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A decision support system for fuzzy multi-objective multi-period sustainable project selection ☆

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ABSTRACT

In this paper, a Decision Support System (DSS) is developed to solve sustainable Multi-Objective Project Selection problem with Multi-Period Planning Horizon (MOPS-MPPH). First, a TOPSIS based fuzzy goal programming (FGP) is proposed which considered uncertain DM preferences on priority of achievement level of fuzzy goals. The FGP essentially considers economic factors like cost, profit, and budget. The output of FGP and other affecting factors (i.e. social and environmental effects, risk of investment, strategic alliance, and organizational readiness) are treated as inputs of a fuzzy rule based system to estimate fitness value of an investment. Properties of the proposed DSS are discussed. It also is compared with an existing procedure on historical data of a financial and credit institute.

1. Introduction

Selection of an optimum portfolio of projects has both practical and theoretical importance. Generally, project selection problem (PSP) is a common paradigm with enough flexibility to be considered through different methodologies in a wide range of applications. This selection includes a set of projects to satisfy a set of criteria with different financial and non-financial natures. Among Different methodologies, Multiple Criteria Decision Making (MCDM) procedures (Hwang & Masud, 1979), including Multi-Objective Decision Making techniques (MODM), are properly fit with real life PSPs.

In a real world investment problem, DMs have reasonable tendency for making multidimensional investment decisions considering both financial/non-financial and internal/external factors. These factors mainly concern economic, social, environmental effects of an investment, risk of investment, organizational readiness, and strategic alliance. The investment decisions become more complicated when DMs also face with uncertain situations. Reducing the dimensions of the original problem in way that the emerged problem holds the aforementioned specification in generating high quality solutions can be interesting.

Considering DM preference about priority structure of achievement level of goals especially in an ambiguous situation makes the MODM problems more realistic. This could be solved through modeling the achievement level of goals and developing fuzzy relation for DM preference about priority of achievement level of goals, simultaneously. Generating high quality solutions, optimizing achievement level of fuzzy goals, and modeling uncertain preference of DM about priority of achievement level of goals in a single approach are also interesting.

Moreover, development of a DSS which can help DM for considering all financial/non-financial and internal/external objectives, constraints and factors in an uncertain situation is practical. This idea persuaded us to propose a DSS in fuzzy situation which can handle all aforementioned properties, concurrently.

The proposed DSS will be represented in two main modules. Using the proposed DSS, a fuzzy MODM problem reduces to a Bi-Objective problem through TOPSIS logic, while we are confident about generating high quality solutions. All objectives of the original MODM problem had efficient effects in conformation of resultant Bi-Objective problem. First module seeks solutions with Minimum distance from Positive Ideal Solution (PIS) and maximum distance from Negative Ideal Solution (NIS), simultaneously. Consequently, the Bi-Objective problem is modeled as a special fuzzy goal programming (FGP). The objective function of final FGP includes uncertain DM preference about priority of achievement level of fuzzy goals which are modeled through linguistic terms parameterized using linear fuzzy relation functions and weighted sum of achievement level of goals, simultaneously.

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It has worth noting that a multi-objective project selection model with multi-period planning horizon (MOPS-MPPH) in a fuzzy environment has also been developed. The MOPS-MPPH can be treated as a proper testimonial of real life MODM problems. The first module will be ended with application of optimization procedure in MOPS-MPPH. The first module which is based on mathematical programming mainly considered financial factors, objectives, and constraints of an investment problem like cost, profit, budget, resource availability, resource utilization and rate of return.

The outputs of first module which are totally assumed as economic effects of an investment, is treated as one of the inputs of second module. In the second module the economic, social, environmental effects, risk of investment, organizational readiness, and strategic alliance of an investment are modeled through linguistic terms parameterized using fuzzy numbers and treated as inputs of a fuzzy rule based (FRB) system. The final output of second module determines the fitness of an investment in form of project considering financial/non-financial and internal/external factors, constraints, and objectives.

The rest of the paper is arranged as follow. Literature of past works associated with proposed DSS is discussed in Section 2. Both modules of proposed DSS are completely represented in Section 3. In Section 4, the first module of proposed DSS and an existing procedure are applied a real case of a financial and credit institute project selection problem. The results are also compared through ANOVA in Section 4. Then, the results of second module of proposed DSS are represented. Finally, the paper will be ended with conclusion remarks and further researches proposal in Section 5.

2. Literature of past works

Formally, an MODM model considers a vector of decision variables, objective functions, and constraints. Generally, the MODM problem can be formulated as (1).

$$(MODM)\quad \begin{cases} Optimize & f(X), \\ s.t. & X \in S = \{X \in R^n | g(X) \leqslant b, X \geqslant 0\}, \end{cases} \tag{1}$$

where $f(X)$ represents k conflicting objective functions, $g(X) \leqslant b$ represents m constraints, S is feasible solution space, and X is an n-vector of decision variables where, $X \in R^n$ (Hwang & Masud, 1979).

