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BI-LEVEL, MULTI –LEVEL MULTIPLE CRITERIA DECISION MAKING AND TOPSIS APPROACH- THEORY, APPLICATIONS AND SOFTWARE: A LITERATURE REVIEW (2005-2015)

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ABSTRACT

This paper presents a literature review on the theory, applications and software of Bi-level, Multi –Level Multiple Criteria Decision Making and TOPSIS (Technique for Order Preference by Similarity Ideal Solution) Approach.

Keywords: Bi-level programming, Multi-level programming, Multiple Criteria Decision Making, TOPSIS.

1. INTRODUCTION

This paper consists of two sections. Section (2) presents a survey on the theory and applications of Bi-Level Multiple Criteria Decision Making (BL-MCDM) problems, Multi-level Multiple Criteria Decision Making (ML-MCDM) problems and TOPSIS approach. Section (3) contains a review on the software of problems in section (2).

2. THEORY AND APPLICATIONS

This section consists of three subsections, subsection (2-1) presents a survey on the theory and applications of Bi-Level Multiple Criteria Decision Making (BL-MCDM) problems, subsection (2-2) gives a survey on the theory and applications of Multi-level Multiple Criteria Decision Making (ML-MCDM) problems and subsection (2-3) introduces a survey on the theory and applications of TOPSIS approach.

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2-1. Bi-Level Multiple Criteria Decision Making :

Bi-level programming, a tool for modeling decentralized decisions, consists of the objective(s) of the leader at its first level and that is of the follower at the second level. Three level programming results when second level is itself a bi-level programming. By extending this idea it is possible to define multi-level programs with any number of levels, [64].

Arroyo, J. M., & Galiana, F. D.[13], generalize the "terrorist threat problem" by formulating it as a bi-level programming problem. Specifically, the bi-level model allows one to define different objective functions for the terrorist and the system operators as well as permitting the imposition of constraints on the outer optimization that are functions of both the inner and outer variables. This degree of flexibility is not possible through existing max-min models.

Reinbolt, J. A. et al. [62], present a general two-level optimization procedure for tuning any multi-joint kinematic model to a patient's experimental movement data. An outer level optimization modifies the model's parameters (joint position and orientations) while repeated inner level optimizations modify the model's degrees of freedom given the current parameters, with the goal of minimizing errors between model and experimental marker trajectories.

Colson, B. et al. [22], consider the approximation of nonlinear bi level mathematical programs by solvable programs of the same type, i.e., bi level programs involving linear approximations of the upper-level objective and all constraint-defining functions, as well as a quadratic approximation of the lower-level objective.

Zahara, E. et al. [95], proved that, the Otsu’s method is an efficient method in image segmentation for bi-level thresholding. However, this method is computationally intensive when extended to multi-level thresholding. In this paper, they present a hybrid optimization scheme for multiple thresholding by the criteria of (1) Otsu’s minimum within-group variance and (2) Gaussian function fitting.

Abo-Sinna M. A. and Baky I.A. [4], introduce interactive balance space approach for solving bi level multi-objective programming problems.

Lu, Jie, et al. [52], particularly propose related theories focusing on an uncooperative decision problem, as this model is the most basic one for bi-level multi-follower decision problems over the nine kinds of relationships. Moreover, this paper extends the Kuhn–Tucker approach for driving an optimal solution from the uncooperative decision model.

Zhang, G. and Lu, J. [96], propose a fuzzy bi-level decision making model for a general logistics planning problem and develops a fuzzy number based K^{th}-best approach to find an optimal solution for the proposed fuzzy bi-level decision problem .The proposed approach illustrates an optimal solution in logistics management, which meets maximally/minimally the objectives of both supplier and distributor . The proposed fuzzy bi-level decision approach can have a wide range of logistics management applications.

Zhang, G. et al. [97], address both fuzzy demands and multi-objective issues and propose a fuzzy multi-objective bi-level programming model. They develop an approximation branch-and-bound algorithm to solve multi-objective bi-level decision problems with fuzzy demands.

Colson, B. et al. [23], introduced an overview of bi-level optimization.

Faísca, N. P. et al. [30], propose a global optimization approach for the solution of various classes of bi level programming problems (BLPP) based on recently developed parametric programming algorithms. They first describe how they can recast and solve the inner (follower’s) problem of the bi-level formulation as a multi-parametric programming problem, with parameters being the (unknown) variables of the outer (leader’s) problem.

