Applied Soft Computing xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

Distributionally robust fuzzy project portfolio optimization problem with interactive returns

Ying Liu, Yan-Kui Liu*

Risk Management & Financial Engineering Laboratory, College of Management, Hebei University, Baoding 071002, China

ARTICLE INFO

Article history:
Received 27 September 2015
Received in revised form 23 July 2016
Accepted 6 September 2016
Available online xxx

Keywords:
Project portfolio selection
Interactive return
Credibilistic optimization
Parametric possibility distribution

ABSTRACT

Effective project selection and staff assignment strategies directly impact organizational profitability. Based on critical value optimization criterion, this paper discusses how uncertainty and interaction impact the project portfolio return and staff allocation. Since the exact possibility distributions of uncertain parameters in practical project portfolio problems are often unavailable, we adopt variable parametric possibility distributions to characterize uncertain model parameters. Furthermore, this paper develops a novel parametric credibilistic optimization method for project portfolio selection problem. According to the structural characteristics of variable parametric possibility distributions, we derive the equivalent analytical expressions of credibility constraints, and turn the original credibilistic project portfolio model into its equivalent nonlinear mixed-integer programming models. To show the advantages of the proposed parametric credibilistic optimization method, some numerical experiments are conducted by setting various values of distribution parameters. The computational results support our arguments by comparing with the optimization method under fixed possibility distributions.

1. Introduction

In the highly competitive economic circumstance, project portfolio selection is a crucial part of managerial strategy for organizations. In general, the project portfolio selection problem involves two key modeling aspects: selecting a suitable subset of projects as a portfolio and assigning the available human resource efficiently. A decision maker should incorporate these two aspects to produce a more robust and realistic formulation for project portfolio selection.

The concept of portfolio origins from financial investment theory. Following the basic thought, some researchers introduce the theoretical foundations into project management field. Although many similar research aspects exist in the financial and project portfolio theory, several authors have identified the differences between them. For instance, Casault et al. [6] mentioned that the project portfolios were different from financial portfolios because projects have no market price despite financial assets; Gutjahr and Froeschl [17] pointed out that investment in projects to be carried out by the own personnel of a firm also required a careful consideration of the available human resources.

The interaction among projects is a critical issue to project portfolio management. The previous theory on project portfolio decision typically assumed that each project was independent. In reality, due to meeting the same consumer need or requiring the same development resources, the return from a project depends not only on its properties but also on the other projects included in the same portfolio. Numerous previous studies about this issue have existed in the literature [9,20,32,33]. However, it has been noted that many of these works merely focused on the enhancement effect of synergy [8,21], and its counterpart cannibalization is an important aspect that has been ignored. The phenomenon of cannibalization often refers to a reduction in portfolio return as a result of the introduction of a new similar product by the similar producer. To address the unilateral influences of interaction, our aim in the present paper is to develop a project portfolio selection model considering both possible positive and negative impact on project portfolio management.

Another critical characteristic of the project portfolio problem is the high degree of uncertainties involved in the decision making process, such as uncertainties in the project return, human resource, and interaction among the projects. To cope with these uncertainties,

* Corresponding author.
E-mail addresses: yingliu@hbu.edu.cn (Y. Liu), yliu@hbu.edu.cn (Y.-K. Liu).

http://dx.doi.org/10.1016/j.asoc.2016.09.022
1568-4946/

probabilistic and fuzzy approaches have been proposed to capture the imprecision of model parameters by considering reasonable distributions. Ballestin and Leus [1] investigated resource-constrained project scheduling with stochastic activity durations, and developed a GRASP-heuristic to produce high-quality solutions. Fernande et al. [12] proposed a non-outranked ant colony optimization II method, which incorporated a fuzzy outranking preference model for optimizing project portfolio problem. Carlsson et al. [5] developed a methodology for valuing options on R&D projects, where future cash flows were estimated by trapezoidal fuzzy numbers.

In the literature, some recent researches addressed both uncertainty and interaction of project portfolio selection. For instance, Girotra et al. [15] empirically investigated the structure and significance of these portfolio-level project interactions, and explained the variance in the value of projects based on interactions with other projects in the firm's portfolio. Ghapanchi et al. [14] used data envelopment analysis to select the best portfolio of IS/IT projects while taking both project uncertainties and project interactions into consideration simultaneously. Gemici et al. [13] presented a multistage stochastic program to maximize expected operating income subject to risk, product interdependency, capacity, and resource allocation constraints.

