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Review

A state-of-the-art survey of TOPSIS applications

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ABSTRACT

Multi-Criteria Decision Aid (MCDA) or Multi-Criteria Decision Making (MCDM) methods have received much attention from researchers and practitioners in evaluating, assessing and ranking alternatives across diverse industries. Among numerous MCDA/MCDM methods developed to solve real-world decision problems, the **T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**olution (TOPSIS) continues to work satisfactorily across different application areas. In this paper, we conduct a state-of-the-art literature survey to taxonomize the research on TOPSIS applications and methodologies. The classification scheme for this review contains 266 scholarly papers from 103 journals since the year 2000, separated into nine application areas: (1) Supply Chain Management and Logistics, (2) Design, Engineering and Manufacturing Systems, (3) Business and Marketing Management, (4) Health, Safety and Environment Management, (5) Human Resources Management, (6) Energy Management, (7) Chemical Engineering, (8) Water Resources Management and (9) Other topics. Scholarly papers in the TOPSIS discipline are further interpreted based on (1) publication year, (2) publication journal, (3) authors' nationality and (4) other methods combined or compared with TOPSIS. We end our review paper with recommendations for future research in TOPSIS decision-making that is both forward-looking and practically oriented. This paper provides useful insights into the TOPSIS method and suggests a framework for future attempts in this area for academic researchers and practitioners.

1. Introduction

Multiple-criteria decision analysis (MCDA) or Multiple-criteria decision making (MCDM) is a sub-discipline and full-grown branch of operations research that is concerned with designing mathematical and computational tools to support the subjective evaluation of a finite number of decision alternatives under a finite number of performance criteria by a single decision maker or by a group (Lootsma, 1999). MCDA/MCDM uses knowledge from many fields, including mathematics, behavioral decision theory, economics, computer technology, software engineering and information systems. Since the 1960s, MCDA/MCDM has been an active research area and produced many theoretical and applied papers and books (Roy, 2005). MCDA/MCDM methods have been designed to designate a preferred alternative, classify alternatives in a small number of categories, and/or rank alternatives in a subjective preference order. A number of literature review papers, i.e., Behzadian, Kazemzadeh, Aghdasi, and Albadvi (2010) on PROMETHEE and Vaidya and Kumar (2006) and Ho (2008) on AHP, show the vitality of the field and the many methods that have been developed.

Among numerous MCDA/MCDM methods developed to solve real-world decision problems, **T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**olution (TOPSIS) continues to work satisfactorily in diverse application areas. Hwang and Yoon (1981) originally proposed TOPSIS to help select the best alternative with a finite number of criteria. As a well-known classical MCDA/MCDM method, TOPSIS has received much interest from researchers and practitioners. The global interest in the TOPSIS method has exponentially grown, which we wish to document in this paper.

This paper provides a state-of-the-art literature survey on TOPSIS applications and methodologies. A reference repository has been established based on a classification scheme, which includes 266 papers published in 103 scholarly journals since 2000. Scholarly papers are further categorized into application areas, publication year, journal name, authors' nationality, and integrating other MADM/MCDM methods into TOPSIS. Our contributions are threefold: developing a classification scheme focused on these practical considerations, a structured review that provides a guide to earlier research on the TOPSIS method, and identifying research issues for future investigation.

The rest of the paper is organized as follows. Section 2 provides a brief overview and the implementation steps used in TOPSIS. Section 3 describes the methodology used in the literature review. Section 4 provides the breakdown of the review, which contains

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nine application areas. Section 5 distributes the selected papers into four further categories. Finally, Section 6 presents concluding remarks.

2. TOPSIS procedure

TOPSIS, developed by Hwang and Yoon in 1981, is a simple ranking method in conception and application. The standard TOPSIS method attempts to choose alternatives that simultaneously have the shortest distance from the positive ideal solution and the farthest distance from the negative-ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. TOPSIS makes full use of attribute information, provides a cardinal ranking of alternatives, and does not require attribute preferences to be independent (Chen and Hwang, 1992; Yoon & Hwang, 1995). To apply this technique, attribute values must be numeric, monotonically increasing or decreasing, and have commensurable units.

Fig. 1 presents the stepwise procedure of Hwang and Yoon (1981) for implementing TOPSIS. After forming an initial decision matrix, the procedure starts by normalizing the decision matrix. This is followed by building the weighted normalized decision matrix in Step 2, determining the positive and negative ideal solutions in Step 3, and calculating the separation measures for each alternative in Step 4. The procedure ends by computing the relative closeness coefficient. The set of alternatives (or candidates) can be ranked according to the descending order of the closeness coefficient.

3. Framework for literature review

This literature review was undertaken to identify articles in high-ranking journals that provide the most valuable information to researchers and practitioners studying live issues concerning the TOPSIS method. With this scope in mind, we conducted an extensive search for TOPSIS in the title, abstract, and keywords of scholarly papers. We particularly targeted library databases: Elsevier, Springer, Taylor and Francis, Emerald, John Wiley, IEEExplore and EBSCO, covering major journals in operation research and management sciences. Conference proceeding papers, master's theses, doctoral dissertations, textbooks, and unpublished working papers were thus excluded from the literature review.

The primary data for this review were gathered from almost 400 cited articles in the library databases published since 2000. As most scholarly papers on TOPSIS have been published since 2000, we choose this year as a starting date for search. An article is included in the review if it thoroughly discusses the application, development or modification of the TOPSIS method or a performance comparison of TOPSIS with other MCDA/MCDM methods. With this purpose in mind, we narrowed the list to 266 major research papers published in 103 journals. The target papers in this review were analyzed, classified, coded, and recorded under a classification scheme, shown in Table 1. As each paper was reviewed, it was classified by several categories: publication year, authors' nationality, journal title, application area, specific sub-area, if it combined or compared other MCDA/MCDM techniques, and if the techniques were applied as a group decision making approach. Although this review cannot claim to be comprehensive, it covers a large portion of the leading publications on TOPSIS methodologies and applications and provides a valuable source for researchers and practitioners.

4. Application areas

This wide range of real-world applications for the TOPSIS method imposed a strong motivation for categorizing applications across different fields and specific sub-areas. Application research studies include case studies, illustrative examples, and/or practical experiences. To show similarities and differences, 266 papers were categorized into nine areas: (1) Supply Chain Management and

Step 1: Construct normalized decision matrix

$$r_{ij} = x_{ij} / \sqrt{(\Sigma x^2_{ij})} \quad \text{for} \quad i = 1, \ldots, m; \; j = 1, \ldots, n \quad (1)$$

where x_{ij} and r_{ij} are original and normalized score of decision matrix , respectively

Step 2: Construct the weighted normalized decision matrix

$$v_{ij} = w_j \, r_{ij} \qquad (2)$$

where w_j is the weight for j criterion

Step 3: Determine the positive ideal and negative ideal solutions.

$$A^* = \{ v_1^*, \ldots, v_n^* \}, \quad (3) \quad \text{Positive ideal solution}$$

where $v_j^* = \{ \max (v_{ij}) \text{ if } j \in J ;\; \min (v_{ij}) \text{ if } j \in J' \}$

$$A' = \{ v_1', \ldots, v_n' \}, \quad (4) \quad \text{Negative ideal solution}$$

where $v' = \{ \min (v_{ij}) \text{ if } j \in J ;\; \max (v_{ij}) \text{ if } j \in J' \}$

Step 4: Calculate the separation measures for each alternative.

The separation from positive ideal alternative is:

$$S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{½} \quad i = 1, \ldots, m (5)$$

Similarly, the separation from the negative ideal alternative is:

$$S'_i = [\Sigma (v_j' - v_{ij})^2]^{½} \quad i = 1, \ldots, m (6)$$

Step 5: Calculate the relative closeness to the ideal solution C_i^*

$$C_i^* = S'_i / (S_i^* + S'_i) \; , \quad (7) \quad 0 < Ci^* < 1$$

Select the Alternative with C_i^* closest to 1.