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Lan, K. M. et al. [46], proposed a combined neural network and tabu search hybrid algorithm for solving the bi-level programming problem. To illustrate the approach, two numerical examples are solved and the results are compared with those in the literature.

Scaparra, M. P., & Church, R. L. [68], present a bi-level formulation of the *r*-interdiction median problem with fortification (RIMF). RIMF identifies the most cost-effective way of allocating protective resources among the facilities of an existing but vulnerable system so that the impact of the most disruptive attack to *r* unprotected facilities is minimized. The model is based upon the classical *p*-median location model and assumes that the efficiency of the system is measured in terms of accessibility or service provision costs.

Sun, H. et al. [74], presented a bi-level programming model to seek the optimal location for logistics distribution centers. The upper-level model is to determine the optimal location by minimizing the planners' cost, and the lower gives an equilibrium demand distribution by minimizing the customers' cost. Based on the special form of constraints, a simple heuristic algorithm is proposed.

Aryanezhad, M. B., & Roghanian, E. A. [14], define multi-level programs with any number of levels. Supply chain planning problems are concerned with synchronizing and optimizing multiple activities involved in the enterprise, from the start of the process, such as procurement of the raw materials, through a series of process operations, to the end, such as distribution of the final product to customers. Enterprise-wide supply chain planning problems naturally exhibit a multi-level decision network structure.

Baky, I.A. [16], presents fuzzy goal programming (FGP) algorithm for solving decentralized bi-level multi-objective programming (DBL-MOP) problems with a single decision maker at the upper level and multiple decision makers at the lower level. A FGP algorithm for DBL-multi-objective linear programming (DBL-MOLP) problems is proposed.

Bianco, L. et al. [18], provide a linear bi-level programming formulation for hazmat transportation network design problem that takes into account both total risk minimization and risk equity. They transform the bi-level model into a single-level mixed integer linear program (MIP) by replacing the second level (follower) problem by its KKT conditions and by linearizing the complementary constraints, and then they solve the MIP problem with a commercial optimization solver.

Abo-Sinna M. A. and Baky I.A. [5], present fuzzy goal programming (FGP) algorithm for solving decentralized bi-level multi-objective programming (DBL-MOP) problems with a single decision maker at the upper level and multiple decision makers at the lower level. A FGP algorithm for DBL-multi-objective linear programming (DBL-MOLP) problems is proposed. This algorithm is extended to solve bi-level multi-objective linear fractional programming (DBL-MOLFP) problems.

Deb, K., & Sinha, A. [26], address certain intricate issues related to solving multi-objective bi-level programming problems. They present challenging test problems, and propose a viable and hybrid evolutionary-cum-local-search based algorithm as a solution methodology.

Kasemset, C., & Kachitvichyanukul, V. [43], describe the decisions involved in the implementation of TOC in a job-shop environment as a bi-level multi-objective mathematical model. On the first level, the decision is made by minimizing idle time on the bottleneck to generate the initial schedule. The second level decision is to improve additional performance measurements by applying the multi-objective technique, while maintaining the bottleneck sequence obtained from the first level decision.

Katagiri, H. et al. [44], consider two-level linear programming problems where each coefficient of the objective functions is expressed by a random fuzzy variable. A new decision making model is proposed in order to maximize both of possibility and probability with respect to the objective function value.

Pramanik, S., & Dey, P. P. [58], present fuzzy goal programming approach to quadratic bi-level programming problem. constructed the quadratic membership functions by determining individual best solutions of the quadratic objective functions subject to the system constraints. The quadratic membership functions are then transformed into equivalent linear membership functions by first order Taylor series approximation at the individual best solution point. Since the objectives of upper and lower level decision makers are potentially conflicting in nature, a possible relaxation of each level decisions are considered by providing preference bounds on the decision variables for avoiding decision deadlock. Then fuzzy goal programming approach is used for achieving highest degree of each of the membership goals by minimizing deviational variables

Sakawa, M. et al. [67], propose new two-level fuzzy random decision making models which maximize the probabilities that the degrees of possibility and necessity are greater than or equal to certain values. Through the proposed models, it is shown that the original two-level linear programming problems with fuzzy random variables can be transformed into deterministic two-level linear fractional programming problems.