However, as Hall et al. [18] pointed out, the full distributional information about the uncertain return in project portfolio problem is often unavailable. Specifically, when the imprecise parameter is affected by the noise of historic data or the ambiguity of expert's opinion, these approaches depending on the exact distribution will be invalid. Robust optimization [4] is a modeling methodology to process optimization problem, in which the uncertainty can be represented as deterministic variability in the value of the parameter. As a more recent approach to optimization, some authors have used robust optimization to deal with stochastic project portfolio problem. For example, Goh and Hall [16] considered projects with uncertain activity times that came from a partially specified distribution within a family of distributions; Hassanzadeh et al. [19] developed a multiobjective binary integer programming model for R&D project portfolio selection, where each imprecise coefficient belonged to an interval of real numbers without prior distribution details; Chen et al. [7] refined a framework for robust linear optimization by introducing a new uncertainty set that captured the asymmetry of the underlying random variables, and demonstrated the framework through an application of a project management problem.

In fuzzy decision systems, credibilistic optimization methods have been studied by many researchers. The interested reader may refer to the recent works [10,11,22–24,31,34], where the possibility distributions of uncertain model parameters are assumed to be known exactly. On the other hand, when the exact possibility distributions of uncertain model parameters are unavailable, some researchers studied credibilistic optimization methods based on distributionally robust model parameters [2,3,25,35], where the distributional robustness refers to the secondary possibility distributions of model parameters are uncertain instead of crisp values in the unit interval [0, 1]. In this study, we employ the interval-valued possibility distribution to describe uncertainty embedded in the secondary possibility distribution, and model the uncertain parameters in project portfolio problems as parametric interval-valued fuzzy variables [29]. More precisely, we take selection variable as the representative of a parametric interval-valued fuzzy variable. The possibility distribution function of a selection variable is variable and depends on spread and location distribution parameters, and it can run over the entire support of the secondary possibility distribution as the location distribution parameters vary their values. The proposed optimization model based on variable possibility distributions leads to robust parametric optimization method for our project portfolio selection problem.

This paper aims to discuss the project portfolio selection problem by a novel robust credibilistic optimization method and wants to gain more insights into project portfolio regarding project interaction. The main contributions of this paper can be summarized as follows.

- We employ interval-valued possibility distributions to characterize uncertain parameters in project portfolio selection problem. When the exact possibility distributions of the uncertain model parameters are difficult to be determined by historic data or the experiences of experts in advance, using our distributionally robust optimization method to model practical project portfolio selection problems can provide a decision maker a set of optimal solutions under various values of distribution parameters, which may facilitate the decision maker to make his informed decision for the project portfolio selection problem.
- Based on optimistic value optimization criterion, a new parametric credibilistic optimization model is built for project portfolio selection problem. The proposed optimization model shows that the portfolio objective of an organization is to maximize the optimistic value of the total portfolio returns under a prescribed credibility level instead of maximizing the expected total project portfolio return.
- In our project portfolio selection problem, we identify two interactions—synergy and cannibalization, and discuss the computational issue considering the additional returns among interactive projects.
- To facilitate the solution of the proposed credibilistic project portfolio selection model, we analyze the properties of optimistic value objective as well as credibility constraints, and turn the original project portfolio selection model into its equivalent mixed-integer programming models. As a result, conventional optimization softwares can be employed to solve our equivalent mixed-integer programming models, hence the original project portfolio selection problem.

The remainder of this paper is organized as follows. Section 2 reviews some basic concepts in fuzzy possibility theory. Section 3 illustrates the problem setting with the consideration of project interaction, and constructs a credibilistic project portfolio selection model based on optimistic value criterion. Section 4 derives the analytical expressions of optimistic value objective and credibility constraints. Section 5 presents the equivalent parametric mixed-integer programming of credibilistic project portfolio selection model. Section 6 conducts some numerical experiments to illustrate our new modeling idea and the efficiency of the proposed parametric programming approach. Section 7 gives our conclusions in this paper.

2. Preliminaries

In this section, we briefly recall some basic concepts in fuzzy possibility theory [29,30], which will be used to model our project portfolio selection problem.

Let $(\Gamma, \mathcal{P}(\Gamma), \tilde{P}os)$ be a fuzzy possibility space [30]. A map $\tilde{\xi} = (\tilde{\xi}_1, \tilde{\xi}_2, \ldots, \tilde{\xi}_n) : \Gamma \mapsto \Re^n$ is called an n-ary type-2 (T2) fuzzy vector. When $n = 1$, the map $\tilde{\xi}$ is called a T2 fuzzy variable.

Please cite this article in press as: Y. Liu, Y.-K. Liu, Distributionally robust fuzzy project portfolio optimization problem with interactive returns, Appl. Soft Comput. J. (2016), http://dx.doi.org/10.1016/j.asoc.2016.09.022