Fig. 1. Stepwise procedure for performing TOPSIS methodology.

Table 1
Classification scheme for literature review.

	Year of publication	Authors	Authors' nationality	Journal of publication	Application area	Specific area	Other techniques combined or compared	Applied as group decision making
1								
2								
...								
266								

Logistics, (2) Design, Engineering and Manufacturing Systems, (3) Business and Marketing Management, (4) Health, Safety and Environment Management, (5) Human Resources Management, (6) Energy Management, (7) Chemical Engineering, (8) Water Resources Management, and (9) Other topics. For those papers that fall into more than one category, the best possible choice was selected based on the target audience as defined by the paper's objective. This ensures that no duplication existed in our classification scheme. The last area covers papers published in fields such as Medicine, Agriculture, Education, Design, Government, and Sports. Table 2 shows the number of papers and their respective percentages in each application area. The top 2 categories – "Supply Chain Management and Logistics" and "Design, Engineering and Manufacturing Systems" – contain over 50% of the total published applications. Few applications have been devoted to "Chemical Engineering" or "Water Resources Management".

The following sections present an extensive review of the 266 scholarly papers classified into nine application areas and their specific sub-areas. First, some papers are briefly mentioned in each section, and each topic is further summarized by specific tables corresponding to their sub-areas. The papers in each table are arranged in alphabetical order by author. The vast majority of application papers have proposed TOPSIS extensions or modifications, which are classified under the "Other techniques combined or compared" column of each table.

4.1. Supply Chain Management and Logistics

Supply Chain Management and Logistics is considered the most popular topic in TOPSIS applications. Supply chain and logistics management covers several specific sub-areas, including supplier selection, transportation, and location problem.

For supplier selection, Chen et al. (2006) proposed a fuzzy systematic approach to extend TOPSIS to solve the supplier selection problem based on supplier profitability, relationship closeness, technological capability, conformance quality, and conflict resolution factors. According to this extended approach, a closeness coefficient was defined to determine the ranking order of all suppliers by simultaneously calculating the distances to the fuzzy positive-ideal and fuzzy negative-ideal solutions. To handle outsourcing decision-making problems, Kahraman et al. (2009) presented a fuzzy group decision-making methodology based on TOPSIS. In this study, the fuzzy TOPSIS approach was used to specify the ranking of alternatives according to an aggregated decision matrix and weight vector and was based on the individual decision matrices and weight vectors. For the location problem, Yong (2006) presented a new TOPSIS approach to select plant locations, where the ratings of various locations for each criterion and the weights of various criteria were assessed using fuzzy linguistic terms. Table 3 summarizes the TOPSIS papers addressed within *Supply Chain Management and Logistics*.

4.2. Design, Engineering and Manufacturing Systems

Design, Engineering and Manufacturing Systems issue is a broad area in the TOPSIS publications. The area typically includes papers in modern manufacturing systems, automation, material engineering, mechatronics, product design, and quality engineering.

In this area, Lin, Wang, Chen, and Chang (2008c) presented a framework that integrates AHP and TOPSIS to help designers identify customer requirements and design characteristics and provide a final design solution for competitive benchmarking. By analyzing organizational management agility, product design, processing manufacture, partnership formation capability and information system integration, Wang (2009) proposed a mass customization manufacturing agility evaluation approach based on the TOPSIS method. Shih (2008) utilized a group decision-making process for the robot selection problem using TOPSIS. Table 4 summarizes the TOPSIS papers in *Design, Engineering and Manufacturing Systems*.

4.3. Business and Marketing Management

Business and Marketing Management is the third most popular area in TOPSIS applications. It covers applications that use TOPSIS for organizational performance, financial measurement, investment projects, customer satisfaction, and competitive advantages. Approximately 12.3% of all papers fall under the *business and marketing management* category.

In this area, Aydogan (2011) proposed integrating AHP and fuzzy TOPSIS to evaluate the performance of four aviation firms using five important dimensions: performance risk, quality, effectiveness, efficiency, and occupational satisfaction. Peng, Wang, Kou, and Shi (2011)offered a new two-step approach to evaluate classification algorithms for financial risk prediction using an empirical study that was designed to assess various classifications. Three ranking methods, TOPSIS, PROMETHEE, and VIKOR, were used as the top three classifiers. Zandi and Tavana (2011b) presented a structured approach using a hybrid fuzzy group permutation and a four-phase QFD model to evaluate and rank agile e-CRM frameworks according to their customer orientation in a dynamic manufacturing environment. Table 5 summarizes TOPSIS papers found under *Business and Marketing Management*.

4.4. Health, Safety and Environment Management

Health, Safety and Environment Management is a more recent topic that utilizes the TOPSIS methodology. It covers several

Table 2
Distribution of papers by application areas

Areas	*N*	%
Supply Chain Management and Logistics	74	27.5
Design, Engineering and Manufacturing Systems	62	23
Business and Marketing Management	33	12.3
Health, Safety and Environment Management	28	10.4
Human Resources Management	24	8.9
Energy Management	14	5.2
Chemical Engineering	7	2.6
Water Resources Management	7	2.6
Other topics	20	7.4
Total	269	100

