd	Iran	434 (18.0)	31	4049	9.33	2 (0–9)	25	88 (20.28)	United States	22 (25.0)	Expert Systems with Applications	16 (3.69)
3rd	India	238 (9.9)	24	1837	7.72	2 (0–7)	16	20 (8.4)	Denmark	4 (20.0)	International Journal of Applied Engineering Research	13 (5.46)
4th	Taiwan	217 (9.0)	46	9544	43.98	6 (1–33.5)	11	23 (10.6)	United States	8 (34.78)	Expert Systems with Applications	19 (8.76)
5th	Turkey	197 (8.2)	33	4436	22.52	6 (1–22)	13	20 (10.15)	Iran	4 (20.0)	Expert Systems with Applications	27 (13.71)
6th	United States	105 (4.4)	22	2994	28.51	7 (1–18)	21	81 (77.14)	China	36 (44.44)	Expert Systems with Applications	5 (4.76)
7th	Lithuania	61 (2.5)	19	1174	19.25	10 (2.5–27)	8	21 (34.43)	Iran	16 (76.19)	Technological and Economic Development of Economy	9 (14.75)
8th	Malaysia	56 (2.3)	8	396	7.07	1.5 (1–4)	14	26 (46.43)	Iran	16 (61.54)	-Expert Systems with Applications -Journal of Theoretical and Applied Information Technology -Life Science Journal	3 (5.36) 3 (5.36) 3 (5.36)
9th	Canada	55 (2.3)	18	1354	24.62	6 (2–25)	17	33 (60.0)	China	13 (39.39)	Expert Systems with Applications	5 (9.10)
10th	United Kingdom	46 (1.9)	13	767	16.67	5.5 (1.75–15.75)	18	26 (56.52)	China	12 (46.15)	Expert Systems with Applications	9 (19.57)
11th	South Korea	37 (1.5)	11	640	17.3	3 (0–18.5)	5	7 (18.92)	China United States	2 (28.57) 2 (28.57)	Expert Systems with Applications	5 (13.51)
12th	Italy	31 (1.3)	13	680	21.94	10 (2–22)	9	12 (38.71)	Australia Finland	3 (25.0) 3 (25.0)	Expert Systems with Applications	3 (9.68)
12th	Australia	31 (1.3)	11	809	26.1	3 (1–19)	10	21 (67.74)	China Iran	5 (23.81) 5 (23.81)	-Applied Thermal Engineering -Energy	2 (6.45) 2 (6.45)
14th	Spain	30 (1.2)	10	435	14.5	5 (0–23.25)	14	8 (26.67)	Germany Iran United States	2 (25.0) 2 (25.0) 2 (25.0)	Expert Systems with Applications	4 (13.33)
15th	Poland	23 (1.0)	5	125	5.43	2 (0–5)	12	9 (39.13)	Canada	3 (33.33)	-Knowledge Based Systems -Studies in Computational Intelligence -Sylwan	2 (8.70) 2 (8.70) 2 (8.70)
15th	Serbia	23 (1.0)	5	71	3.09	1 (0–5)	1	1 (4.35)	Turkey	1 (100.0)	-Expert Systems with Applications -Journal of Intelligent and Fuzzy Systems -Metalurgia International	2 (8.70) 2 (8.70) 2 (8.70)
17th	Egypt	20 (0.8)	7	241	12.05	2.5 (1.0–11.5)	5	8 (40.0)	Saudi Arabia	5 (62.5)	-Applied Mathematical Modelling -Life Science Journal	3 (15.0) 3 (15.0)
18th	Greece	19 (0.8)	12	455	23.94	16 (5–41)	1	1 (5.26)	Spain	1 (100.0)	Expert Systems with Applications	6 (31.58)
19th	France	18 (0.7)	11	289	16.05	11.5 (5.5–21.5)	10	13 (72.22)	Iran	6 (46.15)	Energy Conversion and Management	5 (27.80)
20th	Hong Kong	15 (0.6)	15	472	31.46	23 (4–40)	9	14 (93.33)	China	11 (78.57)	International Journal of Production Research	3 (20.0)

Abbreviations: SCR = Standard Competition Ranking; Q1–Q3 = lower quartile–upper quartile

[a] Equal countries have the same ranking number, and then a gap is left in the ranking numbers

[b] Proportion of published documents with international authors from the total documents published by each country

Table 3
Ranking of top twenty most productive journals - AHP research.

SRC[a]	Name of the Journal	No. of documents (%)	*h*-index	Total citations	Average citations	Median citation (Q1-Q3)	Impact factor[b]
1st	Expert Systems with Applications	204 (2.0)	50	7430	36.42	19.5 (8.25–49.75)	2.981
2nd	European Journal of Operational Research	199 (1.95)	58	14,027	70.48	33 (14–66)	2.679
3rd	International Journal of Production Research	100 (0.98)	29	2872	28.72	15 (5–31.75)	1.693
4th	Biotechnology an Indian Journal	95 (0.93)	0	0	0	0	NA
5th	Jisuanji Jicheng Zhizao Xitong Computer Integrated Manufacturing Systems CIMS	86 (0.84)	9	357	4.15	2.5 (1–7)	NA
6th	International Journal of Advanced Manufacturing Technology	85 (0.83)	23	1599	18.81	8 (2–23)	1.568
7th	Mathematical and Computer Modelling	71 (0.7)	20	1483	20.8	11 (3–25)	1.366
8th	Nongye Gongcheng Xuebao Transactions of the Chinese Society of Agricultural Engineering	67 (0.66)	7	200	2.98	2 (0–5)	NA
9th	Environmental Earth Sciences	61 (0.6)	12	490	8.03	2 (0.5–11)	1.765[c]
9th	Computers and Industrial Engineering	61 (0.6)	23	1561	25.59	16 (5.5–38.5)	2.086
11th	International Journal of Production Economics	60 (0.59)	35	4374	72.9	50.5 (13–78.25)	2.782
12th	Journal of Chemical and Pharmaceutical Research	52 (0.51)	2	17	0.32	0	NA
12th	Journal of Natural Disasters	51 (0.5)	7	143	2.8	1 (0–3)	NA
12th	Shengtai Xuebao/ Acta Ecologica Sinica	51 (0.5)	5	95	1.86	0 (0–2)	NA
15th	Natural Hazards	50 (0.49)	12	487	9.74	3.5 (0 −11.5)	1.746
15th	Journal of Environmental Management	50 (0.49)	23	1614	32.28	17 (6.75–44.75)	3.131
15th	Xitong Gongcheng Lilun Yu Shijian System Engineering Theory and Practice	50 (0.49)	8	191	3.82	2 (1–5)	NA
18th	Journal of Cleaner Production	48 (0.47)	15	807	16.81	7 (0.25–20.5)	4.959
19th	Socio Economic Planning Sciences	44 (0.43)	15	935	21.25	11 (4–31.75)	NA
20th	Journal of the Operational Research Society	43 (0.42)	19	1253	29.13	15 (5–37)	1.225
20th	Dianli Xitong Baohu Yu Kongzhi Power System Protection and Control	43 (0.42)	8	217	5.04	3 (1–6)	NA

Abbreviations: SCR = Standard Competition Ranking; Q1–Q3 = lower quartile–upper quartile; IF = impact factor.
[a] Equal journals have the same number of ranking, and then a gap is left in the numbers of rankings.
[b] Impact factors of journals were documented from Journal citation reports (JCR): 2015 edition released by Thomson Reuters.
[c] Impact factor was extracted from Journal citation reports (JCR): 2014 edition released by Thomson Reuters.

Table 4
Ranking of top twenty most productive journals - TOPSIS research.