2.1. Project selection problem through mathematical programming

Timothy and Kalu (1999) developed a goal programming for capital budgeting under uncertainty. Badri, Davis, and Davis (2001) developed a 0–1 goal programming model for information system (IS) project selection. Gupta, Mehlawat, and Saxena (2008) applied MCDM via fuzzy mathematical programming to develop comprehensive models of asset portfolio optimization. Xu, Fang, Shi, Yu, and Liu (2009) presented a fuzzy 0–1 integer chance-constrained programming model to find the solution for multi-project and multi-item investment. NSGA-II was applied to solve the optimization model with a small modification of the constraint-handling rule. Khalili-Damghani, Sadi-Nezhad, and Aryanezhad (2011) proposed a DSS based on fuzzy mathematical programming and fuzzy rule based to select optimum portfolio of investments.

2.2. Dimension reduction in multi-objective programming

In real cases of multi-objective modeling, a serious challenge will arise when several objectives are involved. So a dimension reduction in objective space is interesting in a way that the information loss is minimized. This process may need to select and omit some objectives in a way that minimum perturbations occur for solution space (Brockhoff & Zitzler, 2010).

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is one of the well-known MADM approaches. TOPSIS was introduced by Hwang and Yoon (1981). Lai, Liu, and Hwang (1996) extended TOPSIS to solve an MODM problem for the first time. They used the compromise property of TOPSIS procedure in generating solutions. So a k-dimensional objective space was reduced to a two-dimensional objective space by a first-order compromise procedure. Although, the dominance structure of the solution space may be disturbed through any dimension reduction procedure (including TOPSIS), but properties of TOPSIS makes it an interesting dimension reduction technique.

Compromise property of TOPSIS helps to generate desired solutions which are far from NIS and near to PIS, simultaneously. This property is a winning advantage in real MODM problems where DM interested in seeking high quality solutions and averse of meeting high risk solutions, simultaneously. All objective functions have effective influence in generating the resultant Bi-Objective problem. On the other hand, no objective is completely omitted. So the structure of the solution space may change as little as possible. The relative importance of the objectives of original MODM problem can easily be controlled through weights and order of compromise operation which are determined by DM.

2.3. Presentation of DM preference

Fuzzy relations are proper paradigms to represent DMs' preferences on different aspects concerning optimization problems and decision making (Chiclana, Herrera, & Herrera-Viedma, 1998, 2001; Fan, Ma, Jiang, Sun, & Ma, 2006).

Definition 2.1. A fuzzy relation is a fuzzy set defined in Cartesian product of crisp sets $U_1, U_2, \ldots, U_n$. More formally, a fuzzy relation R in $U_1 \times U_2 \times \cdots \times U_n$ is defined as the fuzzy set $R = \{((U_1, U_2, \ldots, U_n), \mu_R(U_1, U_2, \ldots, U_n)) | (U_1, U_2, \ldots, U_n) \in U_1 \times U_2 \times \cdots \times U_n\}$ where, μ_R: $U_1 \times U_2 \times \cdots \times U_n \to [0, 1]$.

Chiclana et al. (1998), Chiclana, Herrera, and Herrera-Viedma (2001) introduced different forms of representation of DMs' preference over a set of alternatives. They also proposed integration procedure for different combination of DMs' preference formats. Suppose $X = \{x_1, \ldots, x_n\}$, $n \geqslant 2$ be a finite set of alternatives. The alternatives are classified from best to worst, using DM preference. DMs' preferences over the set of alternatives, X, can be represented as a fuzzy preference relation in following way.

Definition 2.2. A fuzzy preference relation: In this case, the DMs' preferences on X is described through fuzzy preference relation, $P \subset X \times X$, with membership function, μ_P: $X \times X \to [0, 1]$, where $\mu_P(x_i, x_j) = p_{ij}$ denotes the preference degree of alternative x_i over x_j.

2.4. Preliminary definitions of fuzzy rule based

An FRB consists of a set of fuzzy IF–THEN rules. It is the heart of the fuzzy system in the sense that all other components are used to implement these rules in a reasonable and efficient manner. Specifically, the fuzzy rule base comprises the following fuzzy IF–THEN rules.

RULE$_\mathbf{i}$: IF x_l is A_1 and … and x_n is A_k, THEN y is B.

where A_k and B are fuzzy sets in a predefined universe of discourse. $\boldsymbol{x} = (x_l, x_2, \ldots, x_n)$ and y are the input and output (linguistic) variables of the fuzzy system, respectively. Let M be the number of rules in the fuzzy rule base; that is, $i = 1, 2, \ldots, M$.

Because the fuzzy rule base consists of a set of rules, the relationship among these rules impose interesting questions. For example, do the rules cover all the possible situations that the fuzzy system