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Portfolio Selection: Assessment of a Framework

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PORTFOLIO SELECTION: ASSESSMENT OF A FRAMEWORK

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ABSTRACT

Decision-making often involves selecting a "portfolio" of alternatives, rather than a single option. For example, in assembling an IS project team, rather than picking one "best" employee, multiple employees are selected based on various skills to fill different positions. The value of the employees depending not only on their individual competency skills, but also on how well they work as a team. The team synergy is important, and the "value" of the portfolio (i.e. IS project team in this case) is different from the sum of the values of the individual team members. Though many studies have been published on portfolio selection in diverse contexts, most of these studies tend to focus on specific problem environments and cannot easily be generalized. This paper assesses and enhances a previously published, general framework for portfolio decisions with respect to its usefulness in classifying and understanding decision problems.

Keywords

Multiple criteria, portfolio selection, decision support

INTRODUCTION

Most individual or organizational portfolio selection decisions involve multiple objectives, which are often incommensurate and conflict with one another. In addition, these decisions are also subject to constraints, further increasing complexity. Techniques to deal with multiple criteria portfolio decision-making (MCDM) problems have been introduced as early as the 1950s using mean-variance analysis (Markowitz, 1952). Markowitz's work is perhaps the principal contributor to investment portfolio decision-making. Since then much more research work has been conducted to improve the existing portfolio selection model and also broaden the scope of portfolio decision-making into the realm of research and development (R&D) project selection, research proposal selection, product/supplier selection, team selection, etc. Regardless of the context of the portfolio selection problems, the ultimate goal of a decision maker is to maximize value by selecting the "ideal" combination of alternatives, i.e. the best portfolio. A number of research studies have been conducted since then to improve the mean-variance model that can deal with multiple objectives in portfolio selection (Klapka and Pinos, 2002; Dörner et al., 2004; Ehrgott et al., 2004). Unlike Markowitz's model that focuses on quantitative values of return and risk, more recent research includes non-quantitative criteria such as quality (Hu and Wang, 2008), competence (Stummer and Kiesling, 2009; Gutjahr et al., 2010) and team synergy (Baykasoglu et al., 2008). To find a "best" solution using non-quantitative criteria (linguistic variables), the application of mathematical programming techniques is not sufficient, hence the emergence of meta-heuristic approaches such as Pareto ant colony optimization (Dörner et al., 2004), supplemented by an integer linear programming preprocessing procedure (Dörner et al., 2006), simulated annealing (Baykasoglu et al., 2007) and genetic algorithms (Stummer and Kiesling, 2009). Researchers have also applied fuzzy logic to deal with non-statistical data and imprecision and uncertainty (Lin et al., 2005; Baykasoglu et al., 2007), where linguistic variables are replaced by suitable fuzzy numbers that can be used in arithmetic operations.

Clearly evidenced from the analysis of the literature is that multiple criteria portfolio selection deals with many different kinds of problems, which require different solution approaches. Thus most published studies focus on specific problem environments and suggest very specific solution methods, which cannot easily be generalized (Weistroffer and Smith, 2005). For this reason Weistroffer and Smith (2005) propose an object oriented framework as a theoretical foundation for classifying problem types and solution approaches and thereby help future researchers and practitioners to solve various types of portfolio problems. The purpose of the framework is not to present a general solution method to solve portfolio selection problems, but rather to identify and classify real world decision problems and to map these problems to appropriate solution approaches. However, the framework has not been evaluated or tested, thus prompting us to try to validate the framework. We use the term "validate" here in an informal sense, meaning that we investigate the applicability and usefulness of the framework in classifying portfolio selection applications, and their solution approaches and mapping specific solution approaches to specific types of portfolio problems. Looking at prior studies from various areas such as financial investment, team selection, project selection, and product/supplier selection, we investigate the fit between the framework and the actual multiple criteria portfolio selection problems identified in these papers. Additionally this paper will also look at limitations and gaps in the framework.