SRC[a]	Name of the Journal	No. of documents (%)	h-index	Total citations	Average citations	Median citation (Q1-Q3)	Impact factor[b]
1st	Expert Systems with Applications	125 (5.18)	46	6422	51.38	32 (14–67)	2.981
2nd	Applied Soft Computing Journal	45 (1.87)	16	1124	24.98	11 (3–32)	2.857
3rd	International Journal of Advanced Manufacturing Technology	40 (1.66)	17	1138	28.45	12 (2.25–28.5)	1.568
4th	International Journal of Production Research	36 (1.49)	15	614	17.06	10.5 (6–22.75)	1.693
5th	Journal of Intelligent and Fuzzy Systems	30 (1.24)	6	99	3.30	1.5 (0–4.25)	1.004
6th	Applied Mathematical Modelling	27 (1.12)	15	679	25.15	17 (8–35)	2.291
7th	Technological and Economic Development of Economy	24 (1.0)	9	343	14.29	5 (0.25–25)	1.563[c]
8th	Mathematical Problems in Engineering	22 (0.91)	4	44	2.00	0.5 (0–2.25)	0.762
9th	Computers and Industrial Engineering	20 (0.83)	8	415	20.75	6.5 (2–31.25)	1.783
9th	Mathematical and Computer Modelling	20 (0.83)	14	1463	73.15	27 (12–123.25)	1.412
9th	Knowledge Based Systems	20 (0.83)	8	385	19.25	6.5 (3–24.5)	2.947
12th	Advances in Information Sciences and Service Sciences	19 (0.79)	7	166	8.73	3 (0–10)	NA
12th	Jisuanji Jicheng Zhizao Xitong Computer Integrated Manufacturing Systems CIMS	19 (0.79)	4	35	1.84	1 (0–3)	NA
14th	Kongzhi Yu Juece Control and Decision	18 (0.75)	5	77	4.27	1 (0–5.25)	NA
14th	Materials and Design	18 (0.75)	11	484	26.88	18 (9.75–30.75)	3.501
16th	International Journal of Computational Intelligence Systems	17 (0.70)	7	165	9.70	4 (1.5–12.5)	0.574
17th	Decision Science Letters	16 (0.66)	3	29	1.81	1 (0.25–3)	NA
17th	International Journal of Applied Engineering Research	16 (0.66)	1	2	0.12	–	NA
17th	Energy Conversion and Management	16 (0.66)	11	250	15.62	12.5 (8.25–20.5)	4.38
20th	Journal of Cleaner Production	15 (0.62)	6	236	15.73	3 (1–25)	3.844
20th	Australian Journal of Basic and Applied Sciences	15 (0.62)	2	14	0.93	0 (0–1)	NA
20th	European Journal of Operational Research	15 (0.62)	12	2121	141.40	49 (17–265)	2.358

Abbreviations: SCR = Standard Competition Ranking; Q1–Q3 = lower quartile–upper quartile; IF = impact factor
[a] Equal journals have the same number of ranking, and then a gap is left in the numbers of rankings
[b] Impact factors of journals were documented from Journal citation reports (JCR): 2015 edition released by Thomson Reuters
[c] Impact factor was extracted from Journal citation reports (JCR): 2014 edition released by Thomson Reuters

Table 5
Ranking of top twenty prevalent areas of interests - AHP research.

SRC[a]	Subject Area	No. of Documents (%)	Most Used Journal	No. of Documents (%)	Most active Country	No. of Documents (%)
1st	Engineering	4218 (41.4)	Expert Systems with Applications	173 (4.1)	China	1747 (41.4)
2nd	Computer Science	2194 (21.45)	Expert Systems with Applications	204 (9.3)	China	711 (32.4)
3rd	Environmental Science	1648 (16.18)	Environmental Earth Sciences	61 (3.7)	China	522 (31.7)
4th	Business, Management and Accounting	1623 (15.93)	International Journal of Production Research	63 (3.9)	United States	315 (19.4)
5th	Decision Sciences	1314 (12.9)	European Journal of Operational Research	199 (15.1)	United States	330 (25.1)
6th	Social Sciences	1237 (12.14)	European Journal of Operational Research	168 (13.6)	United States	249 (20.1)
7th	Mathematics	1143 (11.22)	European Journal of Operational Research	199 (17.4)	China	327 (28.6)
8th	Agricultural and Biological Sciences	945 (9.28)	Biotechnology an Indian Journal	95 (10.1)	China	457 (48.4)
9th	Earth and Planetary Sciences	931 (9.14)	Environmental Earth Sciences	61 (6.6)	China	463 (49.7)
10th	Energy	715 (7.02)	Journal of Cleaner Production	48 (6.7)	China	345 (48.3)
11th	Economics, Econometrics and Finance	415 (4.07)	International Journal of Production Economics	61 (14.7)	China	365 (88.0)
12th	Medicine	344 (3.38)	Safety Science	24 (7.0)	China	81 (23.5)
13th	Materials Science	319 (3.13)	Zhongnan Daxue Xuebao Ziran Kexue Ban Journal of Central South University Science and Technology	28 (8.8)	China	142 (44.5)
14th	Multidisciplinary	301 (2.95)	Journal of Applied Sciences	34 (11.3)	China	161 (53.5)
15th	Biochemistry, Genetics and Molecular Biology	227 (2.23)	Biotechnology an Indian Journal	95 (41.9)	China	138 (60.8)
16th	Chemical Engineering	212 (2.08)	Harbin Gongcheng Daxue Xuebao Journal of Harbin Engineering University	13 (6.1)	China	89 (42.0)
17th	Physics and Astronomy	179 (1.76)	Zhongnan Daxue Xuebao Ziran Kexue Ban Journal of Central South University Science and Technology	26 (14.5)	China	114 (63.7)
18th	Pharmacology, Toxicology and Pharmaceutics	93 (0.91)	Journal of Chemical and Pharmaceutical Research	52 (56.0)	China	70 (75.3)
19th	Chemistry	70 (0.69)	Advances Journal of Food Science and Technology	31 (44.3)	China	31 (44.3)
20th	Arts and Humanities	65 (0.64)	Xian Jianzhu Keji Daxue Xuebao Journal of Xian University of Architecture and Technology	9 (13.8)	China	17 (26.2)
20th	Psychology	65 (0.64)	Technological Forecasting and Social Change	19 (13.8)	Taiwan	18 (27.7)

Abbreviations: SCR = Standard Competition Ranking
[a] Equal categories have the same number of ranking, and then a gap is left in the numbers of rankings

0.18%), etc. As well in case of TOPSIS research, the English language was the dominant used language (2043 documents; 85.0%), followed by Chinese (347 documents; 14.4%). The other world languages had limited usage such as Persian (13; 0.54%), Lithuanian (12; 0.50%), Turkish (7; 0.30%), etc. The prevalent of English language stems from the fact that it is the universal language of science (Montgomery, 2004). The evolution of Chinese language is starting to be active from the beginnings of the last decade (Montoya, García-Cruz, Montoya, & Manzano-Agugliaro, 2016).

4.5. Analysis the distribution of research based on research areas

The major portion of published research related to AHP methods was in the field of Engineering (4218 documents; 41.4%) as shown in Table 5. The most used journal in this research area was Expert Systems with Applications journal (173; 4.1%), and the country with the highest contributions in engineering was China (1747; 41.4%). Computer Science (2194; 21.5%) and Environmental Science (1648; 16.2%) followed respectively the Engineering research area in the term of number of published documents. Table 5 displays the ranking of top twenty prevalent areas of interests in AHP research. The Engineering research area was also the most prevalent subject category through analyzing research areas of TOPSIS methods as shown in Table 6 with a total of (1166 documents; 48.3%). Expert Systems with Applications journal was the most used journal in this research area (120; 10.3%), and china was the most active country (440; 37.7%). Computer Science (835; 34.6%) and Mathematics (416; 17.3%) research areas were in the second and third positions respectively in terms of research productivity related to TOPSIS methods.

4.6. Analysis of most cited published documents

Among the most popular bibliometric indicators used to evaluate research quality is the number of citations the article has received (Duque Oliva, Cervera Taulet, & Rodríguez Romero, 2006). In this study as shown in Tables 7 and 8, we analyzed the top twenty most cited articles related to AHP and TOPSIS methods. In the AHP published research, the most cited article was entitled by "*How to make a decision: The analytic hierarchy process*" by Saaty (1990). This article harvested 1870 citations at the time of data analysis. In this article, the author discussed the principles and the philosophy of the AHP method (Saaty, 1990). A brief overview on the most cited articles in descending order in terms of number of citations is given below:

An article entitled " *IDF Diabetes Atlas: Global estimates of the prevalence of diabetes for 2011 and 2030*" by Whiting, Guariguata, Weil, and Shaw (2011) assumed the second most cited article position with 1096 citations at the time of data analysis. In this study, the authors collected publications related to prevalence of diabetes from PubMed database and Google Scholar. They classified these studies according to a number of criteria such as: population size, diagnosis used method, type of the study, etc., and used the AHP method to score the criteria with an aim to select or discard these data sources based on lower and upper thresholds (Whiting et al., 2011).

In the third position, there was a review article entitled "*Analytic process: An overview of applications*" by Vaidya and Kumar (2006). This review presented a literature review of the applications of the AHP method by analyzing 150 application papers. They aimed form this study to provide a ready reference on AHP

Table 6
Ranking of top twenty prevalent areas of interests - TOPSIS research.