Emam, O. E. [29] propose an interactive approach for solving bi-level integer multi-objective fractional programming problem.

Youness, E. A., Emam, O. et al [92], present an algorithm to solve a bi-level multi-objective fractional integer programming problem involving fuzzy numbers in the right-hand side of the constraints. The suggested algorithm combine the method of Taylor series together with the Kuhn Tucker conditions to solve fuzzy bi-level multi-objective fractional integer programming problem (FBLMOFIPP) then Gomory cuts are added till the integer solution is obtained.

Gang, Jun, et al. [31] focus on a stone industrial park location problem with a hierarchical structure consisting of a local government and several stone enterprises under a random environment. The problem is solved using a bi-level interactive method based on a satisfactory solution and Adaptive Chaotic Particle Swarm Optimization (ACPSO)

2-2. Multi –Level Multiple Criteria Decision Making :

Locatelli, M. [50], discuss the multilevel structure of global optimization problems. Such problems can often be seen at different levels, the number of which varies from problem to problem. At each level different objects are observed, but all levels display a similar structure.

Pramanik, S. & Roy, T. K. [59], propose a procedure for solving multilevel programming problems in a large hierarchical decentralized organization through linear fuzzy goal programming approach. The tolerance membership functions for the fuzzily described objectives of all levels as well as the control vectors of the higher level decision makers are defined by determining individual optimal solution of each of the level decision makers. Since the objectives are potentially conflicting in nature, a possible relaxation of the higher level decision is considered for avoiding decision deadlock.

Kumar, R. et al. [45], propose a generalized formulation for multilevel redundancy allocation problems that can handle redundancies for each unit in a hierarchical reliability system, with structures containing multiple layers of subsystems and components. Multilevel redundancy allocation is an especially powerful approach for improving the system reliability of such hierarchical configurations, and system optimization problems that take advantage of this approach are termed multilevel redundancy allocation optimization problems (MRAOP).

Russo, U. et al. [65], investigate the kinetics involved in the programming operation (i.e., transition from the high resistance to the low resistance state), which occurs by voltage-driven ion migration and electrochemical deposition, and results in CF formation and growth. The main kinetic parameters controlling the programming operation are extracted from our electrical data. Also, CF growth and corresponding resistance decrease is shown to be controllable with reasonable accuracy in pulse mode by employing a variable load resistance which can dynamically control the programming kinetics.

Yeh, W. C. [90], present a novel particle swarm optimization algorithm (PSO) called the two-stage discrete PSO (2DPSO) to solve MMRAP in series systems such that some subsystems or modules consist of different components in series.

Almeder, C. [12], presented a new approach combining an ant-based algorithm with an exact solver for (mixed-integer) linear programs to solve multi-level capacitated lot-sizing problems. A MAX–MIN ant system is developed to determine the principal production decisions, a LP/MIP solver is used to calculate the corresponding production quantities and inventory levels.

2-3. TOPSIS Approach:

Abo–Sinna, M. A. and Abou-El-Enien, T. H. M. [2], introduce an algorithm for solving large scale multiple objective decision making (LSMODM) problems by use of TOPSIS.

Abo–Sinna, M. A. and Abou-El-Enien, T. H. M. [3], extend TOPSIS for solving interactive large scale multiple Objective programming problems involving fuzzy parameters. An interactive fuzzy decision making algorithm for generating α-Pareto optimal solution through TOPSIS approach is provided where the decision maker (DM) is asked to specify the degree α and the relative importance of objectives.

Yurdakul, M. & Ic, Y. T.[94] developed a performance measurement model (PMM) for manufacturing companies using the AHP and TOPSIS approaches. The developed PMM measures a company's level of performance in critical dimensions and combines these performance scores to obtain a ranking score.

Shyur, H. J. [71], models the COTS (commercial off-the-shelf) evaluation problem as an MCDM problem and proposes a five-phase COTS selection model, combining the technique of ANP (analytic network process) and modified TOPSIS.

Jahanshahloo, G. R. et al. [40], extend the TOPSIS method for decision-making problems with interval data. By extension of TOPSIS method, an algorithm to determine the most preferable choice among all possible choices, when data is interval, is presented.