RESEARCH PROCEDURE

To find papers describing portfolio selection, several databases were searched without date restriction, specifically IBM INFORM, Academic Search Complete, ACM Digital Library and Business Source Complete. The following key words were used: Multiple Criteria, Multiple Objectives, Markowitz, Portfolio Selection, Team Selection, Project Selection, Product Selection, Supplier Selection and Decision Support Systems. The inclusion criteria were primary research studies irrespective of research methodology, which focused upon multiple alternatives and solution method. We also manually searched the reference lists of relevant papers identified in the primary search. Initially, abstracts of the papers found were reviewed in accordance with the inclusion criteria, and the full texts of the selected abstracts were retrieved. All selected papers were critically analyzed using the framework by Weistroffer and Smith (2005).

THE THEORETICAL FRAMEWORK

The portfolio selection framework can be represented by a three dimensional matrix as shown in Figure I. Weistroffer and Smith (2005) identified three dimensions along which to differentiate multi criteria portfolio selection problems, which are portfolio cardinality, alternative type, and dependency type. Based on these three dimensions, as shown in Figure I, twelve possible problem types emerge. The following section describes each of these dimensions and categorizes prior literature into specific problem domains and solution methods used.

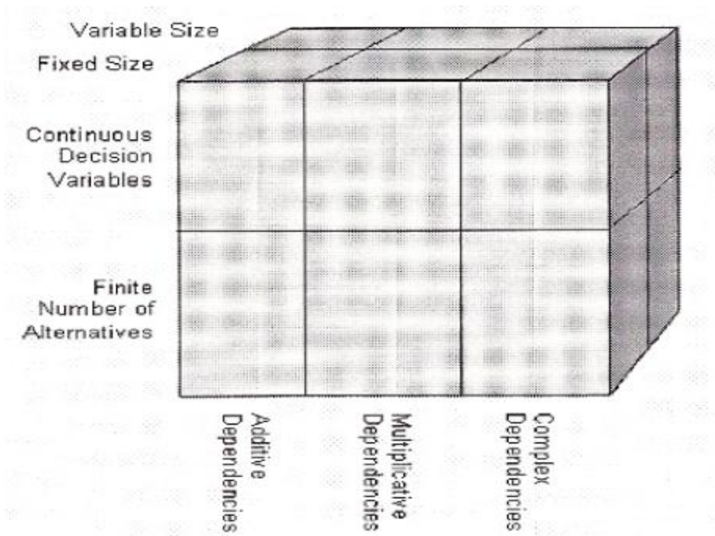

Figure I. Types of Portfolio Decision Problems

Dimension 1 – Cardinality of the Portfolio

When selecting a portfolio of investments, team members, projects, etc, the number of alternatives that make up the portfolio may be fixed in advance or may be variable. An example of a fixed size portfolio may be hiring exactly 4 new faculty members for an information systems department at a university, or selecting the starting players in a soccer match (exactly 11). For variable size portfolios, the exact number of members in the portfolio is determined only during the selection process, based on other criteria. An example given by Weistroffer and Smith (2005) is an automobile maker's decision on the type of car engines offered. More options in car engines will satisfy a wider spectrum of consumer preferences, while fewer options would simplify the production process. Thus the size of the portfolio is influenced by two factors, 'production cost' and 'coverage'.

