PROJECT PORTFOLIO SELECTION BASED ON GRASP

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Abstract: The selection and scheduling of a portfolio of projects is a task frequently found among the strategical activities performed by management staff in several industries. When choosing a project to be selected and scheduled into a portfolio, managers have to deal with conflicting criteria, resource constraints, distinct scenarios, and changes during the planning and execution phases. In this work, we describe the functionalities of a decision support system (DSS) prototype designed to help managers make better decisions, when constructing a portfolio of projects. The DSS software was developed to solve portfolio selection problems originating at a large corporation in the power generation industry. It implements a heuristic algorithm, which finds solutions at least 50% nearer the best solution for a real-word input instance, when compared to manually produced solutions.

Keywords: decision making, metaheuristics, project portfolio, scheduling.

INTRODUCTION

Decision makers are usually confronted with the problem of constructing a project portfolio by selecting and scheduling projects over a period of time. This is known as the project portfolio selection (PPS) problem. There are several formulations for the PPS problem and various methods for solving PPS variants have been proposed in the literature [1], [2], [3]. A PPS problem can be summarized as follows: given a set of projects, with the corresponding resource requirements and limitations to be executed over a predetermined time horizon, find an instance of a project portfolio, that is, a selection and a schedule of projects, that maximizes a given objective function over all viable portfolios.

DSS softwares and frameworks have also been proposed for the PPS problem. Stewart [4] presents a multi-criteria DSS for R&D projects selection for the power generation industry. Archer and Ghasemzadeh [5] present frameworks for the development of DSS, as well as examples of DSS prototypes. More recent examples of DSS were presented by Klapka [6], and Lin et al. [7].

In Section 2, we present a particular variant of the PPS problem found in the power generation industry. Section 3 briefly describes a greedy heuristic for solving the PPS problem based on the GRASP metaheuristic and presents experimental results demonstrating the heuristic's quality. In Section 4, we present a prototype for a decision making support system that implements the heuristic and offers features that support the construction, modification, and comparative analysis of portfolios. Finally, in Section 5, we summarize the results and discuss new improvements.

Problem Description

AES-Tietê is a leading power generation company operating in Brazil, whose mission is to generate and sell energy by safer and sustainable means. To achieve such a mission, AES-Tietê managers are responsible for the yearly task of selecting and scheduling projects over a period of time, given their costs and abilities to control risk, and the company available resources; i.e. there is the yearly task of constructing a project portfolio. We describe here the characteristics and assumptions on the input data available to decision makers at AES-Tietê.

Planning Horizon (PH): A sequence of monthly periods; usually 60 months.

Available Resources: Yearly amount of available resources.

Projects: A set of projects provided by AES-Tietê technical staff, each project comprising several parameters:

1) *Project identifier*: a unique, numeric identifier.

2) *Controlled risk*: a value that indicates how much risk will be controlled by the project, in case it is selected and executed. The greater the controlled risk, the larger is the avoided risk.

3) *Costs*: project costs as distributed along the PH.

4) *Resource category*: projects can be classified into two resource categories (CAPEX or OPEX) according to the nature of the costs they incur [8]. The total sum of project costs per year cannot surpass the amount of resources available in that year, for each resource category.

The initial input data provided by AES-Tietê defines not only the set of projects and constraints, but also a project portfolio, that is a manual solution to the PPS called the *initial portfolio*. Even though the initial portfolio is a valid solution for the PPS problem, we do not take it into consideration during the optimization process. We adopted as the PPS objective function the portfolio cumulative controlled risk, that is, the sum of controlled risk contribution from all projects, in order to reward controlling as much risk as possible, and as early as possible. The contribution of a project is measured from its termination month to 2T, where T is the number of months in the PH. A period of 2T months was used to accommodate projects that go beyond the end of the PH.

In a companion paper [8], [9], we formalize a model that describes the input instance, the constraints, the objective function, as well as the heuristic for solving the PPS problem presented here.

Heuristic Solution and Experiments

Heuristic

The DSS prototype presented here implements the k-random cascading risk greedy heuristics (kCRGH), a simple variant of the GRASP [10] metaheuristic designed by us to solve the PPS problem. GRASP is a multi-start metaheuristic that generates good quality solutions for many combinatorial optimization problems.

The kCRGH algorithm implements a slightly modified version of the GRASP construction phase, avoiding the candidate list update and the local search phase in order to improve computational performance. For sorting all possible pairs of projects and months within the PH, we used a benefit function [8] that expresses a trade-off between the total contribution to controlled risk and the total cost of each project, when scheduled at a certain month.