Jahanshahloo, G. R. et al. [41], extend the TOPSIS method for decision-making problems with fuzzy data. In this paper, the rating of each alternative and the weight of each criterion are expressed in triangular fuzzy numbers. The normalized fuzzy numbers is calculated by using the concept of α-cuts.

Wang, Y.M., and Elhag, T. M. [83], propose a fuzzy TOPSIS method based on alpha level sets and presents a nonlinear programming (NLP) solution procedure. The relationship between the fuzzy TOPSIS method and fuzzy weighted average (FWA) is also discussed; It is shown that the proposed fuzzy TOPSIS method performs better than the other fuzzy versions of the TOPSIS method.

Yong, D. [91], proposed a new TOPSIS approach for selecting plant location under linguistic environments, where the ratings of various alternative locations under various criteria, and the weights of various criteria are assessed in linguistic terms represented by fuzzy numbers.

Işıklar, G., & Büyüközkan, G.[37], propose a multi-criteria decision making (MCDM) approach to evaluate the mobile phone options in respect to the users' preferences order. Firstly, the most desirable features influencing the choice of a mobile phone are identified. the experiences of the telecommunication sector experts and the studies in the literature. Two MCDM methods are then used in the evaluation procedure. Analytic Hierarchy Process (AHP) is applied to determine the relative weights of evaluation criteria and the extension of the TOPSIS is applied to rank the mobile phone alternatives.

Wang, T. C., & Chang, T. H. [81], develop an evaluation approach based on the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), to help the Air Force Academy in Taiwan choose optimal initial training aircraft in a fuzzy environment where the vagueness and subjectivity are handled with linguistic terms parameterized by triangular fuzzy numbers. This study applies the fuzzy multi-criteria decision-making (MCDM) method to determine the importance weights of evaluation criteria and to synthesize the ratings of candidate aircraft.

Chen, T.Y., and Tsao, C. Y. [21], extend the TOPSIS method for decision-making problems with interval-valued fuzzy sets. They present experimental analysis.

Mahdavi, Iraj, et al. [53], design a model of TOPSIS for the fuzzy environment with the introduction of appropriate negations for obtaining ideal solutions and apply a new measurement of fuzzy distance value with a lower bound of alternatives. Then similarity degree is used for ranking of alternatives.

Önüt, S., & Soner, S. [55] , propose a fuzzy TOPSIS to solve the solid waste transshipment site selection problem in Istanbul, Turkey. The criteria weights are calculated by using the AHP.

Liu, P. [48], proposed a method to resolve the multi-attribute decision-making problem using TOPSIS method based on attribute weights and attribute values are all interval vague value. Firstly, based on the operation rules of the interval vague value, the interval Vague attribute value is made by weighted operation, and the ideal and negative ideal solutions are calculated based on the score function. Then the distance of interval vague value is defined, as well as the distance between each project and the ideal and negative ideal solutions.

Dağdeviren, M., et al. [24], develop an evaluation model based on the analytic hierarchy process (AHP) and the TOPSIS method, to help the actors in defence industries for the selection of optimal weapon in a fuzzy environment where the vagueness and subjectivity are handled with linguistic values parameterized by triangular fuzzy numbers. The AHP is used to analyze the structure of the weapon selection problem and to determine weights of the criteria, and fuzzy TOPSIS method is used to obtain final ranking.

Sun, C. C., & Lin, G. T.[73], use the fuzzy TOPSIS method based on fuzzy sets in solving MCDM problems. From our research results, the security and trust are the most important factors for improving the competitive advantage of shopping website.

Cavallaro, F. [20], propose and test the validity and effectiveness of the proposed fuzzy multi-criteria method based on TOPSIS approach to compare different heat transfer fluids (HTF) in order to investigate the feasibility of utilizing a molten salt.

Wei, J. [85], introduce TOPSIS method to investigate the multiple attribute decision making problems with linguistic information, in which the information about attribute weights is incompletely known, and the attribute values take the form of linguistic variables.

Ye, F. [89], extended TOPSIS method for group decision making with interval-valued intuitionistic fuzzy numbers to solve the partner selection problem under incomplete and uncertain information environment. And the feasibility and practicability of the extended TOPSIS method are further manifested through an illustrative example. Results show that this extended TOPSIS method for group decision making with interval-valued intuitionistic fuzzy numbers is more suitable to cope with the partner selection problem under incomplete and uncertain information environment.