SRC[a]	Subject Area	No. of documents (%)	Most used journal	No. of documents (%)	Most active country	No. of documents (%)
1st	Engineering	1166 (48.34)	Expert Systems with Applications	120 (10.3)	China	440 (37.3)
2nd	Computer Science	835 (34.62)	Expert Systems with Applications	125 (15.0)	China	352 (42.2)
3rd	Mathematics	416 (17.25)	Journal of Intelligent and Fuzzy Systems	29 (7.0)	China	175 (42.1)
4th	Business, Management and Accounting	309 (12.81)	International Journal of Production Research	31 (10.0)	Iran	69 (22.3)
5th	Decision Sciences	276 (11.44)	International Journal of Production Research	36 (13.0)	Iran	49 (17.8)
6th	Environmental Science	240 (9.95)	Journal of Cleaner Production	17 (7.1)	China	73 (30.4)
7th	Energy	186 (7.71)	Journal of Cleaner Production	17 (9.1)	China	76 (40.9)
8th	Social Sciences	164 (6.8)	Journal of Information and Computational Science	11 (6.7)	China	46 (28.0)
9th	Earth and Planetary Sciences	113 (4.68)	Xitong Gongcheng Lilun Yu Shijian System Engineering Theory and Practice	11 (9.7)	China	57 (50.4)
10th	Agricultural and Biological Sciences	108 (4.48)	Advance in Environmental Biology	11 (10.2)	China	57 (52.8)
11th	Materials Science	101 (4.19)	Material and Design	18 (17.8)	China	25 (24.8)
12th	Multidisciplinary	98 (4.06)	Australian Journal of Basic and Applied Sciences	15 (15.3)	Iran	42 (42.9)
13th	Economics, Econometrics and Finance	97 (4.02)	Technological and Economic Development of Economy	24 (24.7)	Lithuania	27 (27.8)
14th	Medicine	64 (2.65)	-Journal of Central South University Medical Sciences -Scientific World Journal	6 (9.4) 6 (9.4)	China	27 (42.2)
15th	Biochemistry, Genetics and Molecular Biology	51 (2.11)	Life Science Journal	13 (25.5)	China	24 (47.1)
16th	Chemical Engineering	46 (1.91)	Energy Sources Part B Economics Planning and Policy	6 (13.0)	China	13 (28.3)
17th	Physics and Astronomy	35 (1.45)	Xi Tong Gong Cheng Yu Dian Zi Ji Shu Systems Engineering and Electronics	6 (17.1)	China	20 (57.1)
18th	Chemistry	30 (1.24)	Advance Journal of Food Science and Technology	8 (26.7)	China	16 (53.3)
19th	Arts and Humanities	17 (0.70)	Group Decision and Negotiation	5 (29.4)	Turkey	4 (23.5)
20th	Pharmacology, Toxicology and Pharmaceutics	11 (0.46)	Journal of Chemical and Pharmaceutical Research	5 (45.5)	China	7 (63.6)

Abbreviations: SCR = Standard Competition Ranking
[a] Equal categories have the same number of ranking, and then a gap is left in the numbers of rankings

method, and to act as an informative summary for practitioners in their future works (Vaidya & Kumar, 2006). It was followed by article entitled "*A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming*" in which, the authors integrated the AHP method and linear programming to consider tangible and intangible factors in the process of choosing the best suppliers and placing the optimum order quantities among them (Ghodsypour & O'Brien, 1998).

The fifth position occupied by a review article to the application of multi-criteria decision making to sustainable energy planning. The authors reviewed 90 publications to analyze the applicability of various MCDA methods in sustainable energy management, and they concluded that the AHP method was the most popular technique in this field and it was followed by outranking techniques (Pohekar & Ramachandran, 2004). This followed by article which was concerned with the applications of Fuzzy AHP in global supplier selection multi-criteria decision problem (Chan & Kumar, 2007). An article concerned with prioritizing the cancer antigens occupied the seventh position in the list of the most cited articles. In this article, the authors developed a list of cancer antigen criteria, selected 75 representative antigens for comparison and ranking and employed the AHP method as a new approach for prioritizing translational research opportunities (Cheever et al., 2009). By employing the AHP method, they were able to examine the current status of the cancer vaccine field, the need for additional efforts to develop effective vaccines and it accentuated the need for prioritization (Cheever et al., 2009).

An overview of the AHP and its applications article by Vargas (1990) was in the eighth position. In the ninth position, a global estimates of diabetes prevalence related article was conducted by Guariguata et al. (2014). Its methodology was based largely on that used in (Whiting et al., 2011) which occupied the second position in the list of top cited articles. It is followed by a review on multi-criteria decision analysis aid in sustainable energy decision-making in which the authors concluded that AHP method was the most popular and comprehensive MCDA method, and the aggregation methods were helpful to get rational results in sustainable energy decision-making (Wang, Jing, et al., 2009). Incorporation of AHP into an information system that supports environmentally conscious purchasing and introducing the environmental dimension into purchasing decisions was examined by Handfield, Walton, Sroufe, and Melnyk (2002) in article occupied the eleventh position in the list.

Karlsson and Ryan (1997) employed AHP method in developing a cost value approach for prioritizing requirements in the field of developing software systems that meet the needs and expectations of stakeholders and applied the developed methodology with an aim to show its efficacy to two commercial projects. Their article was in the twelfth positions in the list. It was followed by article realized by Kahraman, Cebeci, and Ruan (2004). The authors of this article developed an analytical tool by employing Fuzzy AHP method to select the best catering firm which is providing the most customer satisfaction and applied it to three Turkish firms (Kahraman et al., 2004). Fuzzy AHP was used by Kahraman, Ertay, and Büyüközkan (2006) in a framework to develop an optimization model that aimed to improve the quality and design of the products and to procure a customer-driven quality system, and this work assumed the fourteenth position in the list. Application of AHP method in vendor selection of a telecommunication system by Tam and Tummala (2001) assumed also the fourteenth position

Table 7
Ranking of top twenty most cited articles - AHP research.

SRC[a]	Authors	Title	Journal name	Times cited	Document Type
1st	Saaty, T.L., 1990	How to make a decision: The analytic hierarchy process	European Journal of Operational Research	1870	Article
2nd	Whiting, D.R., et al., 2011	IDF Diabetes Atlas: Global estimates of the prevalence of diabetes for 2011 and 2030	Diabetes Research and Clinical Practice	1096	Article
3rd	Vaidya, O.S. and Kumar, S., 2006	Analytic hierarchy process: An overview of applications	European Journal of Operational Research	870	Review
4th	Ghodsypour, S.H. and O'Brien, C., 1998	A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming	International Journal of Production Economics	572	Article
5th	Pohekar, S.D. and Ramachandran, M., 2004	Application of multi-criteria decision making to sustainable energy planning - A review	Renewable and Sustainable Energy Reviews	501	Review
6th	Chan, F.T.S. and Kumar, N., 2007	Global supplier development considering risk factors using fuzzy extended AHP-based approach	Omega	478	Article
7th	Cheever, M.A., et al., 2009	The prioritization of cancer antigens: A National Cancer Institute pilot project for the acceleration of translational research	Clinical Cancer Research	438	Article
8th	Vargas, L.G., 1990	An overview of the analytic hierarchy process and its applications	European Journal of Operational Research	385	Article
9th	Guariguata, L., et al., 2014	Global estimates of diabetes prevalence for 2013 and projections for 2035	Diabetes Research and Clinical Practice	381	Article
10th	Wang, J.-J., et al., 2009	Review on multi-criteria decision analysis aid in sustainable energy decision-making	Renewable and Sustainable Energy Reviews	363	Review
11th	Handfield, R., et al., 2002	Applying environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process	European Journal of Operational Research	357	Article
12th	Karlsson, J. and Ryan, K., 1997	A cost-value approach for prioritizing requirements	IEEE Software	343	Article
13th	Kahraman, C., et al., 2004	Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey	International Journal of Production Economics	324	Article
14th	Kahraman, C., et al., 2006	A fuzzy optimization model for QFD planning process using analytic network approach	European Journal of Operational Research	321	Article
14th	Tam, M.C.Y. and Tummala, V.M.R., 2001	An application of the AHP in vendor selection of a telecommunications system	Omega	321	Article
16th	Al-Harbi, K.M.A.-S., 2001	Application of the AHP in project management	International Journal of Project Management	320	Article
17th	Saaty, R.W., 1987	The analytic hierarchy process-what it is and how it is used	Mathematical Modelling	314	Article
18th	Deng, H., 1999	Multicriteria analysis with fuzzy pairwise comparison	International Journal of Approximate Reasoning	310	Article
19th	Forman, E.H. and Gass, S.I., 2001	The analytic hierarchy process - An exposition	Operations Research	308	Article
20th	Harker, Patrick T. andVargas, Luis G., 1987	Theory of ratio scale estimation: Saaty's analytic hierarchy process.	Management Science	304	Article

Abbreviations: SCR = Standard Competition Ranking
[a] Equal documents in terms of number of citations have the same number of ranking, then a gap is left in the numbers of ranking

in the list. The authors concluded that, the employment of AHP method was vital in reducing the required time in selecting a vendor (Tam & Tummala, 2001).

Al-Harbi (2001) employed the AHP method for contractor prequalification decision problem in the field of project management and his article occupied the sixteenth position in the list. The article of Saaty (1987) which entitled " *The analytic hierarchy process-what it is and how it is used*" was in the seventeenth position. The author introduced the method discussed the rank reversal and preservation in this work (Saaty, 1987). Deng (1999) presented a fuzzy approach to tackle qualitative multi criteria analysis problem in his article that assumed the eighteenth position in the list. In the nineteenth position, an article that discussed the reasons behind the successful applications of the AHP method and the competing methodologies was presented by Forman and Gass (2001). In the last position in the list, an article that addressed debated issues concerning with the theoretical foundations of the AHP method was presented by Harker and Vargas (1987). The Authors also illustrated through proofs and examples the deficiencies of these criticisms (Harker & Vargas, 1987).