Table 3
Applied papers in "Supply Chain and Management and logistics".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Alimoradi, Yussuf, and Zulkifli (2011)	Determining the best place to locate a manufacturing facility	Fuzzy TOPSIS	
Araz, Eski, and Araz (2008)	Determining the number of Kanbans and the container size for JIT manufacturing systems	Artificial neural network and simulation meta-modeling	
Awasthi, Chauhan, and Goyal (2011a)	Evaluating environmental supplier performance	Fuzzy TOPSIS	•
Awasthi, Chauhan, and Omrani (2011c)	Selecting the best location to implement an urban distribution center	Fuzzy TOPSIS	•
Awasthi, Chauhan, Omrani, and Panahi (2011d)	Selecting sustainabletransportation systems	Fuzzy TOPSIS	•
Awasthi, Chauhan, and Goyal (2011b)	Evaluating the service quality of urban transportation systems	SERVQUAL and fuzzy TOPSIS	
Bhattacharya, Sarkar, and Mukherjee (2007)	Ranking items in categories A, B and C for ABC analysis	Analysis of variance (ANOVA)	
Boran, Genç, Kurt, and Akay (2009)	Selecting the most appropriate supplier	Intuitionistic fuzzy TOPSIS	•
Bottani and Rizzi (2006)	Selecting the most suitable logistics service provider	Fuzzy TOPSIS	•
Buyukozkan, Feyzioglu, and Nebol (2008)	Selecting a suitable partner for a strategic alliance in a logistics value chain	Fuzzy AHP and fuzzy TOPSIS	
Celik (2010)	Selecting a marine supplier based on the operational requirements of a ship	AHP	
Chamodrakas, Alexopoulou, and Martakos (2009)	Customer evaluation in the order acceptance process of suppliers	Fuzzy TOPSIS	
Chamodrakas, Leftheriotis, and Martakos (2011)	Evaluating four service providers	Fuzzy TOPSIS and simulation	
Chen, Lin, and Huang (2006)	Supplier selection problem	Fuzzy TOPSIS	
Chen (2011)	Ranking potential suppliers in the Taiwanese textile industry based on SWOT analysis	Fuzzy approach and DEA	•
Cheng (2008)	Solving the winner bid determination problem	Fuzzy multiple-objective programming	
Cheng, Ye, and Yang (2009)	Selecting the optimal collaborative manufacturing chain for manufacturing complex parts	Non-dominated sorting genetic algorithm (NSGA-II) and multi-objective optimization	
Cheng, Chao, Lo, and Tsai (2011)	Web service selection problem	Fuzzy TOPSIS and Service Component Architecture	
Chu (2002)	Selecting plant location	Fuzzy TOPSIS	•
Chu and Lin (2009)	Facility site selection problem	Fuzzy TOPSIS	•
Dalalah, Hayajneh, and Batieha (2011)	Supplier selection problem	Fuzzy DEMATEL and fuzzy TOPSIS	•
Deng and Chan (2011)	Supplier selection problem	Fuzzy approach and Dempster Shafer theory of evidence	•
Erkayman, Gundogar, Akkaya, and Ipek (2011)	Selecting a logistics center in Turkey	Fuzzy TOPSIS	
Ertugrul (2010)	Facility location selection problem of a textile company	Fuzzy TOPSIS	•
Ertugrul and Karakasoglu (2008)	Facility location selection problem of a textile company	Fuzzy AHP and fuzzy TOPSIS	•
Fan and Feng (2009)	Identifying the most competitive port for developing a large-scale logistic center	Extended TOPSIS with fuzzy	
Fazlollahtabar, Mahdavi, Talebi Ashoori, Kaviani, and Mahdavi-Amiri (2011)	Selecting the best suppliers in the electronics market	AHP, multi-objective nonlinear programming and multiple linear regression model	
Gharehgozli, Rabbani, Zaerpour, and Razmi (2008)	Ranking incoming orders in the food processing industry	Fuzzy AHP	
Hatami-Marbini and Tavana (2011)	Selecting a suitable material supplier for a high-technology manufacturing company	Fuzzy TOPSIS and fuzzy ELECTRE I	•
Hsu and Hsu (2008)	Selecting an information technology supplier for outsourcing clinical needs	Delphi method and entropy method	
Huang and Li (2010)	Evaluating seven computer retailers in a purchasing decision problem	-	•
Jahanshahloo, Khodabakhshi, Lotfi, and Goudarzi (2011)	Evaluating six cities for establishing a data factory	Data envelopment analysis (DEA) and TOPSIS with interval data	
Jahanshahloo, Lotfi, and Davoodi (2009)	Evaluating six cities for establishing a data factory	TOPSIS with interval data	
Jolai, Yazdian, Shahanaghi, and Azari-Khojasteh (2011)	Supplier selection and order allocation problem among six automobile mirror suppliers	Multi-objective mixed integer linear programming, goal programming, fuzzy AHP and fuzzy TOPSIS	•
Joshi, Banwet, and Shankar (2011)	Assessing possible alternatives for the continuous improvement of a company's cold chain performance	Delphi method and AHP	•
Kahraman, Ates, Çevik,and Gülbay, (2007a)	E-service provider selection problem	Hierarchical fuzzy TOPSIS	
Kahraman, Engin, Kabak, and Kaya (2009)	Ranking information systems providers	Hierarchical fuzzy TOPSIS	•
Kandakoglu, Celik, and Akgun (2009)	Ranking shipping registry alternatives in the maritime transportation industry based on a SWOT analysis	AHP	•
Kannan, Pokharel, and Kumar (2009)	Selecting the best third-party reverse logistics provider	Fuzzy TOPSIS andInterpretive structural modeling (ISM)	•
Kara (2011)	Supplier selection problem in paper production	Two-stage stochasticprogrammingand fuzzy TOPSIS	•
Kocaoglu et al. (in press)	Evaluating company performance based on SCOR metrics	AHP and SCOR model	
Kuo (2011)	Selecting the location of an international distribution center in Pacific Asia	Fuzzy DEMATEL andANP	
Kuo and Liang (2011)	Selecting the location of an international distribution center in Pacific Asia	DEMATEL, fuzzy ANP, fuzzy simple additive weighting (SAW) and fuzzy TOPSIS	

Kuo, Tzeng, and Huang (2007)	Selecting the location of an international distribution center in Pacific Asia	Fuzzy SAW and fuzzy TOPSIS	•
Kuo, Yang, Cho, and Tseng (2008)	Finding the most suitable dispatching rule for a flow shop with multiple processors	AHP, Taguchi method, and simulation	
Li et al. (2011a)	Finding the optimal logistics center location	Axiomatic fuzzy set clustering method	
Liao and Kao (2011)	Supplier selection problem in a watch firm	Multi-choice goal programming and fuzzy TOPSIS	
Lin, Chen, and Ting (2011)	Supplier selection based on an Enterprise resource planning (ERP) model in an electronics firm	ANP and linear programming	
Lin and Tsai (2009)	Selecting an ideal city for medical service ventures using overall performance	ANP and nominal group technique	•
Lin and Tsai (2010)	Selecting alternative locations for investing hospitals	ANP and nominal group technique	•
Lin and Chang (2008)	Order selection and pricing process of a manufacturer (supplier) with make-to-order and limited production capacities	Mixed integer programming and fuzzy approach	•
Lin and Li (2008)	Land-use design model for regional transit-oriented development planning	Grey programming	
Lin, Lee, Chang, and Ting (2008a)	Subcontractor selection problem from an engineering corporation	Grey number and Minkowski distance function	•
Lin, Lee, and Ting (2008b)	Subcontractor selection problem from an engineering corporation	Grey number and Minkowski distance function	
Ning, Lam, and Lam (2011)	Selecting an optimal construction site layout among generated layout alternatives in the design stage	Fuzzy TOPSIS, Max–min ant system, and Pareto-based ant colony optimization algorithm	
Önüt, Kara, and Isik (2009a)	Supplier evaluation approach for a telecommunications company	Fuzzy ANP and fuzzy TOPSIS	
Onut, Kara, and Mert (2009b)	Selecting material handling equipment for a steel construction compnay	Fuzzy ANP and fuzzy TOPSIS	
Özcan, Çelebi, and Esnaf (2011)	Warehouse location selection problem	AHP, ELECTRE and grey theory	
Roghanian, Rahimi, and Ansari (2010)	Selecting a suitable material supplier to purchase key components for new products	Fuzzy TOPSIS	•
Safari et al. (in press)	Selecting an appropriate site for mineral processing plant	Fuzzy TOPSIS	
Sheu (2008)	Evaluating six types of global logistics and operational modes	Fuzzy AHP and adaptive neuro-fuzzy inference system	•
Shyur and Shih (2006)	Strategic vendor selection problem	Nominal group technique, ANP and modified TOPSIS	•
Singh and Benyoucef (2011)	Supplier selection for a sealed-bid reverse auction for B2B Industrial purchase	Entropy method and fuzzy TOPSIS	
Taleizadeh, Akhavan Niaki, and Aryanezhad (2009)	A multi-product inventory control problem	Fuzzy approach, integer-nonlinear programming, and genetic algorithm	
Torlak, Sevkli, Sanal, and Zaim (2011)	Ranking major air carriers in the Turkish domestic airline industry	Fuzzy approach	
Wang, Cheng, and Huang (2009)	Lithium ion battery protection IC supplier selection problem.	Fuzzy AHP and fuzzy hierarchical TOPSIS	•
Wang (2011)	Selecting an efficient location for a new factory	Fuzzy TOPSIS	•
Wang et al. (2011a)	Selecting a suitable supplier for a key component in producing a new product	Fractional programming, quadratic programming, and interval-valued intuitionistic fuzzy TOPSIS	
Yang, Bonsall, and Wang (2009)	Choosing an appropriate container transport mode to prevent delivery delay	Fuzzy TOPSIS, entropy method and MAUT	
Yang, Bonsall, and Wang (2011)	Vessel selection for a particular cargo transfer in voyage chartering	AHP and approximate interval TOPSIS	
Yong (2006)	Selecting a location to build a new plant	Fuzzy TOPSIS	•
Zeydan, Çolpan, and Çobanoglu (2011)	Evaluating suppliers based on efficiency and effectiveness in a car manufacturing factory	Fuzzy AHP, fuzzy TOPSIS and DEA	
Zhang, Shang and Li (2012)	Evaluating third-party logistics providers	Fuzzy approach, K-means clustering and entropy method	