Lo, C. C., et al. [49], present an evaluation method based on TOPSIS to help service consumers and providers to analyze available web services with fuzzy opinions.

Sadi-Nezhad, S., & Damghani, K. K.[66] presented a TOPSIS approach based on preference ratio and an efficient fuzzy distance measurement for a Fuzzy Multiple Criteria Group Decision-Making Problem (FMCGDMP). Preference ratio with a moderate modification for negative fuzzy numbers was used as an efficient ranking method for fuzzy numbers in a relative manner.

Tan, Y. T., et al. [75], introduce a quantitative method for assisting contractors to select appropriate projects for bidding by considering multiple attributes and integrating decision group member opinions using the TOPSIS approach.

Abou-El-Enien, T. H. M. [8], focus on the solution of a Large Scale Integer Linear Vector Optimization Problems with chance constraints (CHLSILVOP) using TOPSIS approach, where such problems has block angular structure of the constraints. He introduce an algorithm based on TOPSIS approach to solve CHLSILVOP with constraints of block angular structure.

Lotfi, F. H., et al. [51], consider some CCR (Charnes, Cooper and Rhodes) model efficient DMUs (Decision Making Units) , and then rank them by using some ranking methods, each of which is important and significant. Afterwards, by using TOPSIS method, they suggest the ranks of efficient DMUs.

Awasthi, A., et al. [15], present a multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. The proposed approach involves identification of potential locations, selection of evaluation criteria, use of fuzzy theory to quantify criteria values under uncertainty and application of fuzzy TOPSIS to evaluate and select the best location for implementing an urban distribution center. Sensitivity analysis is performed to determine the influence of criteria weights on location planning decisions for urban distribution centers.

Dalalah, D., et al. [25], present a hybrid fuzzy model for group Multi Criteria Decision Making (MCDM). A modified fuzzy DEMATEL (Decision-making trial and evaluation laboratory) model is presented to deal with the influential relationship between the evaluations criteria. The modified DEMATEL captures such relationship and divides the criteria into two groups, particularly, a modified TOPSIS model is proposed to evaluate the criteria against each alternative. A fuzzy distance measure is used in which the distance from the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) are calculated. The presented hybrid model was applied on an industrial case study for the selection of cans supplier/suppliers at Nutridar Factory in Amman-Jordan to demonstrate the proposed model.

Liao, C. N., & Kao, H. P. [47], propose integrated fuzzy techniques for order preference by similarity to ideal solution (TOPSIS) and multi-choice goal programming (MCGP) approach to solve the supplier selection problem. The advantage of this method is that it allows decision makers to set multiple aspiration levels for supplier selection problems.

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Park, J. H., et al. [56], extend the TOPSIS method to solve multiple attribute group decision making (MAGDM) problems in interval-valued intuitionistic fuzzy environment in which all the preference information provided by the decision-makers is presented as interval-valued intuitionistic fuzzy decision matrices where each of the elements is characterized by interval-valued intuitionistic fuzzy number (IVIFNs), and the information about attribute weights is partially known.

Torlak, G., et al. [76], use fuzzy TOPSIS multi-methodological approach in the Turkish domestic airline industry. They start by describing exceedingly complex nature of competition in the sector. Then, they deal with the constituent parts of the research methodology and the eclectic approach itself. The implementation of fuzzy TOPSIS method in the Turkish domestic airline industry reveals the ranking of major air carriers in light of key success variables in the sector. They, also, provide an evaluation of empirical findings of fuzzy TOPSIS method from a managerial perspective.

Tsaur, R. C. [77], present TOPSIS as a multi-attribute decision making (MADM) technique for ranking and selection of a number of externally determined alternatives through distance measures. When the collected data for each criterion is interval and the risk attitude for a decision maker is unknown, we present a new TOPSIS method for normalizing the collected data and ranking the alternatives.

Vahdani, B., et al. [78], present a novel fuzzy modified TOPSIS method by a group of experts, which can select the best alternative by considering both conflicting quantitative and qualitative evaluation criteria in real-life applications. The proposed method satisfies the condition of being the closest to the fuzzy positive ideal solution and also being the farthest from the fuzzy negative ideal solution with multi-judges and multi-criteria.