Table 8 displays the top twenty most cited articles in TOPSIS applications. The most cited article which harvested 1131 citations at the time of data analysis pertained to the topic of extended TOPSIS method to fuzzy environment by employing linguistic terms, which can be expressed in triangular fuzzy numbers, to describe the rating of alternatives and the weights of criteria (Chen, 2000). A comparative study between TOPSIS method and VIKOR method with illustration example to show their similarities and differences was conducted by Opricovic and Tzeng (2004) and occupied the second position in the list. In the third position, it was a study conducted by Chen, Lin, and Huang (2006) in which they applied fuzzy TOPSIS method to identify the most suitable material suppliers for a high-technology manufacturing company, and concluded that the model was very well suited for this decision problem. Fourthly, it was a study concerned with evaluation of airline service quality where the authors employed AHP method to derive the weights of evaluation criteria, and TOPSIS method with Fuzzy set theory to rank the alternatives (Tsaur, Chang, & Yen, 2002). It was followed by a study that proposed a methodology to extend TOPSIS method for group decision making and based on internal aggregation of preferences of group decision makers (Shih et al., 2007). The authors conducted a comparative analysis between their proposed approach and the other approach which based on external aggregation of group preference, and found that their model was robust and efficient (Shih et al., 2007).

Table 8
Ranking of top twenty most cited articles - TOPSIS research.

SRC[a]	Authors	Title	Journal name	Times cited	Document Type
1st	Chen, C.-T., 2000	Extensions of the TOPSIS for group decision-making under fuzzy environment	Fuzzy Sets and Systems	1131	Article
2nd	Opricovic, S. and Tzeng, G.-H., 2004	Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS	European Journal of Operational Research	808	Article
3rd	Chen, C.-T. et al., 2006	A fuzzy approach for supplier evaluation and selection in supply chain management	International Journal of Production Economics	615	Article
4th	Tsaura, S.-H. et al., 2002	The evaluation of airline service quality by fuzzy MCDM	Tourism Management	366	Article
5th	Shih, H.-S. et al., 2007	An extension of TOPSIS for group decision making	Mathematical and Computer Modelling	348	Article
6th	Boran, F.E. et al., 2009	A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method	Expert Systems with Applications	346	Article
7th	Deng, H. et al., 2000	Inter-company comparison using modified TOPSIS with objective weights	Computers and Operations Research	331	Article
8th	Wang, Y.-M. and Elhag, T.M.S., 2006	Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment	Expert Systems with Applications	328	Article
9th	Opricovic, S. and Tzeng, G.-H., 2007	Extended VIKOR method in comparison with outranking methods	European Journal of Operational Research	322	Article
10th	Zanakis, S.H. et al., 1998	Multi-attribute decision making: A simulation comparison of select methods	European Journal of Operational Research	301	Article
11th	Lai, Y.-J. et al., 1994	TOPSIS for MODM	European Journal of Operational Research	264	Article
12th	Tzeng, G.-H. et al., 2005	Multi-criteria analysis of alternative-fuel buses for public transportation	Energy Policy	236	Article
13th	Wang, T.-C. and Chang, T.-H., 2007	Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment	Expert Systems with Applications	230	Article
14th	Jahanshahloo, G.R. et al., 2006	An algorithmic method to extend TOPSIS for decision-making problems with interval data	Applied Mathematics and Computation	222	Article
15th	Triantaphyllou, E. and Chi-Tun, L., 1996	Development and evaluation of five fuzzy multiattribute decision-making methods	International Journal of Approximate Reasoning	218	Article
16th	Jahanshahloo, G.R. et al., 2006	Extension of the TOPSIS method for decision-making problems with fuzzy data	Applied Mathematics and Computation	212	Article
17th	Dağdeviren, M. et al., 2009	Weapon selection using the AHP and TOPSIS methods under fuzzy environment	Expert Systems with Applications	208	Article
18th	Chen, M.-F. and Tzeng, G.-H., 2004	Combining grey relation and TOPSIS concepts for selecting an expatriate host country	Mathematical and Computer Modelling	202	Review
19th	Wang, J.-W. et al., 2009	Fuzzy hierarchical TOPSIS for supplier selection	Applied Soft Computing Journal	185	Article
20th	Shyur, H.-J. and Shih, H.-S., 2006	A hybrid MCDM model for strategic vendor selection	Mathematical and Computer Modelling	184	Article

Abbreviations: SCR = Standard Competition Ranking
[a] Equal documents in terms of number of citations have the same number of ranking, then a gap is left in the numbers of ranking

An article that employed intuitionistic fuzzy TOPSIS method in supplier selection to establish effective supply chain assumed the sixth position in the list (Boran, Genç, Kurt, & Akay, 2009). Deng, Yeh, and Willis (2000) proposed a modified TOPSIS method which is applicable for cases where reliable subjective weights cannot be obtained and based on determining objective weights of criteria by entropy measure. Their article occupied the seventh position in the list. It was followed by a study conducted by Wang and Elhag (2006) in which they proposed a fuzzy TOPSIS method based on alpha level sets and principles of fuzzy extension and solved it as a nonlinear programming problem. To show its applicability, they applied it to a bridge risk assessment problem and concluded that it performs better than the other fuzzy procedures of the TOPSIS method (Wang & Elhag, 2006). In the ninth place, it was a comparison study between four MCDA methods (i.e. extended VIKOR, TOPSIS, PROMETHEE, and ELECTRE) (Opricovic & Tzeng, 2007), and followed by a comparative analysis to evaluate the performance of eight MCDA methods and TOPSIS was among them (Zanakis, Solomon, Wishart, & Dublish, 1998).

In the eleventh position, Lai, Liu, and Hwang (1994) extended TOPSIS method to solve multi objective problem based on using first order compromise method to reduce the objective space and applied it to a water quality management problem. It was followed by the work of Tzeng, Lin, and Opricovic (2005) who applied AHP, TOPSIS and VIKOR methods to choose the best fuel mode for buses. They used AHP to create the weights of criteria, and used TOPSIS and VIKOR separately to identify the best alternative of fuel modes and compared the outputs of the two methods (Tzeng et al., 2005). The application of TOPSIS method to select the optimal initial training aircraft under fuzzy environment which has been conducted by Wang and Chang (2007) occupied the thirteen position. In fourteenth position, it was a study conducted by Jahanshahloo, Lotfi, and Izadikhah (2006) in which they proposed an algorithm to extend TOPSIS method to deal with value in attributes that are in the form of intervals. It was followed by the work of Triantaphyllou and Lin (1996) who provided a general overview on different fuzzy MCDA methods under certain situations to test their accuracy.

The work of Jahanshahloo et al. (2006), who presented an extension of TOPSIS method to solve decision problem under fuzzy environment by using fuzzy triangular numbers and employing the concept of α-cuts to normalize the fuzzy numbers, was in the sixteenth position. It was followed by the work of Dağdeviren, Yavuz, and Kilinç (2009) who employed AHP method, to create the weights of criteria, and fuzzy TOPSIS method, to rank the alternatives, in solving a decision problem related to weapon selection. Application of a combined grey relational model with the concepts of TOPSIS to solve a decision making problem related to expatriate assignment was in the eighteenth position (Chen & Tzeng,

Table 9
Ranking of top twenty most productive institutions - AHP research.

SRC[a]	Name of the institution	Country	No. of documents (%)
1st	University of Tehran	Iran	173 (1.7)
2nd	Islamic Azad University	Iran	121 (1.19)
3rd	Istanbul Teknik Universitesi	Turkey	109 (1.07)
4th	Chongqing University	China	102 (1.00)
5th	North China Electric Power University	China	99 (0.97)
5th	Tsinghua University	China	99 (0.97)
7th	National Chiao Tung University Taiwan	Taiwan	88 (0.86)
8th	Chinese Academy of Sciences	China	83 (0.81)
8th	Shanghai Jiaotong University	China	83 (0.81)
10th	Zhejiang University	China	81 (0.80)
11th	University of Pittsburgh	United States	79 (0.78)
12th	National Cheng Kung University	Taiwan	77 (0.76)
13th	City University of Hong Kong	China	75 (0.74)
13th	Central South University China	China	75 (0.74)
13th	Tongji University	China	75 (0.74)
16th	Hong Kong Polytechnic University	China	74 (0.73)
17th	Harbin Institute of Technology	China	71 (0.7)
18th	Islamic Azad University, Science and Research Branch	Iran	69 (0.68)
19th	Tianjin University	China	66 (0.65)
20th	China University of Mining Technology	China	65 (0.64)

Abbreviation: SCR = Standard Competition Ranking
[a] Equal institutions have the same number of ranking and then a gap is left in the numbers of rankings

Table 10
Ranking of top twenty most productive institutions - TOPSIS research.

