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Project selection and adjustment based on uncertain measure

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ABSTRACT

This paper discusses a project selection and adjustment problem in the situation where some project parameters are given by experts' estimates because of lack of historical data. Uncertain variables are used to describe these project parameters and the use of them is justified. Based on uncertain measure, a cost overrun risk which describes the average amount of investment outlay exceeding the available budget is proposed, and a new optimization model which simultaneously considers the selection of new projects and the adjustment of existing ones is developed. To solve the proposed problem, the deterministic equivalents of the model are provided and a genetic algorithm is offered. As an illustration, an example is also presented and discussed.

1. Introduction

To maintain its competitiveness, a company needs to optimally allocate its resources like capital and lands to not only new projects but also the existing project adjustments such that the total investments can bring the company maximum profit. This is project selection and adjustment problem. In the past, little attention was paid to the existing project adjustments. Scholars used to focus on only new project selection. Since it is usually difficult to give exact and determinate project parameter values, scholars explored a number of ways to handle project selection problems with indeterminate project parameters. Traditionally, researchers regard the indeterminate parameters as random variables, and the most important contribution in the field was made by Charnes and Cooper [4] who proposed a chance-constrained programming method to deal with the problem. Since then, scholars have considered more realistic settings and proposed a variety of programming methods to handle the problems. For example, Gustafsson and Salo [16] developed a contingent portfolio programming for project selection. Medaglia et al. [31] proposed an evolutionary approach for selecting multiobjective linearly constrained projects. Fang et al. [10] added security portfolio selection into project selection. Gemici-Ozkan et al. [15] proposed a semiconductor industry project selection method. And Shakhsi-Niaei et al. [33] considered real-world constraints like segmentation, logical, and budget constraints and used a two-phase Monte Carlo simulation method to select projects under randomness.

Though probability theory helps people greatly in selecting projects with indeterminate project parameters, its use is on the condition that people have enough suitable historical data. However, in some situations people may lack historical data. Nothing but experts' belief degrees of the project parameters are available. For example, for new projects that produce new types of products, there are no historical data about the initial outlays or the future incomes. Then the parameters have to be given by experts' estimations instead of by historical data. However, it is found that people's estimations can be very

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different from probabilities [34] and using people's belief degrees as probabilities to make decision can lead to counterintuitive results. Here, we give an example. Suppose there are 10 independent projects whose return rates are identically and uniformly distributed between 6% and 11%. Investors want to know if they evenly allocate their capital to these ten projects whether the total return rate can be equal to or bigger than the target rate which is set at 11%. It is clear if investors have sufficient historical data, they can use uniform random variables evenly distributing between 6% and 11% to describe the project return rates and get that $\Pr\{\sum_{i=1}^{10} \xi_i/10 \geq 11\%\} = 0$ where ξ_i denotes the return rate of each project. It is seen that the total investment return cannot be bigger than the target return rate of 11%. However, suppose investors have no historical data and can only estimate the parameter values of the project return rates. Kahneman and Tversky [25] have found that when lacking past data, people give too much weight to the chance of unlikely events, which implies that people include in their estimations much wider range of values than the indeterminate parameter may really take. Suppose in the case, people estimate that the return rate of each project will distribute evenly between 5% and 30%. Then if investors still treat the estimations as probabilities, it can be got from random simulation that this time $\Pr\{\sum_{i=1}^{10} \xi_i/10 \geq 11\%\} \approx 1$, which implies that it is almost sure that they can get return rate equal to or bigger than 11%. This result can also be confirmed by the law of large numbers. It is seen that by inappropriately using probability theory, an event that will surely not happen is derived to be an event that will surely happen. For more paradox examples, readers can find them in Liu [29] and Zhang et al. [38].

