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A *De Novo* multi-approaches multi-criteria decision making technique with an application in performance evaluation of material handling device ☆

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ABSTRACT

Application of multiple conventional approaches to a particular multi-criteria decision making (MCDM) problem often suffers rank reversal giving rise to confusion and ambiguity in appropriate decision making. To eradicate the confusion, this paper proposes a *De Novo* multi-approaches multi-criteria decision making method namely Technique of Precise Order Preference (TPOP). The TPOP first examines the inconsistency in the ranking order of the alternatives of a MCDM problem by using multiple conventional approaches. If inconsistency/rank reversal in ranking order of the alternatives exists then TPOP, using advanced version of entropy weighting method introduced in this research work, measures weights of the final selection values of conventional approaches. Subsequently, TPOP based on these weights and final selection values computes precise selection indices (PSI) that determines accurate ranking order for the alternatives. The proposed technique is illustrated by two real life examples on material handling device (MHD) ranking and selection problems. The first example is initially solved using five conventional integrated fuzzy multi-criteria decision making techniques (FMCDMs) whereas the second example is taken from previous researchers' works. The results obtained using TPOP justify the validity, applicability and requirements of the proposed technique. The study shows that the proposed multi-approaches, multi-criteria decision making technique can be a useful and effective model in MCDM.

1. Introduction

Over preceding two decades, due to globalization and fierce competition among business organizations, decision makers always realize an intense necessity of proper decision making for survival in the industry. In industry, often a decision making problem deals with multi-criteria and multi-alternatives. A decision making process is related to both financial and technical aspects. A proper decision in industry not only reduces cost but also increases profitability, stability and competitive advantages. An improper decision may mislead an organization to the wrong direction and may lead to gradual deterioration. Thus a proper decision making is always the key of success and improper decision making is responsible for failure. Making decision on considering multiple conflicting criteria/attributes is known as the multi-criteria decision-making (MCDM) (Bhattacharya, Sarkar, & Mukherjee, 2005; Kahraman, Cevik, Ates, & Gulbay, 2007; Parkan & Wu, 1999; Yu & Hu, 2010; Zhang, Fan, & Liu, 2010).

An MCDM problem must contain at least two alternatives and at least two conflicting criteria. MCDM problems are classified into diverse aspects and strategies. The criteria are classified in two ways; firstly, as subjective (qualitative/intangible), objective (quantitative/tangible) and critical (that need to be satisfied before further processing) criteria and secondly, as benefit criteria (higher value is desirable) and cost criteria (lower value is desirable). In an MCDM problem a finite set of alternatives/strategies can be evaluated considering multi-criteria. Choosing a suitable technique to measure the criteria to evaluate the performance and to select alternatives can help the evaluators and analysts to determine the proper preference order and selection of the alternatives.

Many elementary techniques have already been proposed to evaluate, rank and select alternatives under MCDM environment. The MCDM techniques include TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), AHP (Analytical

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Hierarchy Process) MOORA (Multi Objective Optimization on the basis of Ratio Analysis), VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje i.e. Multi-criteria Optimization and Compromise Solution), GRA (Grey Relational Analysis), COPRAS-G (Complex Proportional Assessment method with the applications of the Grey systems theory), SAW (Simple Additive Weighting), ELECTRE (ELimination Et Choix Traduisant la REalité that means ELimination and Choice Expressing REality), PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations), etc. In complex situation, two or more elementary techniques are suitably integrated to construct a hybrid method. When the multi-criteria decision is made with certainty using deterministic approach then the model is termed as classical MCDM. Classical MCDM considers objective criteria and deals with crisp value.

When multi-criteria decision is made under uncertain environment with vague, ambiguous and imprecise data, fuzzy set theory is applied. The concept of combining the fuzzy set theory with MCDM is mentioned as fuzzy multi-criteria decision-making (FMCDM). A fuzzy set can be explained mathematically by assigning to each possible individual in the universe of discourse a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which that individual is similar to or compatible with the concept represented by the fuzzy set. Thus, individual may belong to the fuzzy set to a greater or lesser degree as indicated by a larger or smaller membership grade (Klir & Yuan, 2005). FMCDM considers subjective criteria and deals with linguistic variables and fuzzy value.

Linguistic variables are words or sentences in a natural or artificial language (Chen, Lien, Tzeng, & Yang, 2008) like "equally important", "weakly important", "essentially important", "very strongly important" and "absolutely important"; "very poor", "poor", "medium", "good" and "very good", etc. Human beings often prefer subjective assessment to objective assessment of alternatives by using linguistic variables. The linguistic variables are converted into corresponding triangular fuzzy numbers (TFN) or trapezoidal fuzzy numbers. Each membership function of TFNs is defined by three points, viz. lower point, middle point and upper point whereas that of a trapezoidal fuzzy numbers by four points. Fuzzy set theory converts the subjective data into numerical (objective/crisp) values through fuzzy operations. Researchers reasonably employ linguistic variables in the complex situations that are difficult to define and quantify with conventional methods (Zadeh, 1975).

