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Application of the non-outranked sorting genetic algorithm to public project portfolio selection

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ABSTRACT

This paper proposes the application of multi-criteria analysis to the problem of allocating public funds to competing programs, projects, or policies, with a subjective approach applied to define the concept of highest portfolio social return. This portfolio corresponds to an attainable non-strictly outranked state of the social object under consideration. Its existence requires a decision-maker (*DM*) to establish a relational preference system of minimal consistency. As the number of feasible portfolios increases exponentially, the *DM*'s asymmetric preference relation should be computable to perform an exploration of the portfolio space. The complexity of many real situations requires evolutionary algorithms, but, in presence of many objectives, evolutionary algorithms are inefficient. We overcome this problem by using the extended non-outranked sorting genetic algorithm (*NOSGA-II*), which handles multi-criteria preferences through a robust model based on a binary fuzzy outranking relation expressing the truth value of the predicate "portfolio *x* is at least as good as portfolio *y*". The *DM* is assumed to be capable of assigning the parameters for constructing the outranking relation. In case of collective decision-making, we first assume that the possible differing values of the group members are not strongly conflicting, so that a consensus can be achieved on the model's parameters. Otherwise, we propose a method in which each member of the heterogeneous group gets his/her own best portfolio. These individual solutions are then aggregated in a group's best acceptable portfolio, which maximizes a measure of group satisfaction and minimizes regret.

The proposal is examined through two real size problems, in which good solutions are reached; the first example is useful to illustrate the case of social-action program selection; the second illustrates the case of basic research project portfolios.

1. Introduction

A central and frequently contentious issue in public policy analysis is the allocation of funds to competing projects. Public financing for social projects is particularly scarce. Very often, the requested budget ostensibly overwhelms what can be granted; moreover, strategic, political and ideological criteria pervade the administrative decisions on such assignments (cf. [20,35]). For accomplishing normative criteria, such as those underlying prevalent public policies or governmental

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ideology, it is convenient to prioritize projects and construct project-portfolios according to rational principles (e.g., maximizing social benefits). According to [15], public projects may be characterized as follows:

- The projects may be undoubtedly profitable, but their effects are indirect, perhaps only visible in the long term, and hard to quantify.
- Aside from their potential economic contributions to social welfare, there are intangible benefits that should be considered to achieve an integral social view.
- Equity, concerning impacts and the social conditions of the benefited individuals, should also be considered.

Governmental decision-makers (*DM*s) and top managers of funding organizations must solve two related problems:

(i) evaluation of particular projects; and
(ii) creation of a project-portfolio.

Although the strategic objective requires solving (ii), some kind of (i) is required as a premise. The most popular approach is cost-benefit analysis (e.g., [3]) though it has received important criticisms (cf. [4,10,14,20,24]) such as:

- the presence of numerous public goods for which no market price is available;
- the difficulty of evaluating "benefits" and "costs" from a "social point of view";
- the difficulty of measuring some effects in well-defined units and, thus, to price them out;
- the rationality of "social preferences" is still open to question, but if social preferences are ill-defined, the meaning of the net social present value of a project is far from obvious;
- the controversial character of the social discounting rate, and moreover, the difficulty of assigning a suitable value to it;
- the controversial assumption of a perfect capital market;
- the overwhelming presence of uncertainty (technological changes, future prices, etc.);
- the difficulty of considering irreversible effects;
- the presence of effects that are highly complex, which may demand very long time periods;
- the presence of effects which are very unevenly distributed among individuals and which can raise important equity concerns.

A contending approach is multi-criteria analysis, which comprises a variety of techniques for exploring the preferences of concerned *DM*s as well as models for analyzing the complexity inherent to real decisions. Some of the broadly known multi-criteria approaches are MAUT (cf. [28]), AHP (cf. [39,40]), and outranking methods [5,22,36]. Multi-criteria analysis constitutes a good option to overcome the limitations of the cost-benefit analysis because it may handle intangibles, ambiguous preferences, and veto conditions. Different multi-criteria methods have been proposed for addressing project evaluation and portfolio selection (e.g., [2,12,15,16,25,31,33,34]. Their advantages are documented in the specialized literature (e.g., [27,30,46]).

Multi-criteria analysis offers techniques for:

- selecting the best project or a small set of equivalent "best" projects (called P_α problem) according to the known classification by Roy [37];
- sorting projects into several predefined categories (e.g., "good", "bad", "acceptable") (P_β problem); and
- ranking projects from the best to the worst (P_γ problem).

These methods are appropriate for evaluating and ranking projects, since multi-criteria information is aggregated at the project level. However, as far as portfolio selection is concerned, the usefulness of multi-criteria methods is questionable. They work on the set of projects, but portfolio selection is a problem of choosing among a set of feasible portfolios, hence multi-criteria information should be aggregated at the portfolio level. The point is that the decision should be made based on the best portfolio rather than on the best individual projects. It is simply not sufficient to compare one project with another. Instead, it is necessary to compare portfolios. The best projects do not necessarily compose the best portfolio.

There are three basic ways of making comparisons at the portfolio level:

First: Each portfolio value is calculated by aggregating the values of its component projects (cf. [14,16,31]). The main difficulty is that projects' values should be assessed in a ratio scale (cf. [16,31]), which may require an enormous effort from the *DM*, mainly when synergetic combinations of projects are considered (e.g., [6]). Additionally, such assessments become questionable, even meaningless, when the *DM* is not a single person but a heterogeneous group.

Second: Each portfolio (let us denote it by C') can be seen as a way to transform the current state of the social object under consideration (denoted by E_0) into a different state E'. From a normative point of view, there should be a value function U agreeing with the *DM*'s preferences on the set of feasible states of the social object. If a cardinal value function U is assessed, the value of C' can be measured by $U(E') - U(E_0)$. Unfortunately, the practical value of this statement is strongly limited for several reasons (cf. [20]). The existence of such cardinal value functions is not guaranteed for real *DM*s (see [37] for a