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A packing-multiple-boxes model for R&D project selection and scheduling

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Abstract

R&D project selection has been a popular research topic since the 1960s, but the scheduling issue has rarely been considered in such research. This paper records the development and application of a heuristic packing-multiple-boxes (PMB, or multi-knapsacks-model) model, which is based on the packing-single-box (PSB) model. The PMB model can be used for both selecting and scheduling candidate R&D projects. The model was established at the request of a case company that conducts up to 20 large R&D projects simultaneously. The example of using this model at the case company for a five-year planning period is provided. Although the model may not be a optimistic one, it provides one solution to solve this problem.

Keywords: R&D project selection; Scheduling; Packing-multiple-boxes model; 0–1 integer programming

1. Introduction

This paper is based on research applied to a case company, here referred to as Company H. Company H conducts large R&D projects that are characterized by the following three features. First, the projects consume up to tens of millions US dollars. Second, the projects' time spans last from several years to decades with highly variable annual costs. Third, many large projects are conducted simultaneously. At the beginning of every five-year planning period, Company H faces a problem of selecting, as well as scheduling, candidate R&D projects in order to meet the budgetary limitations.

At the time this research started, Company H had eight candidate R&D projects for the forthcoming five-year period. Their total and annual costs in this planning period are shown in Table 1, with all the data having been filtered for reasons of confidentiality. Although projects P1, P2, and P3 were started in the previous planning period, such ongoing projects may be suspended or even cancelled if their contributions are lower than new candidate projects after the re-evaluation prior to the forthcoming planning period. As such, they are also regarded as candidate projects at the beginning of every planning period. Projects P4–P8 are new candidates, and P5 and P6 will last more than five years. It should be noted that the procedure for estimation of total costs is omitted in this paper, but readers who are interested in project cost estimation are directed to references including those of Humphreys and English (1993); Greer and Nussbaum (1990).

The total budget for the forthcoming planning period is 440 monetary units (Table 1). The money is appropriated to Company H annually from its government. The average budget for each of the five years is 88 units. The government allows only plus/minus 16% variation (budget flex) around the average budget figure each year.

The priorities in terms of the importance and contribution of each of the candidate projects are estimated by the experts of Company H using a 0–100 scale. The detailed criteria for measuring the importance and contribution were not, however, open to the author. The final data concerning candidate projects are shown in Table 1, with candidate projects being ranked according to their priority score. The company desires the selected projects to start as early as possible. The importance of the projects at Company H is very much time-related and the risk is high. If a project is

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Table 1
The contribution scores, total costs, and annual costs of the 8 candidate projects, and the total and annual budgets, for the forthcoming five-year period

Project	Priority	Total Cost	Annual cost				
			Year 1	Year 2	Year 3	Year 4	Year 5
P1	88	70	21	26	23		
P2	76	71	30	24	17		
P3	65	74	28	27	19		
P4	53	62	4	11	26	16	5
P5	41	160	9	10	34	49	58
P6	32	161	21	25	30	35	50
P7	29	92	4	12	30	32	14
P8	29	63	2	9	23	21	8
Sum		753	119	144	202	153	135
Budget		440	88	88	88	88	88

delayed at the start or suspended at some time during its execution, its importance and contribution will decrease. However, the company does not quantify the decrease in the contribution.

The estimated cost of the eight candidate projects is 753 units, which exceeds the available budget by some considerable margin. It is clear that not all of the candidate projects can be supported in the forthcoming five-year period. Some of them should be selected while others should be rejected or delayed. In the past, Company H used to select projects according to their contribution value under the constraint of the total budget (i.e. 440 units). For the forthcoming five-year period, such a method would select projects P1–P5 under the constraints of the total budget, at a total cost of 437 units. The selected projects would start from the first year of the period. Other projects that were rejected would be considered for the next five-year period, assuming that their contribution scores remained sufficiently high at that stage. The solution seems appropriate for the selection of R&D projects. A portfolio of R&D projects is selected under the financial constraint and the objective value is maximised. However, if the total annual costs of the selected projects are distributed year-by-year along the five-year period, problems occur even supposing the total budget is sufficient, as shown in Fig. 1. In some years, some projects executed by Company H have run out of financial resources and the projects had to be suspended, while in other years, the company had to consider how to use all the available financial resources. The schedule needed to be adjusted every year. This, therefore, was the problem that Company H had experienced in the past and which it wants to solve for the forthcoming five-year period.

The occurrence of this problem is related to the special shape of the annual cost distribution of large R&D projects. The annual cost distribution is represented by a mathematical function that relates project cost and time. Such a function is called a cost curve. The cumulative cost of large R&D projects follows an S-shaped curve (Humphreys and English, 1993; Murmis, 1997) as shown in Fig. 2(a). However, the milestone costs (e.g. annual costs) follow a bell-shaped curve (Humphreys and English, 1993, p. 152), as shown in Fig. 2(b).

The annual costs of all the R&D projects in Company H follow the bell-shape curve, as the data in Table 1 reflect. Because some R&D projects at Company H last more than five years, the data in Table 1 show just part of the bell-shape cost curve for projects P1, P2, P3, P5, and P6. When several projects are overlapping as scheduled using the current method of Company H (i.e. all projects are scheduled to start in the first year), the total annual costs of these projects will be uneven and will diverge from the budget line. That is why in some years the total annual costs are higher than the resources available and the project plan is disrupted, while in other years the total annual costs are lower than the budget and the available resources are not sufficiently used, as experienced in the past by Company H. Therefore, it is necessary to construct a multi-project schedule during the project selection process so that the total costs in each year of the planning period will be close to budget and show a smooth pattern over the five-year period. In summary, the tasks of Company H at

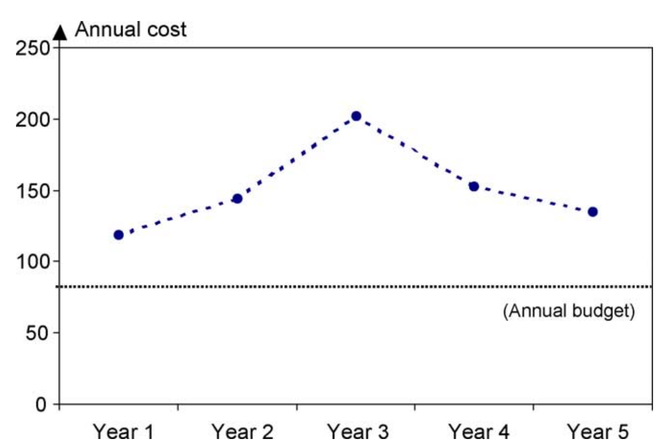

Fig. 1. The distribution of total annual cost according to the original scheduling method used by Company H (annual budget = 88 units).