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A hybrid knowledge and model system for R&D project selection

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Abstract

Decision models and knowledge rules are widely used to assist in decision-making. They are common decision support devices that should be effectively managed in decision support systems. Research and development (R&D) project selection is a complicated and knowledge intensive decision-making process where decision models and knowledge rules play an important role. This paper presents a hybrid knowledge and model system, which integrates mathematical models with knowledge rules, for R&D project selection. The system is designed to support the whole decision process of R&D project selection and has been used in the selection of R&D projects in the National Natural Science Foundation of China (NSFC). © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Selection of research and development (R&D) project is an important and recurring activity in many organizations. It is also a challenge task that takes place in a complicated and knowledge intensive decision-making process (Ghasemzadeh & Archer, 2000). In the past four decades, a variety of decision models have been developed to support the R&D project selection (Martino, 1995). According to a recent literature review (Henriksen & Traynor, 1999), the current decision models and methods fall into the following categories: (1) *Mathematical Programming and Optimization*, including integer programming (IP), linear programming (LP), non-linear programming (NLP), goal programming (GP), and dynamic programming (DLP), portfolio optimization. (2) *Decision Analysis*, including multi-attribute utility theory (MAUT), decision trees, risk analysis, the analytic hierarchy process (AHP), and scoring; (3) *Economic Models*, such as internal rate return (IRR), net present value (NPV), return on investment (ROI), cost-benefit analysis, and option pricing theory; (4) *Interactive Method*, such as Delphi, Q-Sort, behavioral decision aids (BDA), and decentralized hierarchical modeling (DHM). But due to the complexity of these models, most of them can hardly be used by managers in real situation (Liberatore & Stylianou, 1995; Schmidt & Freeland, 1992).

Recently, decision support systems (DSS) have been developed and used for R&D project selection. They are

to facilitate the use of the models and to support decision activities in R&D project selection (Ghasemzadeh & Archer, 2000; Kocaoglu & Iyigun, 1994; Liberatore, 1988a,b; Stewart, 1991). Liberatore (Liberatore, 1988a,b; Liberatore & Stylianou, 1995) reports the use of expert support systems and DSS for R&D project selection where AHP is used for strategic planning, spreadsheet model for rating projects, and cost-benefit analysis with ILP for resource allocation. An integrated DSS has been proposed for R&D project selection (Iyigun, 1993). It uses scoring method for project screening, AHP for criterion weight, Delphi for collecting information on requirements, ILP with heuristics for resource allocation, and NPV for analysis of benefit interactions. A DSS (Ghasemzadeh & Archer, 2000) has been developed that uses linear goal programming (LGP) and AHP methods to integrate multiple objectives into a single objective, and 0–1 integer LP to maximize the overall objective of the portfolio. However, current DSS can hardly integrate knowledge rules and decision models to support the whole process of R&D project selection.

This paper reports the experience of building an hybrid knowledge and model system for the R&D project selection in the National Natural Science Foundation of China (NSFC) (Tian et al., 2002). The system makes use of both models and knowledge rules and supports the whole decision support process. Decision models are used to deal with well-structured decision problems, while knowledge rules are appropriate for ill-structured decision situations. They complement each other and provide powerful supports to the whole decision making processes.

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Table 1
Major decision tasks in R&D project selection process

Decision task	Decision-makers	Responsibilities
Proposal submission	Department as well as the division managers of NSFC	Ensure the completeness of proposal
	Applicants Research office coordinators of the institutes the applicants affiliated	Ensure the applicants and the proposal meet the requirements
Assignment of external reviewers	Division managers Managers of other divisions	Assign each proposal to one or more peer reviewers For those across disciplines, may transfer to another division
Peer review	Division managers External reviewers	Peer reviewers evaluate the proposals assigned Division managers coordinate the process as coordinators Validate the peer reviewer's results
Aggregation of review results	Division managers	Make decision for those unvalid review results Recommend proposal list for panel evaluation (margin proposals selection)
Panel evaluation	Department and division managers Domain experts employed	Make decisions for margin proposals Suggest a funded list
Final decision	Top managers Department and division managers	Confirm the final recommendation list Adjust the list and treat exception cases

The rest of this paper is organized as follows. Section 2 introduces the background information on the R&D project selection at NSFC. The proposed hybrid knowledge and model system is described in Section 3. Section 4 discusses the implementation issues. Section 5 gives the conclusions.

2. Background

Founded in 1986, the NSFC is the largest government funding agencies in China with the primary aim to promote basic and applied research. There are seven scientific departments, four bureaus, one general office and three associated units at NSFC. The scientific departments are the decision units responsible for the selection and management of projects. They are classified according to the scientific research areas, e.g. mathematical and physical sciences, chemical sciences, life sciences, earth sciences, engineering and material sciences, information sciences, and management sciences, respectively. Departments are further divided into 40 divisions with different focus on specific disciplines.

Every year, the NSFC receives more than 25 000 proposals. The project selection process is coordinated by the top managers of NSFC and is accomplished by the seven scientific departments as well as their divisions. The overall project selection task is decomposed and assigned to departments, and departments further decompose their tasks and assign to divisions. Division managers then assign external reviewers and experts to evaluate proposals. NSFC has a unique way of project selection. It relies greatly on external experts (i.e. external reviewers and panel members) to evaluate and recommend projects for funding in a fair and reasonable manner. For this purpose, it maintains an

external reviewer database with more than 30 000 records, and employs more than 700 experts from 69 disciplines for panel evaluation.

The major decision tasks of the R&D project selection in NSFC are summarized in Table 1. Totally, there are six tasks: *Proposal submission*, *Assignment of external reviewers*, *Peer review*, *Aggregation of review results*, *Panel evaluation*, and *Final decision*. For each of these tasks, usually a group of decision makers are involved. Table 1 presents the task names, decision-makers involved and their responsibilities.

During its peak seasons in March/April, NSFC staff (both department and division managers) are extremely busy with proposal submission and evaluation of proposals. An individual manager may have to check hundreds of proposals in a week to ensure the validity of the proposals and their applicants. Soon a matching of proposals with external reviewers is conducted and the evaluation forms are to be sent out for external reviewer's comments. After the external reviewers return their evaluation comments, managers have to aggregate the evaluation results for each proposal. To reduce the burden of decision makers, a hybrid knowledge and model system is proposed and developed where decision models as well as the knowledge rules are designed to facilitate the decision-tasks of R&D project selection.

3. The hybrid knowledge and model system

3.1. Architecture overview

The system architecture of the hybrid knowledge and model system for R&D project selection is shown in Fig. 1.

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