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European Journal of Operational Research 172 (2006) 1018–1039
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

Interfaces with Other Disciplines

Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology

Harel Eilat, Boaz Golany *, Avraham Shtub

Faculty of Industrial Engineering and Management, The Technion—Israel Institute of Technology, Technion City, Haifa, 32000 Israel

Received 18 November 2003; accepted 8 December 2004
Available online 28 January 2005

Abstract

We propose and demonstrate a methodology for the construction and analysis of efficient, effective and balanced portfolios of R&D projects with interactions. The methodology is based on an extended data envelopment analysis (DEA) model that quantifies some the qualitative concepts embedded in the balanced scorecard (BSC) approach. The methodology includes a resource allocation scheme, an evaluation of individual projects, screening of projects based on their relative values and on portfolio requirements, and finally a construction and evaluation of portfolios. The DEA–BSC model is employed in two versions, first to evaluate individual R&D projects, and then to evaluate alternative R&D portfolios. To generate portfolio alternatives, we apply a branch-and-bound algorithm, and use an accumulation function that accounts for possible interactions among projects. The entire methodology is illustrated via an example in the context of a governmental agency charged with selecting technological projects.

Keywords: Data envelopment analysis; R&D projects; Portfolio analysis; Balanced scorecard

1. Introduction

Portfolio selection problems can be decomposed into two major classes: dynamic vs. static problems. In the dynamic class (Bard et al., 1988; Cooper et al., 1997), at every decision point there are projects that have already started—denoted as *active* projects, and a set of proposed projects—known as *candidate* projects. The decision space includes both groups, and may involve the continuation of active projects at various budgeting levels; termination of other active projects; and launching new projects. In this paper we focus

* Corresponding author. Tel.: +972 4 829 4512; fax: +972 4 829 5688.
E-mail address: golany@ie.technion.ac.il (B. Golany).

0377-2217/$ - see front matter
doi:10.1016/j.ejor.2004.12.001

Nomenclature

n_p	total number of projects
G	a group of candidate projects
Q_k	the group of projects in portfolio k
m	number of inputs (resources) for a project/portfolio
s	number of outputs (benefit dimensions) for a project/portfolio
R	$m \times n_p$ matrix of available/allocated inputs (resources)
R_i	total amount of input/resource i available
r_{ic}	amount of input (resource) i allocated to category c
x_{ij}	amount of input (resource) i required for project j
y_{rj}	amount of output (benefit) r expected from project j given success
v, μ	vectors of variables associated with the inputs and outputs in the DEA model
$\hat{x}_{ik}$	amount of input (resource) i required for portfolio k
$\hat{y}_{rk}$	amount of output (benefit) r expected from portfolio k given success
p_j	probability of success of project j
U^i	the resource interaction matrix of input (resource) i
V^r	the value interaction matrix of output (benefit) r
P	the outcome interaction matrix
B^r	the expected value interaction matrix of output (benefit) r
z_k	a vector that represents a particular selection of projects in portfolio k ($z_{jk} = 1$ if project j is included portfolio k, otherwise $z_{jk} = 0$)
C_ℓ	group ℓ of measures representing a BSC-like card

on the class of static portfolio selection problems (e.g., Beaujon et al., 2001; Basso and Peccati, 2001). This class addresses situations in which all the projects that are considered at the decision point are candidates.

The static setting may occur in both the business and the government sectors. As an example of the former, consider a venture capital firm that wishes to invest resources in a set of new technologies. It sets aside a certain budget dedicated for this purpose and announces a "call-for-proposals" to solicit proposals in various areas. Similarly, in the not-for-profit sector, a governmental agency may have a certain budget dedicated for new projects. Decision points may occur once a period, and the decision is which new projects to support.

Such decision problems are an important management issue (Roussel et al., 1991; Cooper et al., 1997). Given that in technology-based organizations the technology strategy is directly linked to the organization's strategy, medium and long-term success of such organizations is often determined by the effectiveness of the portfolio selection process (Roussel et al., 1991, Chapter 6; Schmidt and Freeland, 1992).

The rationale of constructing an R&D project portfolio is quite similar to that of constructing a financial portfolio. As observed by Markowitz (2002), an investing agent concerned only with the expected value of financial options would have been required to invest only in one stock to maximize the value of such a portfolio. However, diversification of financial options is a common practice whose aim is to avoid the risk of "putting all eggs in one basket". The same rationale works in the context of R&D projects where risk is one of the main characteristics of the environment and, typically, a single R&D project cannot reflect properly the many objectives of an R&D strategy. Hence, diversification in R&D projects is essential.

The static portfolio selection problem is a complex one. It is concerned with the allocation of scarce resources, such as funds, manpower and facilities, to a set of candidate projects that best serves the objectives of the relevant organization, in the face of tradeoffs among key strategic dimensions (e.g. risk and reward,