SRC[a]	Name of the institution	Country	No. of documents (%)
1st	Islamic Azad University	Iran	115 (4.77)
2nd	University of Tehran	Iran	70 (2.9)
3rd	Islamic Azad University, Science and Research Branch	Iran	63 (2.61)
4th	Vilniaus Gedimino technikos universitetas	Lithuania	50 (2.07)
5th	North China Electric Power University	China	43 (1.78)
6th	Istanbul Teknik Universitesi	Turkey	41 (1.70)
7th	Tarbiat Modares University	Iran	37 (1.53)
8th	Iran University of Science and Technology	Iran	33 (1.37)
8th	Yildiz Teknik Universitesi	Turkey	33 (1.37)
10th	Shanghai Jiaotong University	China	32 (1.33)
11th	Central South University China	China	31 (1.29)
11th	Islamic Azad University, Central Tehran Branch	Iran	31 (1.29)
13th	National Chiao Tung University Taiwan	Taiwan	30 (1.24)
14th	Huazhong University of Science and Technology	China	25 (1.04)
15th	Southeast University	China	24 (1.0)
15th	Amirkabir University of Technology	Iran	24 (1.0)
17th	Harbin Institute of Technology	China	23 (0.95)
18th	Gazi Universitesi	Turkey	22 (0.91)
18th	National Cheng Kung University	Taiwan	22 (0.91)
20th	Tamkang University	Taiwan	21 (0.87)

Abbreviation: SCR = Standard Competition Ranking
[a] Equal institutions have the same number of ranking and then a gap is left in the numbers of rankings

2004). It was followed by the work of Wang, Cheng, and Huang (2009) who proposed an algorithm to modify Chen's Fuzzy TOPSIS and applied it to supplier selection problem and compared its outcomes with other methods. In the end of the list, it was a study of Shyur and Shih (2006) who incorporated analytic network process with modified TOPSIS and applied it to a vendor selection decision problem.

It is well observed that, European Journal of Operation Research journal was the most prolific journal in terms of number of articles in the list of top cited articles related to AHP research. There was five articles which have been published in this journal and reserved positions in the list of most cited articles. While in case of TOPSIS research, the most prolific journals were European Journal of Operation Research and Expert Systems with Applications. There was four articles in each of the two journals which have been documented in the list of most cited articles. Related to citation rates, it is possible for the number of citations for each published document to be different from one research database to another. Despite this evidence, Scopus database sustains as one of the best techniques in tracking, analyzing, and comparing citations (De Granda-Orive, Alonso-Arroyo, & Roig-Vázquez, 2011).

4.7. The leading institutions that contributed to AHP and TOPSIS literature

The top productive institution in AHP research as shown in Table 9 was University of Tehran, Iran which published 173 documents (1.7%), followed by Islamic Azad University, Iran (121; 1.2%), and Istanbul Teknik Universitiesti, Turkey (109; 1.1%). Iran and Turkey are active countries in decision sciences, which include information systems and management; management science and operation research; and statistics, probability and uncertainty, at global level. Based on database of SCImago Journal & Country Rank, that includes countries and journals scientific indicators developed from Scopus database, Iran has the twenty third position in decision sciences at global level and ranked the second among Middle Eastern countries, followed by Turkey. There was thirteen institutions from China in the list of most prolific institutions at global level in fields of research related to AHP methods which is a true reflection to the active participation of China in this field of research.

In case of TOPSIS method and as shown in Table 10, there was seven institutions from Iran in the list of top prolific institutions. Three of these institutions, Islamic Azad University (115; 4.8%), University of Tehran (70; 2.9%), Islamic Azad University; Science and Research Branch (63; 2.6%) were in the first three positions in the list. Vilniaus Gedimino technikos universitetas, Lithuania was in the fourth position (50; 2.1%). Six institutions form China were in the list, three from Turkey and three from Taiwan.

4.8. The leading authors who contributed to AHP and TOPSIS research

In AHP research, the most prolific author as shown in Table 11 was Saaty, T. L., the inventor of AHP technique, who published 52 (0.51%) documents in fields related to AHP methods. He was followed by Dey, P. K. (45; 0.44%) from Aston University, United Kingdom, Kahraman, C. (42; 0.41%) from Istanbul Teknik Universitesi, Turkey. The most prolific author in fields of research related to TOPSIS methods as shown in Table 12 was Zavadskas, E. K. from Vilniaus Gedimino technikos universitetas, Lithuania, who published 27 (1.1%) documents, followed by Kahraman, C. (24; 1.0%) from Istanbul Teknik Universitesi, Turkey, Ilangkumaran, M. (15; 0.62) from K S Rangasamy College of Technology, India. There was six prolific authors who are listed in the list of most prolific authors in AHP research and concurrently they are listed in the list of most prolific authors in TOPSIS research with relatively more contributions towards AHP research. They were Kahraman, C. from Istanbul Teknik Universitesi; Tzeng, G. H. from National Taipei University, Graduate Institute of Urban Planning, Taipei, Taiwan; Zavadskas, E. K. from Vilniaus Gedimino technikos universitetas, Lithuania; Tavan, M. from Universitat Paderborn, Business Information Systems Department, Paderborn, Germany; Ilangkumaran, M. from K S Rangasamy College of Technology, Depart-

Table 11
Ranking of top twenty most prolific authors-AHP research.

SRC[a]	Author	No. of documents (%)	Affiliation
1st	Saaty, T.L.	52 (0.51)	University of Pittsburgh, Katz Graduate School of Business, Pittsburgh, United States
2nd	Dey, P.K.	45 (0.44)	Aston University, Birmingham, United Kingdom
3rd	Kahraman, C.	42 (0.41)	Istanbul Teknik Universitesi, Department of Industrial Engineering, Istanbul, Turkey
4th	Chan, F.T.S.	28 (0.27)	Hong Kong Polytechnic University, Department of Industrial and Systems Engineering, Hong Kong, China
5th	Chin, K.S.	26 (0.26)	City University of Hong Kong, Dept. of Syst. Engineering and Engineering Management and Centre of Systems Informatics Engineering, Hong Kong, China
6th	Tzeng, G.H.	24 (0.24)	National Taipei University, Graduate Institute of Urban Planning, Taipei, Taiwan
7th	Lin, C.T.	23 (0.23)	Ming Chuan University, Department of Business Administration, Taipei, Taiwan
8th	Lee, A.H.I.	22 (0.22)	Chung Hua University, Department of Technology Management, Hsin-chu, Taiwan
9th	Chang, C.W.	21 (0.21)	Toko University, Department of Digital Content Design and Management, Chiayi, Taiwan
9th	Ataei, M.	21 (0.21)	University of Isfahan, Department of Electrical Engineering, Isfahan, Iran
11th	Zavadskas, E.K.	20 (0.20)	Vilniaus Gedimino technikos universitetas, Institute of Internet and Intelligent Technologies, Vilnius, Lithuania
12th	Moreno-Jimenez, J.M.	19 (0.19)	Universidad de Zaragoza, Grupo Decisión Multicriterio Zaragoza, Zaragoza, Spain
12th	Dolan, J.G.	19 (0.19)	University of Rochester, Department of Public Health Sciences, Rochester, United States
14th	Sarkar, B.	18 (0.18)	Jadavpur University, Department of Production Engineering, Kolkata, India
14th	Ramanathan, R.	18 (0.18)	Nottingham Trent University, Division of Management, Nottingham, United Kingdom
14th	Tavana, M.	18 (0.18)	Universitat Paderborn, Business Information Systems Department, Paderborn, Germany
14th	Wang, Y.M.	18 (0.18)	Fuzhou University, Institute of Decision Sciences, Fuzhou, China
14th	Wu, C.R.	18 (0.18)	Toko University, Department of Leisure Recreation and Travel Management, Chiayi, Taiwan
19th	Sadiq, R.	17 (0.17)	The University of British Columbia, Department of Civil Engineering, Vancouver, Canada
19th	Azizi, M.	17 (0.17)	University of Tehran, Faculty of Natural Resources, Tehran, Iran
19th	Ilangkumaran, M.	17 (0.17)	K S Rangasamy College of Technology, Department of Mechanical Engineering, Namakkal, India
19th	Buyukozkan, G.	17 (0.17)	Galatasaray Universitesi, Industrial Engineering, Istanbul, Turkey

Abbreviation: SCR = Standard Competition Ranking
[a] Equal institutions have the same number of ranking and then a gap is left in the numbers of rankings

Table 12
Ranking of top twenty most prolific authors-TOPSIS research.