There have been published studies that deal with fixed size, as well as studies that deal with variable size portfolios. Fitzpatrick and Askin (2005) propose a solution method for forming effective work teams consisting of 4, 8 or 12 members. Hsieh (2010) proposes a model for selecting cross-functional/cross-departmental teams with the objective of maximizing the contribution of different knowledge areas for product development. The complexity of the assessment criteria, i.e. the various members' capabilities, restricts the model to teams consisting of 2 to 10 members only. Other studies have focused on variable size portfolios. For example Dong et al. (2004) propose an integrated framework for selecting efficient investment portfolios, which can change based on individuals' specific preferences and experiences. In the same vein but in a different context, Stummer and Kiesling (2009) deal with the selection of projects with the objective to maximize current and future competence. The proposed tool does not require the decision-maker to pre-determine the size of the project portfolio, but rather allows them to explore the solution space (efficient portfolios determined in the first phase) to determine their preferred portfolio. Numerous other approaches have been used to solve variable size portfolios such as meta-heuristics optimization methods (Gutjahr et al., 2010; Stummer and Kiesling, 2009), analytical hierarchy process (Kunene and Weistroffer, 2008) and fuzzy logic (Baykasoglu et al., 2007; Lin et al., 2005).

Dimension 2 – Discrete or Continuous Set of Alternative

The second dimension for classifying real world multi criteria portfolio selection problems deals with discrete or continuous alternatives. In discrete alternative problems, the decision space consists of a finite set of potential alternatives and each of the alternatives is explicitly known. Typical examples include selecting among different stocks for investment, selecting projects for development, and selecting among the individuals to form a team.

Continuous alternative problems involve an infinite set of alternatives determined by constraints and evaluated by some utility or value function. The decision maker must construct the most appropriate portfolio based on his or her preferences and depending on criteria functions. A typical context may be designing a product, as in the auto engine portfolio example of Weistroffer and Smith (2005), where engine characteristics, such as horsepower, fuel efficiency, and cost may be modeled as continuous functions. Numerous published studies deal with discrete alternative multiple criteria portfolio selection (Klapka and Pinos, 2002; Abdelaziz et al., 2007; Baykasoglu et al., 2007; Lin et al., 2005). The study by Klapka and Pinos (2002) looks at the issue of large size R&D portfolios. The proposed approach can handle multi-criteria selection of hundreds of projects simultaneously with tens of criterion functions, both linear and non-liner, and tens of resource limitations. The interactive model combines both Steward's (1991) scalarizing function and the synergistic effects approach of Santhanam and Kyparisis (1995). Yu et al., (2009) propose optimal assets allocation based on a pre-determined number of assets with consideration of the quality of the assets. In a different context, Baykasoglu et al., (2007) and Hsieh (2010) consider team selection where the number of employees in the solution space is known. Sun and Steuer (1996) develop an interactive procedure known as Quad Tree purposely to solve the discrete alternative multiple criteria problem. In spite of the realization of the existence of continuous alternatives problems there has been very little work published on solving this type of problem, with the exception of the work of Narasimhan et al. (2006). In their work, the solution space is determined by a set of parameters, including both pricing and non-pricing aspects such as quality of the product, delivery reliability, responsiveness and innovativeness of the product. In its simplest form, the buyers' strategic purchasing objective function is known, and the solution space can include any values that satisfy the objective function constructed from the continuous criteria or attributes.

Dimension 3 – Additive, Multiplicative and Complex Dependency

Additive dependency type can be explained as a situation where the value provided by the alternatives that comprise the portfolio complement each other. For example Dong et al., (2004) propose an integrated framework for selecting efficient investment portfolios, which can change based on individuals' specific preferences and experiences. The portfolio value can be expressed as a sum of the values of the members of the portfolio (Weistroffer and Smith, 2005).

Multiplicative dependency refers to the synergistic effects due to interactions among the members of the portfolio. For example, Fitzpatrick and Askin (2005) look at the selection of teams, where the skills of selected workers are considered in ensuring that the group as a whole has the necessary skills to be an effective team that can work together. Hsieh (2010) also highlights the importance of synergistic effects by taking into account interpersonal characteristics such as the non-additive cooperative effects and capability overlaps. Along the same line, the project selection model of Klapka and Pinos (2002) allows for the calculation of synergistic benefits occurring between two or three projects using the synergistic effects approach of Santhanam and Kyparisis (1995). Baykasoglu et al., (2007) emphasize the interpersonal relations between team candidates. Their model accounts for constraints such as preventing specific persons to be on the same team with specific other persons.