Table 4
Applied papers in "Design, Engineering and Manufacturing Systems".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Athanasopoulos, Riba, and Athanasopoulou (2009)	Devising an expert system for selecting coating material candidates	Fuzzy TOPSIS	
Azadeh, Nazari-Shirkouhi, Hatami-Shirkouhi, and Ansarinejad (2011a)	The optimum operator allocation problem in cellular manufacturing systems	Fuzzy AHP and simulation	
Azadeh, Kor, and Hatefi (2011b)	Determining the most efficient number of operators and efficient operator assignment measurements in cellular manufacturing systems	DEA, Principal component analysis (PCA), entropy method, and genetic algorithm-TOPSIS simulation approach	
Bhangale, Agrawal, and Saha (2004)	Evaluating and ranking candidate robots	–	
Braglia, Frosolini, and Montanari (2003)	Prioritizing failures in failure mode, effects and criticality analysis	Fuzzy TOPSIS	
Chang (2010)	Selecting an optimal wire saw in photovoltaic wafer manufacture	AHP	
Chang and Chen (2010)	Identifying the optimal-performing machine using precision	Fuzzy AHP and Delphi method	
Cheng, Feng, Tan, and Wei (2008)	Ranking alternative mold schemes according to their mold ability indices	Fuzzy TOPSIS	
Chu and Lin (2003)	Robot selection to perform a material-handling task.	Fuzzy TOPSIS	•
Davoodi et al. (2011)	Selecting the best geometrical bumper beam concept to fulfill the safety parameters of the defined product design specification	–	
Fazlollahtabar (2010)	Ranking automobile seat comfort based on consumer preferences	AHP and entropy method	
Gamberini, Grassi, and Rimini (2006)	Assembly line re-balancing problem	Kottas and Lau heuristic approach and multiple-objective optimization	
Garcia-Cascales and Lamata (2009)	Selecting a cleaning system for pieces of four stroke engines	Fuzzy TOPSIS and fuzzy AHP	
Gauri, Chakravorty, and Chakraborty (2011)	Optimizing multiple responses for the ultrasonic machining process	Signal-to-noise ratio, PCA, grey relational analysis, weighted principal component, and Taguchi method	
Geng, Chu, and Zhang (2010)	Design concept evaluation problem of a horizontal directional drilling machine	Weighted least squares model and cross-entropy of vague sets	•
Goyal, Jain, and Jain (In press)	Ranking Pareto frontiers when handling reconfigurable machine tool optimization and cost–benefit issues	Entropy method, NSGA-II, and multi-objective optimization	
He, Tang, and Chang (2010)	Quality relation weight evaluation for a car design improvement project	Design for Six Sigma (DFSS) and Quality function deployment (QFD)	
Huang and Tang (2006a)	Setting optimum values of critical process parameters in melt spinning	Taguchi method, neural network, and genetic algorithm	
Huang and Tang (2006b)	Resolving multiple parameter values in melt spinning processes	Taguchi method, Neural network and genetic algorithm	
Jee and Kang (2000)	Ranking and selecting the optimal material for a flywheel	Entropy method	
Kahraman, Buyukozkan, and Ates (2007b)	Identifying non-dominated new product candidates and selecting the best new product idea	Hierarchical fuzzy TOPSIS and fuzzy heuristic multi-attribute utility function	•
Kahraman, Cevik, Ates, and Gulbay (2007c)	Evaluating industrial robotic systems	Hierarchical fuzzy TOPSIS	
Kalantari, Rabbani, and Ebadian (2011)	Determining customers' prioritization for order acceptance/rejection in a hybrid make-to-Stock/make-to-Order production environment	Mixed-integer mathematical programming, and Fuzzy TOPSIS	
Kim, Lee, Cho, and Kim (2011)	Modeling consumer product adoption processes in a competitive automobile market	Agent-based model and fuzzy TOPSIS	
Koulouriotis and Ketipi (2011)	Evaluating alternative robots to perform a material handling task	Fuzzy digraph method and fuzzy TOPSIS	
Kumar and Agrawal (2009)	Selecting the best available electroplating process for ornamental purposes	Graphical methods	
Kwong and Tam (2002)	Selecting the best concurrent solution design for low power transformers	Case-based reasoning	
Li et al. (2009)	Assessing three command and control systems	Fractional programming and intuitionistic fuzzy	•
Liao (2003)	Improving the quality of the injection molding or submerged arc welding processes	Taguchi method	
Lin et al. (2008c)	Performing competitive benchmarking to identify the most competitive design alternative for further detailed design	AHP	
Lu, Yang, and Wang (2011)	Identifying the most robust production control strategy to identify an optimal scenario from alternative lean pull system designs	Value stream mapping (VSM), Taguchi technique and simulation	
Majumdar, Sarkar, and Majumdar (2005)	Ranking cotton fibers based on quality values	AHP	
Majumdar, Kaplan, and Göktepe (2010)	Selecting a navel rotor spinning machinebased on quality parameters	AHP	
Malekly, Mousavi, and Hashemi (2010)	Evaluating conceptual bridge superstructure designs	Fuzzy QFD and fuzzy TOPSIS	
Maniya and Bhatt (2010)	Selecting a proper material based on the design engineers' requirements	Graph theory and matrix approach and preference selection index method	
Milani, Shanian, Madoliat, and Nemes (2005)	Gear material selection for power transmission	Entropy method	

Lozano-Minguez, Kolios, and Brennan (2011)	Selecting the most suitable support structures' options for offshore wind turbines	–	
Moghassem (2010)	Selecting the most suitable machine parts and settings according to the desired end product specifications	–	
Monjezi, Dehghani, Singh, Sayadi, and Gholinejad (2010)	Selecting the most appropriate blasting pattern	–	
Ölçer (2008)	Ship design and shipping problem: to rank the set of Pareto optimal solutions from best to worst	Multi-objective combinatorial optimization and genetic algorithm	
Önüt, Kara, and Efendigil (2008)	Selecting vertical CNC machining centers for a manufacturing company	Fuzzy AHP and fuzzy TOPSIS	
Prabhakaran, Babu, and Agrawal (2006)	Selecting subsystems for a composite product development	Graphical methods	
PhaneendraKiran et al. (2011)	Selecting an optimal mechatronic system		
Rao and Davim (2008)	Evaluating and ranking materials for a given engineering design	AHP	
Rao (2008)	Ranking flexible manufacturing systems for the given industrial application	AHP	
Rathod and Kanzaria (2011)	Evaluating the best choice of phase change material used in solar domestic hot water systems	Fuzzy TOPSIS and AHP	
Rostamzadeh and Sofian (2011)	Prioritizing effective 7Ms (Management, Manpower, Marketing, Method, Machine, Material, and Money) to improve production systems performance	Fuzzy AHP and fuzzy TOPSIS	
Shih (2008)	Robot selection problem	Incremental benefit–cost ratio	•
Su, Chen, and Lu (2010)	Obtaining the optimized manufacturing parameter combination for a multi response process optimization	Taguchi Method	
Thakker, Jarvis, Buggy, and Sahed (2008)	Optimal selection of wave energy extraction turbine blade material	Value engineering study	
Vahdani, Mousavi, and Tavakkoli-Moghaddam (2011a)	The robot selection problem for material handling and rapid prototyping process selection problem	Modified TOSIS with fuzzy approach	•
Rao (2006)	Evaluating and ranking work materials for a given machining operation	AHP	
Wang and Chang (2007)	Evaluating initial propeller-driven training aircraft	Fuzzy TOPSIS	
Wang (2009)	Selecting the most suitable agile manufacturing system	2-Tuple fuzzy linguistic approach	
Yang, Chen, and Hung (2007)	Operator allocation decisions problem for a production line	Fuzzy based method and AHP	
Yang and Chou (2005)	Finding the surrogate objective function for multiple responses in a integrated-circuit packaging company	Taguchi method and simulation optimization	
Yang and Hung (2007)	Layout design problem for an IC packaging company.	Fuzzy approach	
Yousefi and Hadi-Vencheh (2010)	Evaluating improvement fields of an Iranian automobile manufacturing industry	AHP and DEAFuzzy TOPSIS and Spearman's rank correlation coefficient	•
Yurdakul and IC (2009)	Selecting the appropriate machine tools for a manufacturing company	Fuzzy TOPSIS and Spearman's rank correlation coefficient	
Zaerpour, Rabbani, Gharehgozli, and Tavakkoli-Moghaddam (2009)	Choosing the proper strategy for producing products in a food processing	Fuzzy AHP, nominal group technique and Spearman's rank correlation coefficient	•
Zandi and Tavana (2011a)	Calculating fuzzy risk values with each intelligent transportation systems architecture	Fuzzy TOPSIS, fuzzy real option analysis, and group multi-objective decision making	•
Zhang, Gao, Shao, Wen, and Zhi (2010)	Performance evaluation in a vehicle design system	Particle swarm optimization and fuzzy approach	•
Zeydan and Çolpan (2009)	Measuring the performance of the 2nd air supply and maintenance center command manufacturing/ maintenance job shops	Fuzzy TOPSIS and DEA	