SRC[a]	Author	No. of documents (%)	Affiliation
1st	Zavadskas, E.K.	27 (1.12)	Vilniaus Gedimino technikos universitetas, Institute of Internet and Intelligent Technologies, Vilnius, Lithuania
2nd	Kahraman, C.	24 (1.00)	Istanbul Teknik Universitesi, Department of Industrial Engineering, Istanbul, Turkey
3rd	Ilangkumaran, M.	15 (0.62)	K S Rangasamy College of Technology, Department of Mechanical Engineering, Namakkal, India
4th	Tavana, M.	13 (0.54)	Universitat Paderborn, Business Information Systems Department, Paderborn, Germany
5th	Ic, Y.T.	12 (0.50)	Baskent Universitesi, Department of Industrial Engineering, Ankara, Turkey
5th	Ahmadi, M.H.	12 (0.50)	University of Tehran, Renewable Energies and Environmental Department, Tehran, Iran
5th	Antucheviciene, J.	12 (0.50)	Vilniaus Gedimino technikos universitetas, Department of Construction Technology and Management, Vilnius, Lithuania
8th	Shirouyehzad, H.	11 (0.46)	Islamic Azad University, Najafabad Branch, Department of Industrial Engineering, Isfahan, Iran
8th	Chung, E.S.	11 (0.46)	Seoul National University of Science and Technology (SNUST), Department of Civil Engineering, Seoul, South Korea
8th	Vahdani, B.	11 (0.46)	Islamic Azad University, Qazvin Branch, Tehran, Iran
8th	Liu, P.	11 (0.46)	Shandong University of Finance, School of Management Science and Engineering, Jinan, China
8th	Yue, Z.	11 (0.46)	Guangdong Ocean University, College of Sciences, Zhanjiang, China
8th	Turskis, Z.	11 (0.46)	Vilniaus Gedimino technikos universitetas, Vilnius, Lithuania
14th	Yurdakul, M.	10 (0.41)	Gazi Universitesi, Department of Mechanical Engineering, Ankara, Turkey
14th	Jozi, S.A.	10 (0.41)	Islamic Azad University, Department of Environment, Tehran, Iran
14th	Deng, Y.	10 (0.41)	Vanderbilt University, School of Engineering, Nashville, United States
17th	Xu, Z.	9 (0.37)	Southeast University, School of Economics and Management, Nanjing, China
17th	Li, D.F.	9 (0.37)	Fuzhou University, School of Economics and Management, Fuzhou, China
17th	Buyukozkan, G.	9 (0.37)	Galatasaray Universitesi, Industrial Engineering, Istanbul, Turkey
17th	Tzeng, G.H.	9 (0.37)	National Taipei University, Graduate Institute of Urban Planning, Taipei, Taiwan
17th	Tavakkoli-Moghaddam, R.	9 (0.37)	Universal Scientific Education and Research Network (USERN), Tehran, Iran

Abbreviation: SCR = Standard Competition Ranking
[a] Equal institutions have the same number of ranking and then a gap is left in the numbers of rankings

ment of Mechanical Engineering, Namakkal, India and Buyukozkan, G. from Galatasaray Universitesi, Industrial Engineering, Istanbul, Turkey.

4.9. Analysis of content analysis outcomes

Fig. 4 displays the density visualization map–item density in association with published research that utilized AHP method. The analysis of co-occurrence of author keywords was performed with a minimum number of occurrences of a keyword set to 20. Out of the total of 20,418 keywords, 174 meet the threshold. For each of the 174 keywords, the number of co-occurrence links was calculated. The central keywords are located in the darkest areas (from red to blue). The same was in Fig. 5 which displays the outcomes of keywords co-occurrence analysis in the form of network visualization map. It divides the keywords into 14 clusters where keywords which are having the most intra-cluster co-occurrence relations are arranged in the same cluster. It gives an indicator of the way in which items within a cluster are related to each other. Furthermore, the volume of the circle in the map is an indicator of

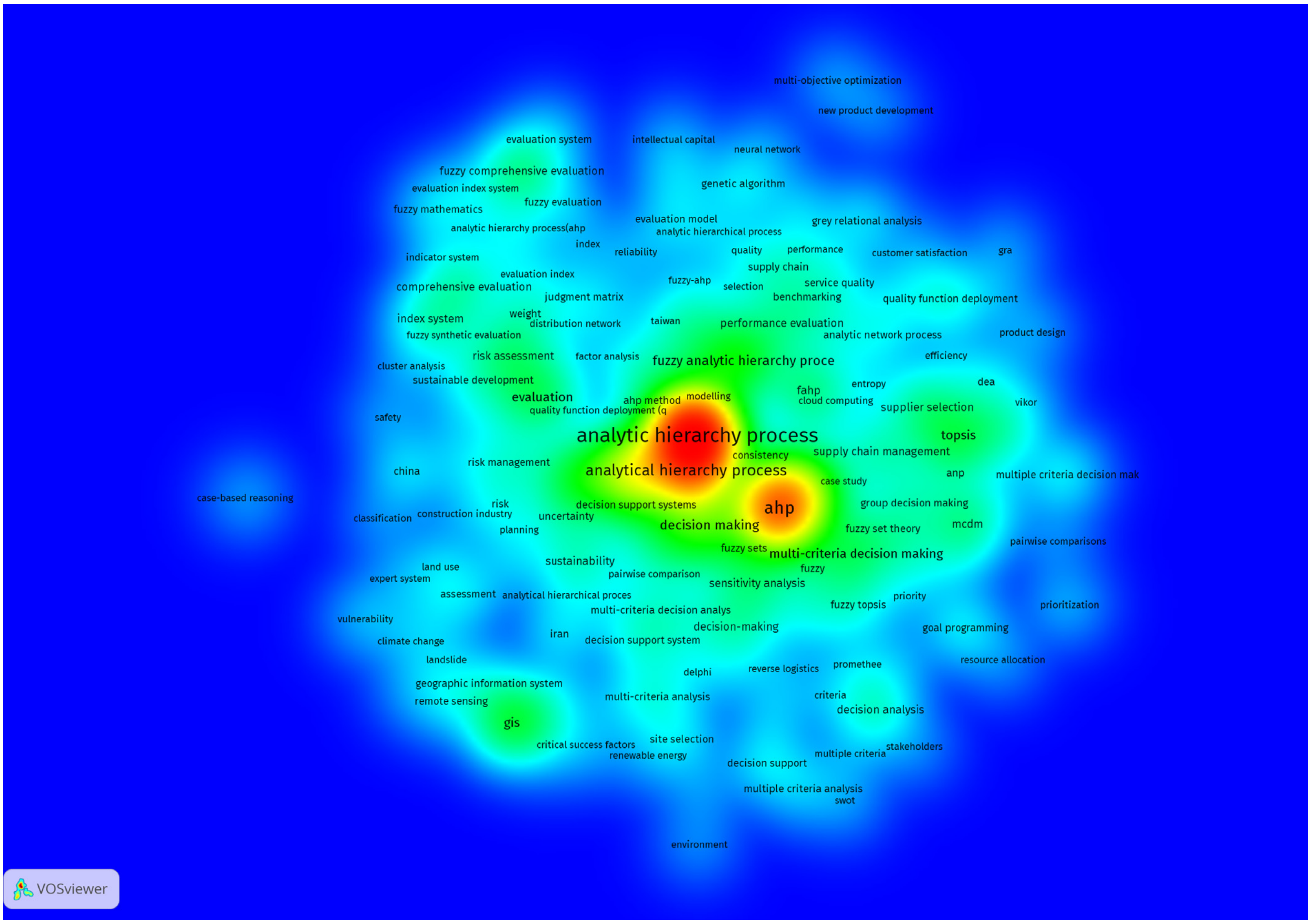

Fig. 4. Density visualization map-item density in association with published research that utilized AHP method. Analysis of co-occurrence of author keywords, minimum number of occurrences of a keyword was set to 20, of the 20,418 keywords: 174 keywords meet the threshold. For each of the 174 keywords, the number of co-occurrence links was calculated. The keywords with the largest number of links are selected.

the contribution of the item (i.e. the larger circle, the higher contributions in terms of occurrence). As traditional AHP method will continue to be requested over the coming periods as shown in Figs. 4 and 5, the use of Fuzzy AHP and the integration of TOPSIS technique with different AHP methods will be an active field in the future. The hot topics of research that utilized AHP methods and will continue to be vital in the future include: the integration of AHP with geographic information systems for different uses (i.e. remote sensing, site selection, land use planning, land slide susceptibility, risk assessment and sustainable development), supply chain management (i.e. supplier selection and evaluation, service quality, new product development, customer satisfaction), risk analysis; evaluation and management, cloud computing, optimization, neural networks, genetic algorithms, projects management, renewable energy and climatic changes research.

Fig. 6 shows the density visualization map–item density in association with published research that utilized TOPSIS method. The same as in case of AHP method, the minimum number of occurrences of a keyword was set to 20. Out of the total of 5592 keywords, 44 meet the threshold. Fig. 7 shows the network visualization map which divides the keywords into 7 clusters. The analysis shows that the integration of TOPSIS method with other MCDA methods like AHP, Fuzzy AHP, VIKOR and fuzzy set theory will continue to be active. The major hot topics that utilized TOPSIS method and expected to be active in the future were: supplier selection, supply chain management, sustainability, performance evaluation and optimization. Iran is expected to continue as an active country in this field of research since it was the only country name appears in the list of top terms of high occurrence frequency.