Complex dependency arises when the effects that the members on the portfolio have on each other cannot be categorized as either additive or multiplicative (Weistroffer and Smith, 2005), i.e. when the effect is important, but cannot easily be modeled. The best example to describe this may be the work of Gutjahr et al., (2010). Looking at project selection, they include different competencies and job assignments of project participants to ensure that the skills complement each other. However, their model not only takes into account employees' different skill sets, but also learning and knowledge depreciation effects. This knowledge depreciation is not a pre-determined attribute of the employees, but will emerge over time (in the portfolio) and hence is a portfolio attribute. Another example may be the work of Narasimhan et al. (2006) on supplier selection with product life-cycle (PLC) considerations. The authors suggest that PLC is a very important aspect because selection criteria (both financial and non-financial) change over time across different stages of the PLC. Thus the decisions for product selection (and probably the suppliers as well) need to be evaluated or reassessed at different stages of the PLC, clearly making this a complex relationship.

Author(s)	Problem Type							Category	Solution Method	Portfolio
	Portfolio Size		Alternative Type		Dependency Type					
	Fixed	Variable	Discrete	Continuous	Additive	Multiplicative	Complex			
Dong et al. (2004)		√	√		√			T7	Mean-Variance Optimization	Financial Investment
Abdelaziz et al. (2007)		√	√		√			T7	Stochastic Model	Financial Investment
Yu et al. (2009)		√	√		√			T7	Genetic Algorithm (GA) Optimization	Financial Investment
Ballestero et al. (2009)		√	√		√			T7	Stochastic Goal Programming (SGP) and Fuzzy Set theory	Financial Investment
Dia (2009)		√	√		√			T7	Data Envelopment Analysis	Financial Investment
Ehrgott et al. (2004)		√	√		√			T7	Local search approach, simulated annealing, tabu search and genetic algorithm	Financial Investment
Stummer and Keisling (2009)		√	√			√		T8	Genetic Algorithm (GA) and an Ant Colony Optimization (ACO)	Project Selection
Gutjhar et al. (2010)		√	√				√	T9	Nondominated Sorting Genetic Algorithm II (NSGA-II) and Pareto ant colony optimization (P-ACO)	Project Selection
Dörner et al. (2004)		√	√				√	T9	Metaheuristic Approach - Pareto Ant Colony Optimization	Project Selection
Lin and Hsieh (2004)		√	√		√			T7	Fuzzy Theory	Project Selection
Carazo et al. (2010)		√	√				√	T9	Metaheuristic procedure - Scatter Search	Project Selection
Klapka and Pinos (2002)		√	√			√		T8	Scalarizing function and synergistic effects.	R&D and IS Project Selection
Hu et al. (2008)		√	√			√		T8	Mean-variance analysis and goal programming approach	R& D Project Selection
Jung and Seo (2010)		√	√		√			T7	Analytical Network Process (ANP)	R & D project selection
Steward (1991)		√	√		√			T7	MCDM Optimization	R&D Project Selection
Glickman (2008)		√	√		√			T7	Stepwise Procedure	R & D Program Portfolio Selection
Lin et al. (2005)		√		√	√			T10	Fuzzy Weighted Average	Strategic Business Unit (SBU) Selection
Hsieh (2010)	√		√			√		T2	Fuzzy set theory, augmented max-min approach and factor space theory	Team Selection
Baykasoglu et al. (2007)		√	√			√		T8	Fuzzy Optimization Approach	Team Selection
Fitzpatrick and Askin (2005)	√		√			√		T2	Heuristic Approach	Team Selection
Narasimhan et al. (2006)		√		√			√	T12	Heuristic Approach	Supplier Selection
Sun and Steuer (1996)		√	√					Not represented	Quad Tree Data Structure	Non-specified

