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Project selection and scheduling with uncertain net income and investment cost

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ABSTRACT

This paper discusses an R & D project selection and scheduling problem in which there are no historical data about the project parameter values. The net income and investment cost in the problem are given by experts' evaluations and treated as uncertain variables. The different interactions among projects and the flexibility of project beginning time are considered. A new cost overrun risk is employed and a new optimisation model for R & D project selection and scheduling problem is given. Furthermore, deterministic equivalents of the model are presented and a genetic algorithm is designed for solving the proposed problem. As an illustration, a numerical example is provided.

1. Introduction

Project selection problem is concerned with selecting a suitable combination of projects from candidates so that the company can obtain maximum profit. A major contribution to the theoretical formulation of the problem was made by Weingartner [31]. In his paper, Weingartner first introduced a mathematical programming method to solve the problem. The objective in his model was to obtain maximum net present value (NPV) and the constraint was budget limitation. He treated the investment cost and net income as deterministic numbers. Later on, a great number of models were extended to increase the relevance and applicability of the basic model to the real world situations. For example, Liberatore [17] developed an expert support system for industrial R&D project selection. Santhanam and Kyparisis [29] considered interdependencies in information system project selection. Padberg and Wilczak [27] investigated the difference between borrowing rates and lending rates. Badri et al. [1] integrated disciplines like R & D, capital budgeting, investment plans, into health service institutions. Lawson et al. [16] applied an R & D project selection model into a small to medium-sized enterprise in UK. All these projects are supposed to begin at the zero time simultaneously. However, the investment capital available at zero time is limited. If all the projects begin simultaneously, some projects would not be selected because of the lack of capital at the beginning time even though the company can have investment capital at subsequent time. If projects can begin at different time, i.e., some begin at zero time and some begin later, the company can make full use of capital and obtain more profits. This type of problem contains project selection and scheduling, and is more complicated than pure project selection. So far, research on this problem is limited. A few scholars such as Coffin and Taylor, Sun and Ma, Medaglia et al., Carazo et al., and Liu and Wang [3,30,25,2,23] have studied this kind of problem. Nevertheless, in all these studies, the project parameters are deterministic values which are not suitable for the real world problem in many situations. In this paper, we are particularly interested in the R & D project selection and scheduling problem in which no one can give the

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exact numbers of the candidate projects parameters. All that a company has about the parameters are just belief degrees offered by experts. People's belief degrees usually have much greater variance than the real frequencies because of their conservatism or optimism. Then if we use probability theory to handle belief degrees, counterintuitive results may occur [22]. In order to model belief degrees, Liu founded an uncertainty theory [18] with its further development [21]. Based on uncertainty theory, Liu [19] proposed uncertain programming which is a type of mathematical programming for solving optimisation problems involving uncertain variables. Nowadays, uncertain programming has been applied to solve a wide range of optimisation problems with parameters given by experts' evaluations, e.g., vehicle routing and project scheduling problems [21], shortest path problem [5], facility location problem [6], single-period inventory problem [28], uncertain aggregate production planning problem [26], and uncertain multi-product newsboy problem [4], etc. Especially, uncertainty theory was first introduced into portfolio selection by Huang [9], accordingly, producing a theory of uncertain portfolio selection. After that, extension of uncertain mean–variance model [11] was further studied, uncertain risk curve [10] and uncertain risk index [12] methods were proposed, and multi-period uncertain portfolio selection [13] and uncertain portfolio adjustment problem [14] were further researched. In 2011, Zhang et al. [32] first applied uncertainty theory to solve a multinational project selection problem with uncertain foreign exchange rates, uncertain operating income and uncertain investment cost of foreign projects. Here, we explore using uncertainty theory to solve an R & D projects selection and scheduling problem according to experts' belief degrees of projects parameter values.

The paper proceeds as follows. Section 2 defines a cost overrun risk and proposes a new project selection and scheduling model. Section 3 presents the deterministic equivalent of the proposed model in general situations and the deterministic equivalent when net income and investment cost are normal uncertain variables. We will provide a genetic algorithm to solve the proposed problem in Section 4. Section 5 presents a numerical example as an illustration. Finally, we will conclude the paper in Section 6. In addition, for better understanding, we will review some fundamentals of uncertainty theory in the Appendix.

2. Uncertain project selection and scheduling model

2.1. Risk index

How to define risk is always an important topic in project selection. In 1952, Markowitz [24] first used variance to define risk. Huang [11] extended Markowitz's idea to portfolio selection with returns given by experts' evaluations. However, variance does not provide direct information about the loss degree level. To make it easy for investors to feel loss degree level, risk index is defined by Huang [12] to measure average loss degree compared with risk free interest rate. In this paper, we extend the idea [12] to capital budgeting to define a cost overrun risk index which measures the average investment amount exceeding the budget.

Definition 1. *Let ξ denote the investment cost of a project and B the investor's available budget at the beginning of the investment. Then the cost overrun risk index is defined by*

$$RI(\xi) = E[(\xi - B)^+],$$

where

$$(\xi - B)^+ = \begin{cases} \xi - B, & \text{if } \xi \geqslant B, \\ 0, & \text{if } \xi < B. \end{cases}$$

Theorem 1. *Let ξ be uncertain investment cost whose uncertainty distribution Φ is continuous and monotonous. Then the cost overrun risk index is expressed as follows:*

$$RI(\xi) = \int_{\beta}^{1} \left(\Phi^{-1}(\alpha) - B\right) d\alpha, \tag{1}$$

where β is obtained via $\Phi^{-1}(\beta) = B$.

The theorem can be proven in a way similar to that in the paper [12]. We omit it here.

It is seen from Definition 1 that the risk index *RI* measures an average amount of investment cost exceeding the available budget. Usually it is easy for investors to tell their tolerable amount toward cost overrun. Thus, let *D* denote the investors' tolerable cost overrun amount, the project is regarded to be affordable if

$$RI(\xi) \leqslant D.$$

2.2. Optimal uncertain project selection and scheduling model

To understand the uncertain project selection and scheduling problem, consider a company that plans to launch several new R & D projects. To use capital available properly in different months, the company does not only need to decide which