5. Implications

The outcomes of this bibliometric study have various major implications for evaluation of the scientific outputs of the AHP and TOPSIS methods. This bibliometric analysis revealed a collection of key data where scholars and researchers can acquire insights into the contributions of countries, journals, institutes and authors in fields of research that employed AHP and TOPSIS methods. Furthermore, it documents the scientific achievements and identifies the hot spots of research and the future research directions. The generated indicators, whether they were quantitative or qualitative indicators, can provide a base for future assessment and analysis of research output in the scrutinized field. For example, indicator such as the productivity of countries, can be utilized to indicate the progress of research productivity of these countries in the future. If future analysis indicates that the productivity indicator is rising in comparison to the generated one in this analysis, this would indicate the progress that a country is making toward increasing its research productivity. The same is applicable for other indicators such as rates of collaboration, and citations. Other implication is related to the possibility of identifying the changes in research trends in the future compared to the existing ones. The hope that

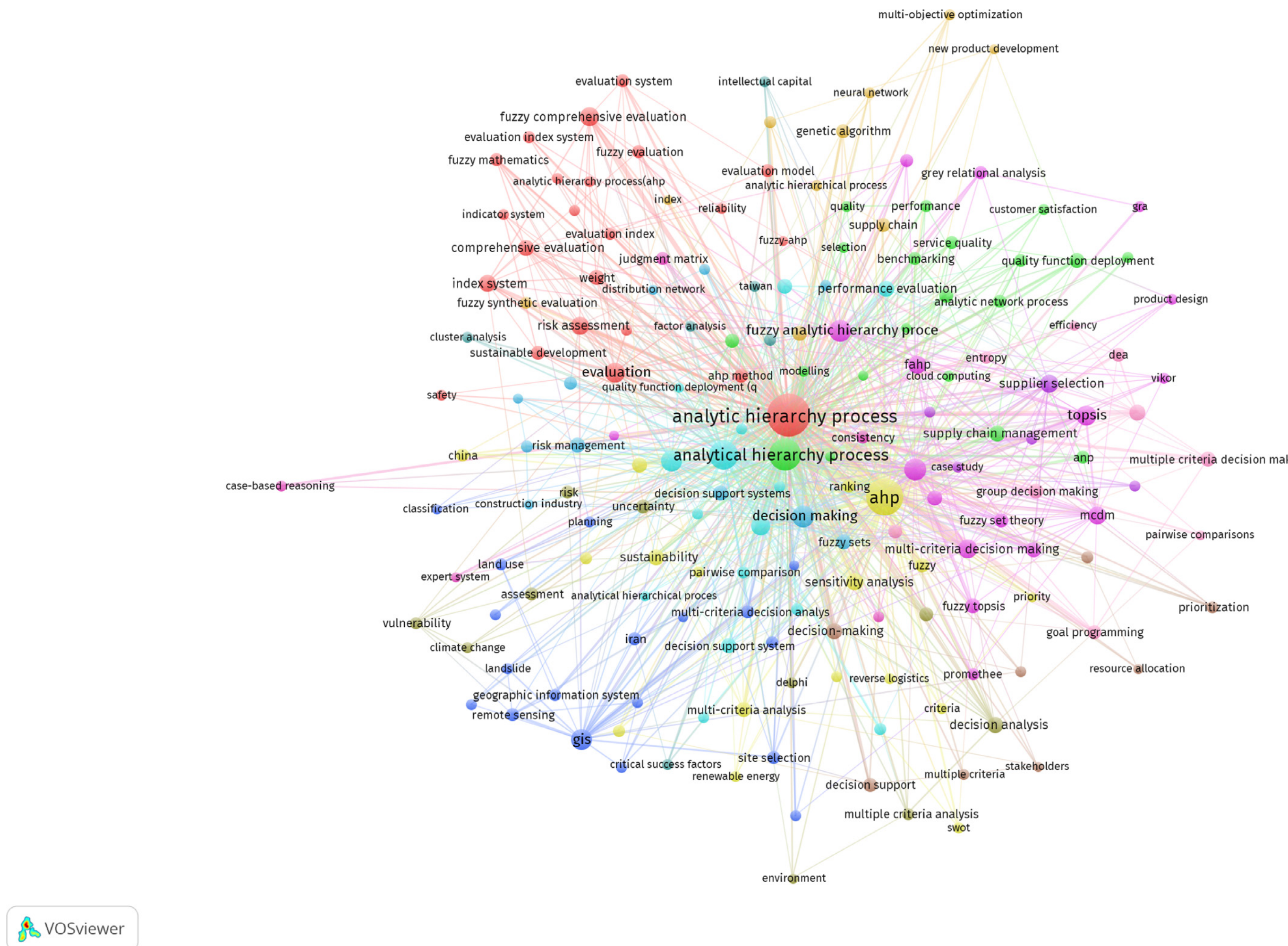

Fig. 5. Network visualization map in association with published research that utilized AHP method. Analysis of co-occurrence of author keywords, minimum number of occurrences of a keyword was set to 20, of the 20,418 keywords: 174 keywords meet the threshold. For each of the 174 keywords, the number of co-occurrence links was calculated. The keywords with the largest number of links are selected. Keywords which are having the most intra-cluster co-occurrence relations are arranged in the same cluster (in this case, there was 14 clusters).

this study will help scholars and practitioners in future works towards advancement of these techniques.

6. Strengths/Limitations

Bibliometric analyses have the potential to generate a data-driven vision of scientific research activities across different research disciplines and are able to present evidence-based depictions, comparisons, and visualizations of research outputs (Rosas, Kagan, Schouten, Slack, & Trochim, 2011). They have been recognized as benefit tools in helping policy makers and researchers to perceive the status of research and science, and to help in future investments based on priorities (Smith & Marinova, 2005) and to shape the future research directions. Despite their expansion across fields of research evaluation, their application is limited to literature published in indexed journals and do not comprise unpublished literature, research published in non-indexed journals, unpublished reports, dissertations, etc. (Rosas et al., 2011). This causes omission of some valuable works in the field. As in most of other bibliometric analyses, some limitations are unavoidable. First, this study considered only documents that are classified as articles and review articles. The exclusion of other types of documents (i.e. conference proceedings papers and reviews, published books, reports, surveys, etc.) might have omitted some useful contributions in the field or relevant research. Second, the evaluation was conducted over publications collected from Scopus database only, which may have excluded relevant publications from other databases such as Web of Science, Google Scholar and PubMed. Third, a further limitation is concerned with the counting of citations which were elicited from Scopus database only. Different research databases mostly offer different figures of citations. Despite that, Scopus database sustains as one of the master search databases which are available in the field of analysing, comparing and tracking citations (De Granda-Orive et al., 2011).

7. Conclusion remarks

The focal point of interest in this work was to conduct a bibliometric analysis on global research in two well-known MCDA methods, precisely AHP and TOPSIS methods along the following dimensions: annual research output, countries productivity, geographic and regions distribution, document types and publishing languages, major journals and research areas categories, performance of authors and evolution of citations, and major institutions that contributed to the published literature related to AHP and TOPSIS methods. Bibliometric techniques and statistical analyses have been employed to derive the quantitative and qualitative performance indicators. The quantitative indicators were iden-