Table 1. Classification of Decision Portfolio Selection Problems

Decision Category	Definition
T1	Fixed Size Portfolio, Finite Number of Alternative and Additive Dependencies
T2	Fixed Size Portfolio, Finite Number of Alternative and Multiplicative Dependencies
T3	Fixed Size Portfolio, Finite Number of Alternative and Complex Dependencies
T4	Fixed Size Portfolio, Continuous Number of Alternative and Additive Dependencies
T5	Fixed Size Portfolio, Continuous Number of Alternative and Multiplicative Dependencies
T6	Fixed Size Portfolio, Continuous Number of Alternative and Complex Dependencies
T7	Variable Size Portfolio, Finite Number of Alternative and Additive Dependencies
T8	Variable Size Portfolio, Finite Number of Alternative and Multiplicative Dependencies
T9	Variable Size Portfolio, Finite Number of Alternative and Complex Dependencies
T10	Variable Size Portfolio, Continuous Number of Alternative and Additive Dependencies
T11	Variable Size Portfolio, Continuous Number of Alternative and Multiplicative Dependencies
T12	Variable Size Portfolio, Continuous Number of Alternative and Complex Dependencies

Table 2. Decision Problem Categorization

THREE DIMENSIONAL PERSPECTIVES

In this second part of the paper we try to map problem contexts of prior studies to one of the 12 categories corresponding to the 12 cubes in Figure I, as well as identify the solution methods that have been used for each of these categories. Our results, as shown in Tables 1 and 2, show that the actual multiple criteria portfolio selection problems identified in these papers do seem to fit with the framework of Weistroffer and Smith (2005). Although a few decision categories such as T1, T3, T4, T5 and T11 are not represented here, we believe that applications in those categories may very well arise. The main objective of the framework, i.e. provide a theoretical foundation for portfolio selection problems in different environments, seems to be validated. Studies on multiple criteria portfolio selection problems come from different application contexts such as financial investment, project selection, team selection, and supplier selection, with varying solution techniques. The results show some consistency in the decision models in specific contexts, for example, in financial investment where all problems seem to be of type T7 (variable size portfolio, discrete number of alternative and additive dependencies). Interestingly, while the problems are of the same type, the solution techniques are diverse, giving the decision maker more options to select the technique that best suits him or her. In the project selection environment, three models are frequently used: T7, T8 and T9. The problems however, share the same portfolio size and alternative type, only differing on the dependency type. This dissimilarity is expected because some projects deal with synergistic effects due to resource constraints and contingency between projects. Others exhibit complex relationships when the start date of one project depends on the end date of the other project. In team selection our results show multiplicative dependency, discrete alternative, but different portfolio size types (T2 and T8).

WEAKNESSES OF THE FRAMEWORK

A weakness of the framework is its lack in addressing diverse kinds of constraints, different from what was previously realized and what is included in many of the published studies. For example many of the studies consider budget limitations as a constraint for the overall portfolio, however in reality, portfolio investments are also subject to segmentation, policy, and logical constraints (Mavrotas et al., 2008). Thus for example, as Mavrotas et al. (2008) point out, in the selection of university research proposals a constraint my be that all departments must be represented, regardless of the proposals' overall rankings, and that certain types of research must be included at specific levels (e.g. 30 %). In another scenario, Hsieh (2010) proposes a model that can deal with the selection of team members from different departments and Fitzpatrick and Askin (2007) point out the constraint of skill categories in team selection. Thus we purport that in the future, the framework may be improved by explicitly embedding the segmentation issues.

CONCLUSION

While many researchers have studied the portfolio selection problem and accompanying solution methods, Weistroffer and Smith (2005) argue that they tend to be problem environment specific and hence cannot easily be generalized. They propose a framework for the general portfolio selection decision problem for classifying portfolio problems according to exemplifying characteristics. In this paper we validated the framework as to how well it represents problem types encountered in the real world by examining prior research on portfolio selection. We conclude that the proposed framework is able to help decision maker in categorizing portfolio selection problems and hence may help in identifying appropriate solution methods.

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