To deal with the project selection problems with the parameters given by people' estimations, scholars have done a lot of research work. With the introduction of fuzzy set theory, scholars explored using fuzzy set theory to handle the problems. For example, Avineri et al. [1] proposed a technique in the selection of transportation projects using a fuzzy weighted average. Kahraman et al. [23] developed the formulas of fuzzy present value, fuzzy equivalent uniform annual value, fuzzy future value, fuzzy benefit-cost ratio and fuzzy payback period for capital budgeting. Kahraman et al. [24] used fuzzy cash flow analysis to measure flexibility of computer integrated manufacturing systems. Huang [17] extended Markowitz's mean-variance idea to provide an alternative fuzzy project selection method. Liao and Ho [26] proposed a fuzzy binomial approach for project evaluation. In addition, Bhattacharyya et al. [3], Zhang et al. [37], Bas [2], and Fernandez et al. [11] discussed different fuzzy project evaluation and selection problems.

These works widened the research perspective for dealing with project selection problems with parameters given by people's estimations. However, further research has found that paradoxes will appear if fuzzy variables are used to describe the estimations of project parameters. Let us mention an example here. Suppose we regard net cash flow of a project as a fuzzy variable. Then it should have a membership function. Suppose it is a triangular fuzzy variable $\xi = (2, 3, 4)$ million dollars. In the fuzzy world, possibility measure and necessity measure are the two basic measures. According to the possibility theory, it is known that $\text{Pos}\{\xi = 3\} = \text{Pos}\{\xi \neq 3\}$ and $\text{Nec}\{\xi = 3\} = \text{Nec}\{\xi \neq 3\}$. In other words, the net cash flow being *exactly 3 million dollars* and *not exactly 3 million dollars* have the same possibility measure and necessity measure, which implies that the two events will happen equally likely. This conclusion is too unreasonable to accept. To model indeterminate quantities given by human beings, Liu [27] proposed an uncertain measure and further developed an uncertainty theory [28] based on an axiomatic system of normality, self-duality, countable subadditivity, and product uncertain measure. Considerable theoretical and application works have been done based on uncertain measure. For example, Liu [27] defined uncertain variable based on uncertain measure and presented the concept of uncertainty distribution to characterize the uncertain variable. Gao [12] studied the properties of continuous uncertain measure. Peng and Iwamura [32] proved a sufficient and necessary condition of uncertainty distribution. Chen and Liu [8] proved the existence and uniqueness theorem for uncertain differential equations. Chen and Ralescu [9] solved a truth value problem in uncertain logic. Chen [5] calculated and proved the properties of the variation of uncertain stationary independent increment processes. Yao and Li [35] proved an uncertain alternating renewal theorem for an uncertain alternating renewal process. In application field, by using uncertainty theory, paradoxes mentioned above disappear. In fact, it has been proven in Liu [30] that people's belief degrees satisfy the four axioms of the uncertainty theory, which implies that uncertainty theory is suitable for modeling human uncertainty. So far, scholars have successfully solved many optimization problems with parameters given by people's estimations by using uncertainty theory. For example, Huang [18] produced an uncertain portfolio theory by introducing uncertainty theory into portfolio selection field. Later, Huang proposed a risk index for measuring portfolio risk [19] and Huang and Ying [21] further solved a portfolio adjustment problem based on risk index. In other optimization fields, Gao [13] handled a shortest path problem, and Gao [14] offered a method for single facility location on networks. In 2011, Zhang et al. [36] proposed a multi-national new project selection method with project parameters given by experts' estimations. In this paper, we will apply uncertainty theory to further discuss an optimal new project selection and existing project adjustment problem.

The rest of the paper is organized as follows. In Section 2 we will develop an optimization model for dealing with the uncertain project selection and adjustment problem. In Section 3, we will provide the deterministic equivalents of the model, and in Section 4 we will present a genetic algorithm for solving the problem. Then in Section 5, we will offer an example. Finally, in Section 6, we will give some concluding remarks. In addition, to help well understand the paper, fundamentals of uncertainty theory will be briefly reviewed in the Appendix.

2. Uncertain project selection and adjustment model

Consider a company which has k numbers of projects in operation. Due to the change of the market, the company is considering if it needs to adjust the existing k projects. In the meantime, there are m numbers of new projects. The company