The method choice made by decision maker or management depends on environment, strategy of decision making, the status and type of the organization. Use of a single method cannot ensure the right selection or the order preference of the alternatives under MCDM/FMCDM environment. Hence the decision makers separately employ several methods on each ranking and selection problem. A literature survey under MCDM/FMCDM is presented in Table 1. This survey reveals that a single research work (of a single researcher or DM/a group of researchers or DMs) often apply many techniques on a decision problem to find the ranking order of the alternatives (Bairagi, Dey, Sarkar, & Sanyal, 2014, 2015; Dagdeviren, Yavuz, & Kilinc, 2008; Ozcan, Celebi, & Esnaf, 2011; Yang, Chiu, Tzeng, & Yeh, 2008). It is also disclosed that a number of different research works (presented by researchers/decision makers) apply various techniques on a single decision problem at different point of time (Agrawal, Kohli, & Gupta, 1991; Chakraborty, 2010; Chatterjee, Athawale, & Chakraborty, 2009, 2010; Fayazbakhsh, Abedian, Manshadi, & Khabbaz, 2009; Jahan, Ismail, Mustapha, & Sapuan, 2010; Jee & Kang, 2000; Karsak & Kuzgunkaya, 2002; Manshadi, Mahmudi, Abedian, & Mahmudi, 2007; Rao, 2007; Rao & Padmanabhan, 2006; Rao & Patel, 2010; Rao, Patel, & Parnichkun, 2011; Sun, 2002). In each and every abovementioned case, rank reversal is a general phenomenon that makes the decision makers confused in proper ranking of alternatives. The best choice as well as the ranking order of all the alternatives is equally important to a rational decision maker. Ranking order is essential for comparison and for differentiation of the alternatives. Hence ranking order matters a lot. It is observed that the effort for finding the unique ranking order in MCDM is ignored in previous literatures, though it deserves the utmost importance. It is obvious from the wide-ranging literature survey that the efforts of the previous researchers for capturing the diverse advantages like less computational time, simplicity, easier mathematical calculation, greater stability and ability of dealing with information of diverse nature is insufficient. Moreover the past literatures did not make any attempt to mitigate the inconsistency of the ranking order of alternatives obtained by different approaches. Separate application of diverse MCDM techniques to same decision problem generates rank reversal that makes the selection procedure difficult and complex. These difficulties and complexities of the literature are removed in the current exploratory research work.

The paper focuses on the introduction of a novel MCDM approach (abbreviated as TPOP) capable of determining precise and a unique order preference to each alternative. This new approach in MCDM essentially removes rank reversal, ambiguity and confusion in decision making assigning distinctive rank and thus enhances the state-of-the-art. Motivation behind the research activities is the gap of rank reversal detected in the literature. The decision makers become confused due to rank reversal and often fail to select, compare and distinguish alternatives. Hence it is essential to introduce a logical as well as a systematic technique in order to guide the decision makers in finding precise order preference and in selecting the most suitable alternative from a given set, because a wrong selection may often negatively contribute to the productivity and flexibility of the entire manufacturing process (Chatterjee et al., 2010). Hence this paper proposes TPOP to find precise order preference of alternative by eliminating rank reversal, confusion and ambiguity in multi-criteria decision making.

The originality of the current paper can be pointed as follows.

(1) This study explores a new approach (TPOP) for precise order preference and selection of alternative in MCDM.
(2) This study introduces the advanced version of entropy weighting method that provides acceptable relative weights.
(3) This study develops and presents the way of eliminating rank reversal in multi-criteria decision making.
(4) The investigation makes group decision using final selection values obtained by conventional methods.

The advantages of the technique are as follows. The technique is simple in calculation, straightforward in application and easy to understand. Also this approach is based on the values of final selection factors of conventional methods and thus avoids unnecessary complexity in data handling.

The objectives of this research paper are to assist and guide decision makers by eliminating confusion and ambiguity in precise evaluation, ranking and selection of alternatives in MCDM/FMCDM environment. These objectives are achieved by

- exploring a new approach (TPOP) for precise order preference,
- introducing the advanced version of entropy weighting method for the new approach,
- short listing the key parameters of material handling device evaluation, ranking and selection,
- using FAHP to compute the subjective weights of the criteria for the existing methodologies, and