Afshar, A., et al. [11], applied Fuzzy TOPSIS Multi-Criteria Decision Analysis to Karun Reservoirs System. They proposed fuzzy multi-criteria decision making process uses the TOPSIS method in both deterministic and uncertain environments.

García-Cascales, M. S., & Lamata, M. T. [32], study the rank reversal phenomenon in the TOPSIS method and propose modifications in the algorithm of Hwang and Yoon in order to solve the problem. Moreover, they present a general demonstration of the proposed modifications in the algorithm, as well as a numerical example to show these modifications.

Wittstruck, D., & Teuteberg, F. [86], develop an integrated Multi-Criteria Decision Model (MCDM) that supports recycling partners. On the basis of a systematic literature review, they identified limitations of the existing approaches and designed an integrated Fuzzy-AHP-TOPSIS model. The approach is validated by means of an empirical study in the electrics and electronics industry.

Baky, I. and Abo-Sinna, M.A. [36] proposed a TOPSIS algorithm for bi-level multiple objective decision making problems.

Wang, X., & Chan, H. K. [82], propose a fuzzy hierarchical TOPSIS approach to assess improvement areas when implementing green supply chain initiatives. It enables decision makers to better understand the complete evaluation process and provide a more accurate, effective and systematic decision support tool.

Dymova, L., et al. [28], propose a new direct approach to interval extension of TOPSIS method which is free of heuristic assumptions and limitations of known methods. By using numerical examples, they show that “direct interval extension of TOPSIS method” may provide the final ranking of alternatives which is substantially different from the results obtained using known methods.

Gu, L. [33], uses TOPSIS method to comprehensively evaluate the performance of six former NBA players in the CBA league 2012-2013 seasons. Select the shooting averages, 3-point field goal percentage, free throw percentage, averaged offensive rebounds, averaged assists, averaged mistakes and averaged scores seven indicators to evaluate a player's offensive ability; Select averaged defensive rebounds, averaged steals, averaged blocked shots and averaged fouls four indicators to evaluate the player's defensive ability; finally use the weighting method to analyze the players comprehensive ability.

Xu, Z., & Zhang, X.[88], develop a novel approach based on TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and the maximizing deviation method for solving MADM problems, in which the evaluation information provided by the decision maker is expressed in hesitant fuzzy elements and the information about attribute weights is incomplete.

Abou-El-Enien, T. H. M. [7] ,extend TOPSIS method for solving Linear Fractional Vector Optimization problems (LFVOP) of a special type, An interactive decision making algorithm for generating a compromise solution through TOPSIS approach is provided where the decision maker (DM) is asked to specify the degree α and the relative importance of the objectives. Finally, a numerical example is given to clarify the main results developed in the paper.

Abo–Sinna, M. A. and Abou-El-Enien, T. H. M. [1] , extend TOPSIS method for solving Large Scale Bi-level Linear Vector Optimization Problems (LS-BL-LVOP). They further extended the concept of TOPSIS for LS-BL-LVOP.

Abou-El-Enien, T. H. M. [9], extended TOPSIS for solving a special type of Two-Level Integer Linear Multiple Objectives Decision Making (ST-TL-IL MODM) Problems with block angular structure. In order to obtain a compromise (satisfactory) integer solution to the ST-TL-ILMODM problems with block angular structure using the proposed TOPSIS approach, a modified formulas for the distance function from the positive ideal solution (PIS) and the distance function from the negative ideal solution (NIS) are proposed and modeled to include all the objective functions of the two levels. In every level, as the measure of "Closeness" dp-metric is used, a k-dimensional objective space is reduced to two –dimensional objective space by a first-order compromise procedure.

Dey, P.P., et al. [27], present a technique for order preference by similarity to ideal solution (TOPSIS) algorithm to linear fractional bi-level multi-objective decision-making problem based on fuzzy goal programming. TOPSIS is used to yield most appropriate alternative from a finite set of alternatives based upon simultaneous shortest distance from positive ideal solution (PIS) and furthest distance from negative ideal solution (NIS).

Abou-El-Enien, T. H. M. [10], extended TOPSIS (Technique for Order Preference by Similarity Ideal Solution) method for solving Two-Level Large Scale Linear Multi objective Optimization Problems with Stochastic Parameters in the right hand side of the constraints (TL-LSLMOP-SP) rhs of block angular structure. In order to obtain a compromise (satisfactory) solution to the (TL-LSLMOP-SP) rhs of block angular structure using the proposed TOPSIS method, a modified formulas for the distance function from the positive ideal solution (PIS) and the distance function from the negative ideal solution (NIS) are proposed and modeled to include all the objective functions of the two levels.