Table 5
Applied papers in "Business and Marketing Management".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Amiri et al. (2009)	Ranking competing firms by their overall performance	Fuzzy approach, linear assignment method, adaptive AHP approach, genetic algorithm, and TOPSIS with interval data	•
Aydogan (2011)	Evaluating performance indicators in four Turkish aviation companies	AHP and fuzzy TOPSIS	
Benitez, Martin, and Roman (2007)	Quality performance evaluation of hotel services	Fuzzy approach	
Chang, Lin, Lin, and Chiang (2010)	Evaluation of the performance of 82 Taiwanese mutual funds for consecutive 34 months	TOPSIS with different distance approaches	
Deng, Yeh, and Willis (2000)	Ranking the relative performance of competing companies in the textile industry	Entropy measure and modified TOPSIS	
Dia and Zéghal (2008)	Evaluating corporations based on the risk factors disclosed in annual reports	Fuzzy approach and regression analysis	
Ertugrul and Karakasoglu (2009)	Evaluating the performance of 15 Turkish cement firms based on financial ratios	Fuzzy AHP	
Feng and Wang (2000)	Performance evaluation problem for airlines with financial ratios	Grey relation analysis	
Garcia, Guijarro, and Moya (2010)	Performance evaluation of alternate companies	Goal Programming and Montecarlo simulation	
Huang and Peng (2011)	Analyzing the tourism destination competitiveness of nine Asian countries	Item response theory and fuzzy Rasch model	
Isiklar and Büyüközkan (2007)	Evaluating mobile phone options according to users' preferences orders	AHP	
Jahanshahloo, Lotfi, and Izadikhah (2006)	Comparing 15 bank branches based on financial ratios	TOPSIS with interval data	
Kabassi and Virvou (2006)	Intelligent user interface problem in the software life-cycle framework	SAW, MAUT, and DEA	
KarimiAzari, Mousavi, Mousavi, and Hosseini (2011)	Selecting a suitable risk assessment model in construction industry	Fuzzy TOPSIS and nominal group technique	•
Khademi-Zare, Zarei, Sadeghieh, and Saleh Owlia (2010)	Ranking customer attributes in QFD	Fuzzy QFD, Fuzzy TOPSIS, and AHP	
Li (2010)	Selecting an investment company based on risk, growth and environment impact analyses	Interval-valued intuitionistic fuzzy approach	
Li et al. (2011b)	Forecasting business failure in China with three data representations	Case-based reasoning	
Lin, Hsieh, and Tzeng (2010)	Selecting the most appropriate commercial vehicle telematics systems for consumers	DEMATEL and ANP	
Peng et al. (2011)	Ranking selected classification algorithms for financial risk prediction	PROMETHEE and VIKOR	
Secme et al. (2009)	Evaluating five commercial banks using several financial and non-financial indicators	Fuzzy AHP	
Shyur (2006)	Ranking commercial-off-the-shelf products by their overall performance in an electronic company	ANP and modified TOPSIS	
Sun (2010)	Evaluating different notebook computer ODM companies based on performance criteria	Fuzzy AHP and fuzzy TOPSIS	
Sun and Lin (2009)	Evaluating the competitive advantages of shopping websites	Fuzzy TOPSIS	
Tan (2011)	Selecting the best investment option	Extended TOPSIS with fuzzy approach and Choquet integral-based Hamming distance	•
Tsaur, Chang, and Yen (2002)	Evaluatingairline service quality	Fuzzy TOPSIS and AHP	
Vahdani, Hadipour, and Tavakkoli-Moghaddam (2010)	Assessing the performance of property responsibility insurance companies	Fuzzy ANP fuzzy TOPSIS, and fuzzy VIKOR (all with Interval-valued fuzzy approach)	
Wang and Lee (2007)	Evaluating airport operation performance with group decision-making	Fuzzy TOPSIS	•
Wu, Lin, and Lin (2009)	Selecting the preferable bancassurance alliance to solve the finance alliance problem	AHP	•
Wu, Lin, and Lee (2010)	Determining the most appropriate marketing strategy for private hotel managers	ANP	
Ye (2010)	Partner selection in forming a new virtual enterprise	Interval-valued intuitionistic fuzzy TOPSIS	•
Yu, Guo, Guo, and Huang (2011)	Ranking e-commerce websites in an e-alliance	Fuzzy TOPSIS and AHP	
Zandi and Tavana (2011b)	Selecting the best agile e-CRM framework according to financial and customer-oriented evaluations	Fuzzy QFD	•
Zhang, Gu, Gu, and Zhang (2011)	Evaluating the tourism destination competitiveness of the Yangtze river delta	Entropy method	

Table 6
Applied papers in "Health, Safety and Environment Management".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Aiello, Enea, Galante, and La Scalia (2009)	Selecting the most suitable extinguisher ozone-depleting substance	Fuzzy TOPSIS and AHP	
Berger (2006)	Generating depictions of the agricultural landscape for use in alternative future scenario modeling	–	
Chen, Blong, and Jacobson (2001)	Determining priority areas for a bushfire hazard reduction burning	Compromise programming and weighted linear combination	
Cheng, Chan, and Huang (2003)	Selecting landfill locations in the solid waste management problem	Inexact mixed integer linear programming, simple weighted addition, weighted product, co-operative game theory, and complementary ELECTRE	
Ekmekçioglu, Kaya, and Kahraman (2010)	Selecting appropriate disposal methods and sites for municipal solid waste	Fuzzy TOPSIS and fuzzy AHP	
Grassi, Gamberini, Mora, and Rimini (2009)	Evaluating risk involved in hazardous activities of the production process of a well-known Italian sausage	Fuzzy TOPSIS	
Gumus (2009)	Selecting the right and most appropriate hazardous waste transportation firm	Fuzzy AHP and Delphi method	•
Han, Jia, and Tan (2003)	Selecting the best compromise solution for process environmental performance assessment	Multi-objective optimization, NSGA-II and AHP	
Huang, Zhang, Liu, and Sutherland (2011)	Environmentally conscious materials selection problem	Uncertainty analysis	
Kabak and Ruan (2010)	Nuclear safeguard evaluation for using nuclear programs for nuclear weapons purposes	SAW, Non-compensatory method, and fuzzy approach	
Krohling and Campanharo (2011)	Selecting the best alternatives to manage oil spill accidents in the sea in Brazil	Fuzzy TOPSIS	•
Li, Zhang, Zhang, and Suzuki (2009b)	Identifying the set of optimal parameters to design and optimize chemical processes based on green chemical principles	Multi-objective mixed integer non-linear mathematical model and NSGA-II	
Liu, Frazier, Kumar, Macgregor, and Blake (2006)	Assessing wetland conditions in the Clarence River Catchment	–	
Olcer and Majumder (2006)	Selecting the set of counter-flooding tanks to achieve an optimal response to a flooding accident	–	
Onut and Soner (2008)	Solid waste transshipment site selection problem	Fuzzy AHP and fuzzy TOPSIS	
Rao and Baral (2011)	Evaluating available waste combinations and selecting the best waste combination	–	
Sadeghzadeh and Salehi (2011)	Ranking development alternatives based on eight technologies of accumulated fuel cells	–	
Shi, Xu, and Li (2009)	Evaluating and prioritizing the ecological revetment projects	Delphi-AHP method and fuzzy TOPSIS	
Simonovic and Verma (2008)	Waste water treatment planning problem	Fuzzy Pareto optimal solution set	
Sivapirakasam et al. (2011)	Selecting process parameters to achieve green electrical discharge machining	Taguchi method and fuzzy TOPSIS	
Soltanmohammadi, Osanloo, and Aghajani Bazzazi (2010)	Determining a preference order of post-mining land uses	AHP	•
Tzeng, Lin, and Opricovic (2005)	Evaluating buses with alternative fuels for public transportation to improve environmental quality	AHP and VIKOR	•
Vahdani, Zandieh, and Tavakkoli-Moghaddam (2011b)	Determining appropriate fuel buses	Fuzzy TOPSIS	•
Wang, Fan, and Wang (2010)	Ratingcandidate aero engines for the aero engine health assessment problem	Fuzzy AHP and fuzzy preference programming	
Wang and Elhag (2006)	Optimal scheme of bridge structure maintenance problem	Fuzzy TOPSIS and nonlinear programming	
Yue (2011a)	Assessing air quality at the Asian Olympic Games in Guangzhou	Extended TOPSIS with interval numbers	•
Zavadskas and Antucheviciene (2006)	Ranking sustainable revitalization alternatives of derelict rural buildings in Lithuania	Fuzzy TOPSIS	
Zavadskas and Antuchevičiene (2004)	Determining redevelopment priorities of buildings (sustainable development approach)	VIKOR	