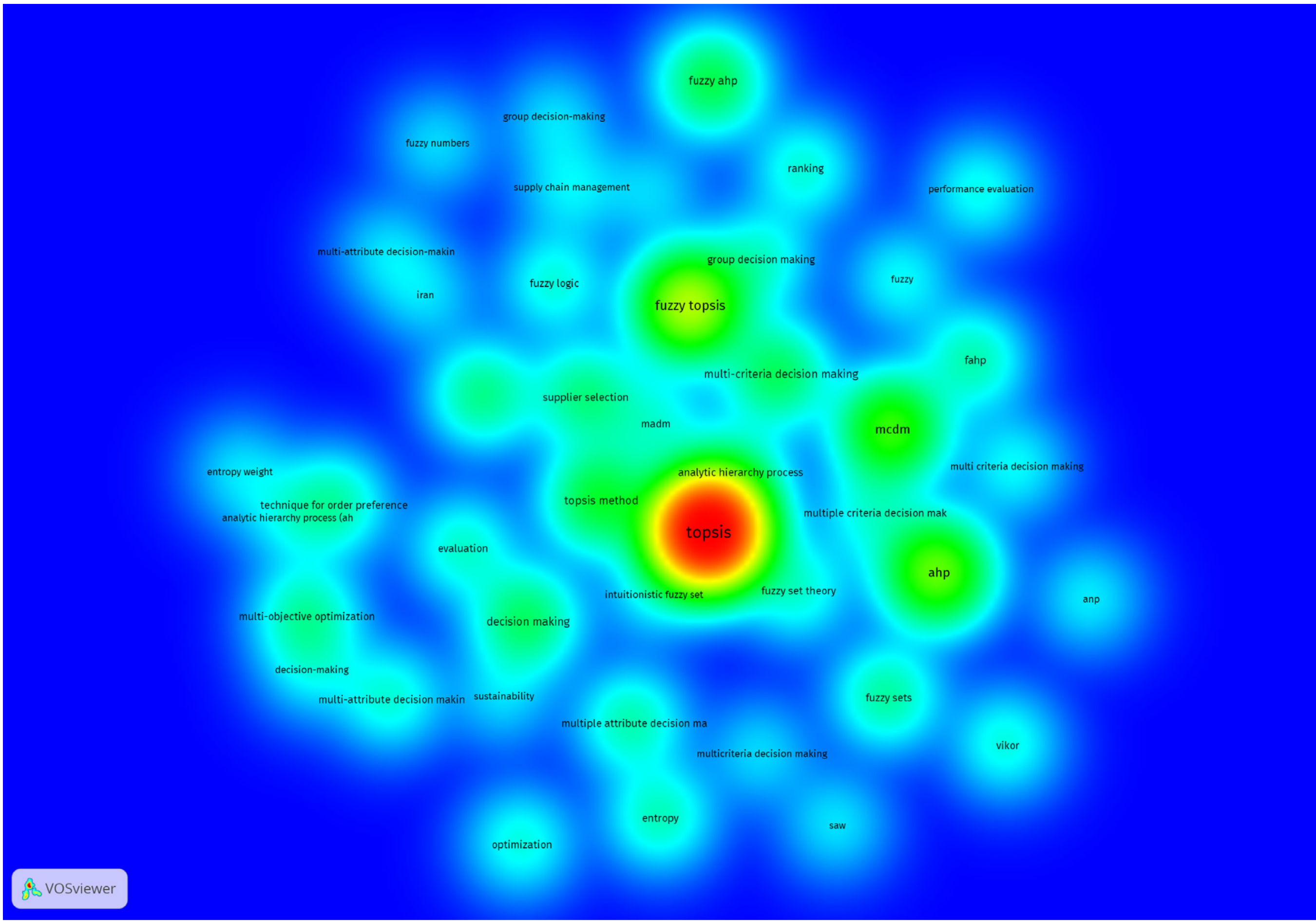

Fig. 6. Density visualization map-item density in association with published research that utilized TOPSIS method. Analysis of co-occurrence of author keywords, minimum number of occurrences of a keyword was set to 20, of the 5592 keywords: 44 keywords meet the threshold. For each of the 44 keywords, the number of co-occurrence links was calculated. The keywords with the largest number of links are selected.

tified based on scientific research output while for the qualitative ones, they based on citation rates and *h*-index values. This bibliometric analysis has confirmed the leading role that China, United States, Taiwan, India, Iran, Turkey and the United Kingdom paly in AHP research in terms of the volume of their contributions. Simultaneously, the leading role of China, Iran, India, Taiwan, Turkey and the United States in TOPSIS research. The superiority of AHP was proved by its predominance in practice and research and evidenced through the huge number of publications. This study revealed that the rates of citations of published literature in AHP and TOPSIS experienced substantial growth in parallel with growth in publications. It can be concluded that research related to AHP and TOPSIS is a rapid growth field which will attract more scientific attention by scholars and researchers in the future.

The United States and China were in the core position of the international collaboration, while the small countries and emerging research countries benefited from research collaboration as a bridge to the scientific community. Active participation of emerging and developing countries in research related to AHP and TOPSIS methods has been witnessed in this analysis which is associated with the increase in their contributions to the global knowledge pool. Without any doubt, the findings of this analysis indicate a trend toward more and more adoption of AHP and TOPSIS methods in solving complex decision making problems.

The employment of AHP techniques in fields of research related to: the different applications of geographic information systems (i.e. remote sensing, site selection; land use planning and sustainable development), various risk models (i.e. risk assessment, risk management, risk analysis and risk evaluation), supply chain management (i.e. supplier evaluation and selection, product design and customer satisfaction), cloud computing, genetic algorithms, neural networks projects management, strategic planning, renewable energy and climatic changes research will continue to be active and indicates the future research trends. The supply chain management and sustainability research will continue to be active fields of research that employ the TOPSIS technique.

Generally, the findings of this analysis provide an overall picture of the development of AHP and TOPSIS research. This could help practitioners and scholars to identify and assess the efforts that have been exerted toward the advancements of research related to these fields. This will help in developing new lines of research for the future and in advancing the use of these methods in more applications. The employed methodology is applicable to other MCDA methods or other subjects.

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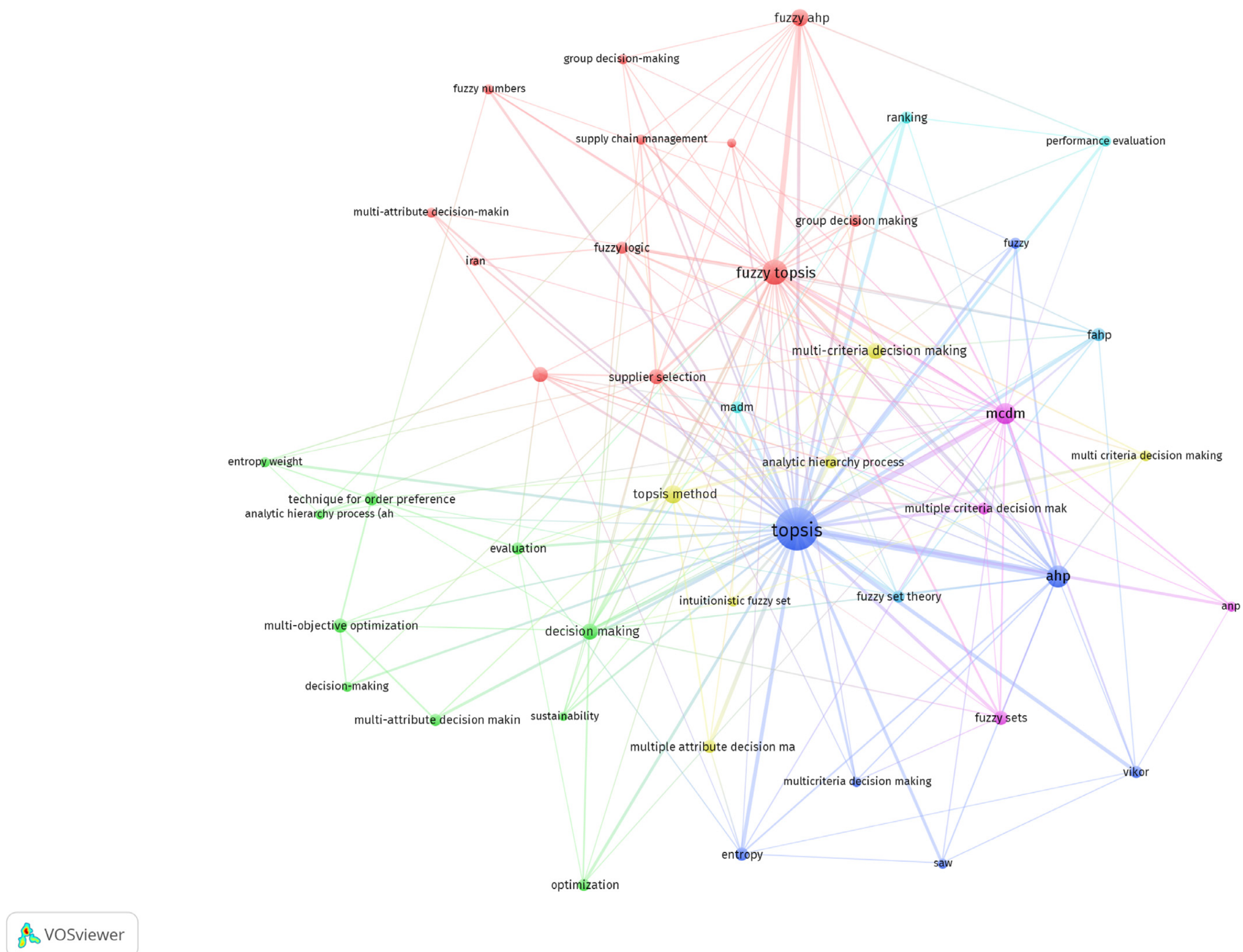

Fig. 7. Network visualization map in association with published research that utilized TOPSIS method. Analysis of co-occurrence of author keywords, minimum number of occurrences of a keyword was set to 20, of the 5592 keywords: 44 keywords meet the threshold. For each of the 44 keywords, the number of co-occurrence links was calculated. The keywords with the largest number of links are selected. Keywords which are having the most intra-cluster co-occurrence relations are arranged in the same cluster (in this case, there was 7 clusters).

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