Abou-El-Enien, T. H. M. [6] , present many algorithms for solving different kinds of Large Scale Linear Multiobjective Optimization (LSLMO) problems using TOPSIS method.

Junior, F. R. L., et al. [42], present a comparative analysis of fuzzy AHP and fuzzy TOPSIS methods in the context of supplier selection decision making. The comparison was made based on the factors: adequacy to changes of alternatives or criteria; agility in the decision process; computational complexity; adequacy to support group decision making; the number of alternative suppliers and criteria; and modeling of uncertainty.

Mittal, V. K., & Sangwan, K. S.[54], aim at identifying and ranking barriers to ECM (Environmentally Conscious Manufacturing) implementation. Twelve barriers have been identified and grouped as economic, internal, policy and societal barriers. A fuzzy TOPSIS multi-criteria decision model has been developed to rank these barriers from government, industry and expert perspectives by using the data inputs from various sources in India. The ranking of the barriers from different perspectives will help the decision/policy makers in government and industry to mitigate these barriers in an effective manner.

Patil, S. K., & Kant, R. [57], propose a framework based on fuzzy analytical hierarchy process (AHP) and fuzzy technique for order performance by similarity to ideal solution (TOPSIS) to identify and rank the solutions of KM adoption in SC and overcome its barriers. The AHP is used to determine weights of the barriers as criteria, and fuzzy TOPSIS method is used to obtain final ranking of the solutions of KM adoption in SC.

Rashid, T., Beg, I., & Husnine, S. M[60], use the TOPSIS method to aggregate the opinion of several decision makers on different criteria, regarding a set of alternatives, where the judgment of the decision makers are represented by generalized interval-valued trapezoidal fuzzy numbers.

Yuen, K. K. F. [93], find that the classical fuzzy TOPSIS produces a misleading result due to some inappropriate definitions, and proposes the rectified fuzzy TOPSIS addressing two technical problems. As the decision accuracy also depends on the evaluation quality of the fuzzy decision matrix comprising rating scores and weights, this research applies compound linguistic ordinal scale as the fuzzy rating scale for expert judgments, and cognitive pairwise comparison for determining the fuzzy weights.

wang, Z. X., & Wang, Y. Y.[84], use the Mahalanobis distance to improve the traditional technique for order preference by similarity to ideal solution (TOPSIS). The improved TOPSIS method has the following properties: (1) an improved relative closeness which is invariant after non-singular linear transformation, and (2) the weighted Mahalanobis distance is the same as the weighted Euclidean distance when the indicators are uncorrelated. The new method is applied to evaluate the competitiveness of the Chinese high-tech industry using data from 2011.

Biswas, P., et al. [19], proposed a new approach for multi-attribute group decision-making problems by extending the technique for order preference by similarity to ideal solution (TOPSIS) to single-valued neutrosophic environment. Ratings of alternative with respect to each attribute are considered as single-valued neutrosophic set that reflect the decision makers' opinion based on the provided information.

Rębiasz, B., et al. [61], propose a practical framework for modelling projects portfolio selection problem with fuzzy parameters resulting from uncertainty associated with decision makers' judgment. A fuzzy multi-attribute decision-making approach is adopted. A two-step evaluation model that combines fuzzy AHP and fuzzy TOPSIS methods is used to rank potential projects. The proposed approach is illustrated by an empirical study of a real case from steel industry involving fifteen criteria and ten projects.

Singh, B., et al. [72], apply Fuzzy Technique for Order Preference by Similarity to Ideal Solution to rank different alternatives. The preliminary results indicate that the proposed model is capable of determining appropriate competition between departments which are Human Resource, Finance, Production, and Quality Assurance. To remove the subjectivity, the linguistic data about the attributes is converted into a crisp score by using fuzzy numbers and then the different alternatives are evaluated based on attributes by TOPSIS approach to find the best alternative according to the industry's requirement.