specific issues, including waste management problems, hazardous reduction, ecological economics, clean and green environment, and land-use planning.

Krohling & Campanharo, 2011 presented a fuzzy TOPSIS for group decision-making to evaluate ten preventive measures in accidents pertaining to oil spills at sea. Sadeghzadeh and Salehi (2011) employed TOPSIS to determine solutions to develop strategic technologies for fuel cells in the automotive industry. Sivapirakasam, Mathew, and Surianarayanan (2011) proposed a combination of Taguchi method and fuzzy TOPSIS to solve the multi-response parameter optimization problem in green electrical discharge machining. Yue (2011) developed a method to determine decision makers' weights under a group decision environment described in an air quality assessment in Guangzhou during 16th Asian Olympic. Table 6 lists TOPSIS publications in *Health, Safety and Environment Management*.

Table 7
Applied papers in "Human Resources Management".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Boran et al. (2011)	Personnel selection in a manufacturing company for a sales manager position	Intuitionistic fuzzy TOPSIS	•
Chen (2000)	Selecting the most suitable candidate for hiring a system analysis engineer	Extended TOPSIS with fuzzy	•
Chen and Tzeng (2004)	Expatriate selection process for staffing and maintaining foreign operations with competent employees	Fuzzy AHP and grey relation model	
Chen and Lee (2010)	Selecting the most suitable candidate for hiring a system analysis engineer	Interval type-2 fuzzy TOPSIS	•
Chen, Li, and Liu (2011)	Evaluating qualified candidates for recruiting an on-site business manager	Ordered weighted averaging	•
Chu, Shyu, Tzeng, and Khosla (2007)	Obtaining anticipated achievements of knowledge communities by conducting a group-decision comparison	SAW and VIKOR	•
Dagdeviren (2010)	Personnel selection problem in manufacturing systems	ANP and modified TOPSIS	
Dursun and Karsak (2010)	Personnel selection problem	2-Tuple fuzzy linguistic representation modeland ordered weighted averaging operator	
Fan and Feng (2009)	Dean selection in the business school of a university in China	Fuzzy TOPSIS	•
Fan and Liu (2010)	Selecting the most suitable candidate for hiring a system analysis engineer	Extended TOPSIS with fuzzy	•
Kelemenis and Askounis (2010)	Selecting a top management team member in an IT department.	Fuzzy TOPSIS	•
Kelemenis et al. (2011)	Selecting a middle-level manager in a large Greek IT firm	Fuzzy TOPSIS	•
Li (2007a)	Selecting the most suitable candidate for hiring a system analysis engineer	Fuzzy TOPSIS and compromise planning	
Li (2007b)	Selecting the most suitable candidate for hiring a system analysis engineer	Compromise ratio method and fuzzy TOPSIS	•
Mahdavi, Mahdavi-Amiri, Heidarzade, and Nourifar (2008)	Selecting the most suitable candidate for hiring a system analysis engineer	Fuzzy TOPSIS	
Milani, Shanian, and El-Lahham (2008)	Selecting a proper strategy for an information technology project based on performance and human behavioral resistance criteria	Entropy method	
Min and Peng (in press)	Evaluating the current emotional intelligence (EI) levels and prioritizing EI training needs for tour leaders	Entropy method	
Saremi, Mousavi, and Sanayei (2009)	Selecting the most suitable external TQM consultant	Nominal group technique and Fuzzy TOPSIS	•
Shih, Shyur, and Lee (2007)	Recruiting an on-line manager in a local chemical company	Extended TOPSIS	•
Tavana and Hatami-Marbini (2011)	Prioritizing five mission simulators for the human exploration of Mars	Adjusted and modified TOPSIS, AHP and entropy method	•
Wang, Liu, and Zhang (2005)	Evaluating candidates to hire an engineer a high technology company	Fuzzy TOPSIS	
Wang and Elhag (2006)	Selecting a system analysis engineer	Fuzzy TOPSIS and nonlinear programming	
Yue (2011b)	Recruiting an on-line manager for a local chemical company	Extended TOPSIS	•

4.5. Human Resources Management

Most papers in *Human Resources Management* are related to evaluating and employing candidates for a professional job. Kelemenis, Ergazakis, and Askounis (2011) proposed a multi-criteria approach based on fuzzy TOPSIS group decision-making to select a middle-level manager in a large IT Greek firm. Boran, Genç, Kurt, and Akay (2011) employed an intuitionistic fuzzy TOPSIS approach to select appropriate personnel from candidates when selecting a sales manager at a manufacturing company. Table 7summarizes papers in *Human Resources Management*.

4.6. Energy Management

Most TOPSIS attempts in *Energy Management* have concentrated on evaluating and selecting energy generation methods and technologies as well as energy system performance. Kaya and Kahraman (2011) proposed a modified fuzzy TOPSIS methodology to select the best energy technology according to technical, economic, environmental and social criteria.Yan, Ling, and Dequn (2011)applied a new GRD–TOPSIS method to investigatetheperformance of coal enterprise energy conservation and pollutant emission reduction.Table 8 summarizes papers in *Energy Management*.

4.7. Chemical Engineering

With only 2.6 percent of the total papers, *Chemical Engineering* contains a small portion of TOPSIS publications. Papers on this topic are often concerned with evaluating and optimally selecting chemical ingredients in experimental environments.

Rao and Baral (2011) described a methodology for the evaluation, comparison, ranking and optimum selection of feed stock for anaerobic digestion using TOPSIS and graphical methods. Sun, Liang, Shan, Viernstein, and Unger (2011) used TOPSIS to evaluate the total natural antioxidants and antioxidant activities across different regions. They concluded that fruits in arid harsh and high-altitude regions can accumulate higher levels of natural antioxidants and display stronger antioxidant activities. Table 9 presents a list of TOPSIS publications in *Chemical Engineering*.