Wang, J., et al. [80], focus on multi-criteria decision-making (MCDM) problems in which the criteria values take the form of hesitant fuzzy linguistic numbers (HFLNs). Having reviewed the relevant literature, the Hausdorff distance for HFLNs is provided and some linguistic scale functions are applied. Subsequently, two hesitant fuzzy linguistic MCDM methods are proposed, which are based on the proposed distance measure and the TOPSIS and TODIM (an acronym in Portuguese of Interactive and Multiple Attribute Decision Making) methods.

3. SOFTWARES

Wu, D., & Olson, D. L. [87] present an analytical model which is based on multi-criteria decision-making approach for selection of appropriate software project using AHP (analytical hierarchy process) and TOPSIS (technique for order preference by similarity of ideal solution) models. Additionally, it is also defining the optimum order among software with prospecting their competency measured by sensitivity analysis in combination with subjective factor and objective factors.

Jablonský, J. [38], presents two freeware software systems that are available for downloading on the author's web pages. The first system is the DEA Excel solver and the second one is Sanna – application of multi-criteria evaluation of alternatives. DEA Excel solver covers all basic DEA models and uses internal MS Excel optimization solver. The application includes standard envelopment models with constant and variable returns to scale including superefficiency models. As the second software system the paper presents a simple MS Excel based application Sanna for multiple criteria evaluation of alternatives using several main MCDM methods (WSA, ELECTRE I and III, PROMETHHEE, ORESTE, TOPSIS and MAPPAC).

Shi, L., & Yang, S. [69], model the software trustworthiness evaluation (STE) problem as a multi-criteria decision-making (MCDM) problem, and proposes both an evaluation framework and a practical approach to evaluate the software trustworthiness based on the fuzzy analytic hierarchy process (FAHP) and fuzzy technique for order preference by similarity to ideal solution (FTOPSIS) methods. FAHP method is utilized to obtain the weights of evaluation criteria. The FTOPSIS method is used to determine the final ranking of the software alternatives. The uncertainty and vagueness included in evaluation procedure are represented as fuzzy triangular numbers.

Resteanu, C., et al. [63], present a method for solving the general Multi-Attribute Decision Making problems, by distributed and parallel computing, with the OPTCHOICE software. One presents the scheduling and load balancing algorithm for concurrent solving of problems sets on a given number of parallel computers.

Hu, X., & Ralph, D.[34], establish sufficient conditions for the existence of pure-strategy Nash equilibrium for this class of bi- level games and give some applications. They show by examples the effect of network transmission limits, i.e., congestion, on the existence of equilibrium.

Victor, M., & Upadhyay, N.[79], investigate the multiple attribute decision making (MADM) problems for evaluating the software quality with intuitionistic trapezoidal fuzzy information. Then, based on the traditional TOPSIS method, calculation steps for solving trapezoidal intuitionistic fuzzy multiple attribute decision-making problems for evaluating the software quality with completely known weight information are given.

Huiqun, H., & Guang, S. [35], an integrated approach of ERP software selection analytic hierarchy process improved by rough sets theory (Rough-AHP) and fuzzy TOPSIS method is proposed to obtain final ranking.

Shi, L., et al. [70], propose a novel software trustworthiness evaluation approach based on combination weights (CW) and improved TOPSIS methods. The determination of CW relies on experts' judgments and mathematical computation together. FAHP method is used to determine the importance of degree of criteria according to the experts' judgment.

Baloul, F. M., et al. [17], describe FTST (Fuzzy TOPSIS-Based Software Tool) software tool for selecting the optimum alternative among many alternatives according to multi specified criteria. FTST tool is designed based on the fuzzy TOPSIS method as one of the most popular methods in multi-criteria decision analysis (MCDA). FTST, as an automated system, could be used as decision support system software for any case where the goal is to select the right and the optimum alternative from many alternatives with intended criteria.

Jablonsky, J. [39], presents two freeware software systems that are available for downloading on the author's web pages. The first system is *DEA Excel Solver* and the second one is *Sanna*– application for multi-criteria evaluation of alternatives. *DEA Excel Solver* covers basic DEA models and uses internal MS Excel optimization solver. The application includes standard envelopment models with constant and variable returns to scale including super-efficiency models. *Sanna* is a simple MS Excel based application for multi-criteria evaluation of alternatives using several important MCDM methods (WSA, ELECTRE I and III, ORESTE, PROMETHEE, TOPSIS, and MAPPAC).

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