4.8. Water Resources Management

The TOPSIS papers in *Water Resources Management* have been devoted to evaluating and selecting alternative water networks and water management scenarios. Dai et al.(2010) presented a combined gray relation analysis and TOPSIS approach for the integrated water resource security evaluation in Beijing city. Afshar,

Table 8
Applied papers in "Energy Management".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Aalami, Parsa Moghaddam, and Yousefi (2010)	Selecting demand response programs using a power market regulator	AHP and entropy method	
Amiri (2010)	Assessing alternative investment projects for oilfield development	Fuzzy TOPSISand AHP	
Azzam and Mousa (2010)	The reactive power compensation problem	Genetic algorithm and multi-objective optimization	
Boran, Boran, and Menlik (2012)	Evaluating renewable energy technologies for electricity generation	Fuzzy TOPSIS	
Chamodrakas and Martakos (2011)	Energy-efficient network selection in heterogeneous wireless networks	Fuzzy TOPSIS and utility functions	
Dhanalakshmi, Kannan, Mahadevan, and Baskar (2011)	Economic and emission dispatch problem	Multi-objective optimization and NSGA-II	
Doukas, Karakosta, and Psarras (2010)	Assessing energy policy objectives	Fuzzy TOPSIS	
Garg, Agrawal, and Gupta (2007)	Evaluating and selecting an optimum thermal power plant	–	
Huang and Huang (2003)	Economic and emission dispatch problem	Abdicative reasoning network,bi-objective optimization, and artificial neural networks	
Jeyadevi, Baskar, Babulal, and Iruthayarajan (2011)	Optimal reactive power dispatch problem	Multi-objective optimization and NSGA-II	
Kaya and Kahraman (2011)	Selecting the best energy technology alternative	Fuzzy AHP and fuzzy TOPSIS	
Opricovic and Tzeng (2007)	Evaluating alternative hydropower systems on the Drina river	VIKOR, PROMETHEE, and ELECTRE	
Thomaidis, Konidari, and Mavrakis (2008)	Ranking energy community countries in Europe	–	
Yan et al. (2011)	Performance evaluation system of coal enterprises based on energy conservation and pollutant emission reduction	Gray correlation degree	

Table 9
Applied papers in "Chemical Engineering".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Ramezani, Bashiri, and Atkinson (2011)	Ranking non-dominated solutions or improving tire tread performance by controlling three chemical ingredients	Multi-response optimization and goal programming	
Rao and Baral (2011)	Optimum selection of feed stock for anaerobic digestion	Graphical methods	
Shanian and Savadogo (2006)	Material selection problem of metallic bipolar plates for polymer electrolyte fuel cells	Entropy method	
Sun et al. (2011)	Evaluating total natural antioxidants and antioxidant activities	–	
Tong, Kwong, and Ip (2003)	Determining the optimal process conditions for transfer molding of plastic dual in-line packages	Taguchi method	
Tong, Wang, Chen, and Chen (2004)	Deriving the overall performance index for multiple responses in the biological reduction of an ethyl acetoacetate process	PCA, Taguchi method, and signal to noise ratio	
Tong, Wang, and Chen (2005)	Deriving the overall performance index for multiple responses in the chemical-mechanical polishing of copper (Cu-CMP) thin films	PCA, Taguchi method, and signal to noise ratio	

Table 10
Applied papers in "Water Resources Management".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Afshar et al. (2011)	Ranking projects in the Karun river basin	Fuzzy TOPSIS	
Boix, Montastruc, Pibouleau, Azzaro-Pantel, and Domenech (2011)	Evaluating multi contaminant industrial water networks	Multi-objective optimization/ Mixed-integer nonlinear programming	
Cheng, Zhao, Chau, and Wu (2006)	Evaluating real-time flood forecasting and flood simulation	Genetic algorithm, and multi-objective optimization	
Dai et al. (2010)	Water resource security evaluation	Gray relation analysis and factor analysis	
Gomez-Lopez, Bayo, Garcia-Cascales, and Angosto (2009)	Selecting the best disinfection technique for treated wastewater	–	•
Srdjevic, Medeiros, and Faria (2004)	Ranking water management scenarios	Entropy method	
Wang et al. (2011b)	Determining single quality attribute importance weights and a comprehensive quality index for better irrigation scheduling	AHP	
Zarghaami, Ardakanian, and Memariani (2007)	Ranking water transfers to the Zayanderud basin in Iran	–	

Table 11
List of papers on "other topics".

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Albayrak and Erensal (2009)	Technological knowledge management tool selection problem for firms involved in foreign direct investment activities	Fuzzy linear programming and linear programming technique for multidimensional analysis of preference (LINMAP)	•
Anisseh, Piri, Shahraki, and Aghamohamadi (in press)	Evaluating university faculty candidates for tenure and promotion	Fuzzy extension of TOPSIS	•
Caterino (2009)	Selecting a strategy to seismically upgrade an existing building	VIKOR	
Hsieh, Chin, and Wu (2006)	The performance evaluation system for an e-library in universities in Taiwan	AHP and Delphi method	
Ignatius, Motlagh, Sepehri, Behzadian, and Mostafa (2010)	Training providers evaluation	AHP, fuzzy TOPSIS, fuzzy PROMETHEE, and SERVQUAL	•
Kao (2010)	Ranking cars based on their specifications	Compromise programming and DEA	
Kao, Wang, Dong, and Ku (2006)	Ranking feasible schedules for project portfolio scheduling problem	Petri nets and Activity-based costing (ABC)	
La Scalia, Aiello, Rastellini, Micale, and Cicalese (2011)	Evaluating pancreatic islet transplant - related information.	Fuzzy TOPSIS	
Li, Huang, and Chen (2010)	The new ground-air missile weapon system selection problem	Heterogeneous multi-attribute group decision making and fuzzy TOPSIS	•
Liu, Zhang, Zhang, and Liu (2010)	Standardizing vulnerability factor values derived by the security analysis model for communication networks in power control systems	AHP and attack graph	
Olson (2004)	Evaluating the performance of a baseball team based on a number of criteria	SMART and Centroid method	
Park, Park, Kwun, and Tan (2011)	Determining the best air-conditioning systems for installation in a library	Interval-valued intuitionistic fuzzy approach	•
Rahimi et al. (2007)	Evaluating patients' medical information in medical diagnostic systems	Modified TOPSIS with fuzzy approach	
Sadi-Nezhad and Khalili Damghani (2010)	Evaluating the performance of traffic police centers	Fuzzy TOPSIS	•
Sobczak and Berry (2007)	Ranking strategic preliminary requirements for management information systems	AHP, weighted sum model and Borda method	•
Wang and Lee (2009)	Selecting a new information system to improve work productivity for a computer center	Fuzzy TOPSIS and entropy method	
Yeh (2002)	Scholarship student selection problem in an Australian university	Entropy method, SAW, simple summation, and weighted product method	
Yeh (2003)	Scholarship student selection problem in an Australian university	Total sum method, SAW, and weighted product method	
Yu, Shen, Pan, and Wu (2009)	Indicator selection in agricultural scholarly journal evaluation	Panel data analysis	
Yurdakul and Ic (2005)	Obtaining a ranking score to develop a performance measurement model for manufacturing companies	AHP	

Table 12
Distribution of techniques combined or compared with TOPSIS.

Techniques combined or compared	*N*	%	Techniques combined or compared	*N*	%
Fuzzy set approach	139	52.2	Grey theory/analysis	7	2.6
Group decision-making approach	76	28.6	Delphi method	6	2.3
AHP	62	23.3	ELECTRE	5	1.9
Entropy method	20	7.5	Neural network	5	1.9
Multi-objective optimization	15	5.6	Compromise planning	4	1.5
Other mathematical programming	14	5.3	DEMATEL	4	1.5
Genetic algorithms	14	5.3	QFD	4	1.5
ANP	13	4.9	Principal component analysis (PCA)	4	1.5
Taguchi method	12	4.5	Nominal group technique	3	1.1
DEA	8	3	Signal-to-noise ratio	3	1.1
Simulation methods	8	3	PROMETHEE	3	0.8
VIKOR	7	2.6	MAUT	2	0.8
SAW	7	2.6	SERVQUAL	2	0.8

Mariño, Saadatpour, and Afshar (2011) employed a fuzzy TOPSIS based on a real water resource management problem to help a group of managers identify critical issues and select the best compromised alternatives. Table 10 summarizes publications in *Water Resources Management*.

4.9. Other topics

Twenty of the 269 TOPSIS applications surveyed are classified under "other topics". Each topic, which covers few publications, addresses decision problems in the medical, education, sport and

Table 13
Distribution by publication year.

Years	*N*	%
2000-2001	5	1.9
2002-2003	12	4.5
2004-2005	13	4.9
2006-2007	41	15.4
2008-2009	65	24.4
Since 2010	130	48.9
Total	266	100

social aspects. Albayrak and Erensal (2009)combined TOPSIS and the linear programming technique for multidimensional analysis of preference (LINMAP) to identify decision making problems in knowledge transfer. Rahimi, Gandy, and Mogharreban (2007) proposed a modified TOPSIS approach to implement a web-based medical diagnostic system. They utilized fuzzy logic to describe the patients' symptoms. Sadi-Nezhad and Khalili Damghani (2010) presented a TOPSIS approach based on the preference ratio method combined with an efficient fuzzy distance measurement for a fuzzy multiple criteria group decision-making problem. The proposed approach was efficiently applied to assess traffic police centers. Table 11 summarizes the TOPSIS publications under "other topics".

Table 14
Distribution by publication journal.

Journal name	N	%
Expert Systems with Applications	65	24.4
International Journal of Advanced Manufacturing Technology	17	6.4
Mathematical and Computer Modeling	13	4.9
Applied Mathematical Modeling	8	3
Applied Soft Computing	7	2.6
Journal of Intelligent Manufacturing	7	2.6
International Journal of Production Research	6	2.3
Computers & Industrial Engineering	5	1.9
International Journal of Production Economics	5	1.9
European Journal of Operational Research	5	1.9
Materials and Design	5	1.9
Computers & Operations Research	4	1.5
Journal of Materials Processing Technology	4	1.5
Tourism Management	4	1.5
Quality and Reliability Engineering International	3	1.1
Applied Mathematics and Computation	3	1.1
Electrical Power and Energy Systems	3	1.1
Engineering Applications of Artificial Intelligence	3	1.1
Information Sciences	3	1.1
Mathematics and Computers in Simulation	3	1.1
Arabian Journal of Geosciences	2	0.8
Automation in Construction	2	0.8
Computers in Industry	2	0.8
Computers and Mathematics with Applications	2	0.8
Electric Power Systems Research	2	0.8
Group Decision and Negotiation	2	0.8
International Journal of Intelligent Systems	2	0.8
Water Resources Management	2	0.8
Waste Management	2	0.8
Journal of the Textile Institute	2	0.8
Seventy-three other journals	73	27.5
Total	266	100

5. Other classification schemes

This section organizes a distribution of TOPSIS publications by the following attributes: (1) combined or compared with other methods, (2) publication year, (3) publication journal, and (4) authors' nationality.

5.1. Distribution by combined or compared with other methods

The recent trend of TOPSIS papers has shifted towards applying the combined TOPSIS rather than the stand-alone TOPSIS. These combinations have made the classical TOPSIS method more representative and workable when handling practical and theoretical problems. Tools commonly used to extend the TOPSIS method include the fuzzy set approach, group decision-making approach, AHP, ANP, entropy method, mathematical programming, and genetic algorithm.

The fuzzy set approach seems to be the most commonly used method in TOPSIS. As the classical TOPSIS method assumes that alternative ratings and criteria weights are crisp numbers, more than half of the TOPSIS publications (52.2%) utilized linguistic variables and fuzzy numbers to handle problems with imprecise information. Many TOPSIS publications (76 papers) were related to group decision making issues, as groups of managers or experts make most crucial and significant decisions in organizations. Decisions made collectively tend to be more effective than decisions made by an individual. Many authors have also suggested using the AHP method in combination with TOPSIS to analyze the structure of complicated decision-making problems and determine criteria weights. When the criteria are independent, the AHP method is a powerful technique. Several studies (13 papers) employed ANP, the more general form of the AHP, while considering complex interrelationships among decision levels and criteria.

A hybrid integration of entropy method with TOPSIS to determine criteria weights has achieved satisfactory results in many TOPSIS publications. Moreover, the TOPSIS approach was combined with multi-objective mathematical programming to identify the optimal compromise solution from the optimal solution set of Pareto distribution.

Other publications compared TOPSIS performance to other MCDA/MCDM methods, including AHP, ELECTRE PROMETHEE, VIKOR, DEMATEL and SAW. The purpose of the comparative papers has been to define the ranking differences between the TOPSIS methods and other MCDA/MCDM methods. Table 12 shows the number and percentage distribution of techniques combined or compared with TOPSIS.

5.2. Distribution by publication year

Table 13 gives valuable information regarding the frequency distribution by publication year. Since 2010, there was a considerable growth in the number of papers published on TOPSIS. Almost half (48.9%) of the total number of papers were published since 2010.

5.3. Distribution by journals

Table 14 shows the number and percentage distribution of scholarly papers by journal publication. Seventy-three of the103 journals have just one paper on TOPSIS. According to Table 14, *Expert Systems With Applications* is the most popular avenue, as it has published 65 papers (24.4%) of the total TOPSIS papers. The *International Journal of Advanced Manufacturing Technology* and the *Mathematical and Computer Modeling*, which respectively published 17 and 13 papers on TOPSIS, are two other popular journals.

5.4. Distributions by authors' nationality

Table 15 shows that 31 countries and nationalities participated in TOPSIS publications. The geographical distribution of the TOPSIS papers in both numbers and percentages shows that most productive authors are from Taiwan, China, Iran, Turkey, and India. The value $N = 305$ in Table 15 stands for the total number of authors from a particular nationality or country that have published paper(s) in TOPSIS. It also shows that 228 out of 266 published papers

Table 15
Distribution by authors' nationality.

Country	*N*	%
Taiwan	63	20.7
China	44	14.4
Iran	40	13.1
Turkey	38	12.5
India	24	7.87
USA	14	4.60
Canada	13	4.26
Greece	10	3.28
UK	7	2.29
Italy	7	2.29
Australia	6	1.96
Spain	5	1.64
Korea	4	1.31
Malaysia	4	1.31
Hong Kong	3	0.98
Belgium	3	0.98
Serbia & Montenegro	3	0.98
Brazil	2	0.66
France	2	0.66
Lithuania	2	0.66
Egypt	1	0.33
Denmark	1	0.33
Singapore	1	0.33
Sweden	1	0.33
Ireland	1	0.33
Jordan	1	0.33
Poland	1	0.33
Portugal	1	0.33
Japan	1	0.33
Austria	1	0.33
Luxemburg	1	0.33
Total	305	100

have authors of the same nationality, 37 papers have authors from two countries, and one paper has authors from three countries. Most TOPSIS publications come from Taiwanese authors (i.e.,63 papers or 20.9%). Chinese, Iranian, and Turkish researchers contributed 44, 40, and 38 papers, respectively. Many papers are from the Asian continent ($N = 185$), compared to Europe ($N = 84$), North and South America ($N = 29$), Australia ($N = 6$) and Africa (N = 1).

6. Concluding remarks

This paper performs a state-of-the-art literature review to classify and interpret the ongoing and emerging issues that apply the TOPSIS methodology. The review categorized 266 scholarly papers from 103 journals since the year 2000 into nine application areas. They are further classified by publication year, publication journal, authors' nationality, and other methods combined or compared with TOPSIS. Overall, we find that though the TOPSIS methodology has been successfully applied to a wide range of application areas and industrial sectors with varying terms and subjects, it requires broader emphasis on interdisciplinary and social decision problems.

Future research on TOPSIS anatomy can be extended in several directions. We can create a window of opportunity to develop the TOPSIS model, particularly in relation to the distance from the positive and negative solutions and the relative closeness to the ideal solution. Although several techniques have been combined or integrated with the classical TOPSIS, many other techniques have not been investigated. These techniques make the classical TOPSIS more representative and workable in handling practical and theoretical problems. Another future research direction, which could be an area of theoretical study, is investigating the marked similarities and differences between TOPSIS and other MCDA/MCDM methods. The insights identified in this review will help channel research efforts and fulfill researchers' and practitioners' needs for easy references to TOPSIS publications.

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