Experiments

We performed experiments to evaluate the quality and the performance of the kCRGH heuristic implemented in the DSS prototype. The heuristic running-time, the objective function value, and the ratio of the objective function value to a PPS upper bound given by starting all projects in the first month, were used as indicators of solution quality. To assess the indicator values and test the robustness of the heuristic, we devised an experiment that consisted of comparing the manual portfolio solution for a real-world instance to the solution generated by kCRGH for the same instance. For a better assessment of the quality indicators and the robustness of the procedure, we also constructed a sample of new datasets using the real-world instance provided by AES-Tietê as a seed and generating similar "real-world"-like instances by randomly disturbing the seed portfolio data. Companion paper [9] gives more details about the input data.

We generated 50 portfolio instances for each of the following disturbance factors: 5%, 10%, 20%, and 30%. These 200 instances plus the seed instance were submitted to the kCRGH algorithm. We adopted, as an optimization parameter a kCRGH/GRASP window size of 5 items when selecting randomly the next item from the candidate list. The optimization procedure was executed 20 times for each input instance, and the best solution was retained for each disturbance factor (DF). Table 1 shows the ratio of the manual portfolio objective function (IOF) to the upper bound (UB). The next columns show the ratio of the optimized portfolio objective function (OOF) to the upper bound (UB), the ratio of the optimized to initial portfolio objective function value (OOF/IOF), and the kCRGH running time (20 repetitions).

Solutions found by kCRGH are at least 50% nearer the best solution in terms of controlled risk, considering the average OOF/UB of 93.49%, when compared to the manual solution, whose average IOF/UB is 88.45%. Moreover, the solutions found by the heuristic obtained this gain in controlled risk, while spending at most the same amount of resources needed in the manual solution. Even disturbance factors as high as 30% did not change this behavior.

Table 1. IOF/UB RATIO, OOF/UB RATIO, OOF TO IOF RATIO , AND RUNNING TIME (TIME) AVERAGE VALUES FOR 0%, 5%, 10%, 20%, AND 30% DISTURBANCE FACTORS WITH A PH OF FIVE YEARS AND 219 PROJECTS.

DF	IOF/UB	OOF/UB	OOF/IOF	Time (s)
0	88,44%	93,51%	1,0573	50,21
5	88,44%	93,48%	1,0570	50,85
10	88,46%	93,49%	1,0569	51,26
20	88,44%	93,47%	1,0568	51,00
30	88,47%	93,50%	1,0569	51,04

A DSS Prototype

We developed a prototype for a decision support system (DSS), called the AES Project Manager, as a part of an ongoing research project whose aim is to improve power generation industry management practices at AES-Tietê.

The design of the prototype focused on the individual project evaluation and portfolio selection phases of the portfolio selection process. A more extensive DSS for the

PPS problem would involve a more elaborate analysis of the complete portfolio selection process, along the lines proposed by Archer and Ghasemzadeh [5, 11], or Chu et al. [12]. On the other hand, the DSS prototype covers and extends the three minimum requirements proposed by Stewart [4], namely: generating good feasible solutions; generating alternative solutions rapidly; and allowing the user to perform what-if scenario evaluations by changing constraints and parameters.

The AES Project Manager prototype implements the kCRGH heuristic, and also allows for portfolio data management and visualization facilities. The software is a client-server, dynamic web application developed in Python using the Django 2.4 framework in accordance with the MVC architecture. Its persistence is based in the integration of Django and PostgreSQL. The presentation layer makes use of the well established JQuery framework and a chart generation javascript framework. The prototype was designed to offer the following features:

a) Portfolio and project management: The portfolio and project management functionalities include features such as the importing of spreadsheet data describing the PPS problem input instance, the exporting of a portfolio to a spreadsheet file, and the CRUD operations over projects and portfolios. These features facilitate what-if scenario evaluations during the portfolio selection process, by allowing to test the effects of adjustments on some project parameters.

b) Portfolio optimization: The portfolio optimization functionality is responsible for the definition of the problem parameters and the execution of the heuristic. When a user selects the optimization feature for the current set of projects, the system shows a form where the user can define the main parameters.

c) Portfolio comparison: To aid the decision maker, the presentation of comparisons is visually attracting, showing data from two or more portfolios in the same graph, and allowing the selection of one of several portfolio parameters (cost, risk, etc.).

d) Data visualization: Portfolio and project parameters relevant to the decision maker, including monthly costs, yearly costs, yearly risks, and cumulative risk, are presented by charts and tables.

CONCLUSION

Project portfolio selection is a problem found in several relevant industries in different circumstances, such as in the power generation industry.

We presented a DSS prototype that implements a GRASP-based heuristic and several features, including data visualization, construction of portfolio solutions using an efficient newly proposed heuristic, and portfolio edition allowing decision makers to test "what-if" scenarios.

Future work will involve the inclusion of new features for use in the phase of individual project evaluation. Future studies will also contemplate the actual usage of the DSS prototype during the planning and construction of a project portfolio in real-word scenarios at large companies.

ACKNOWLEDGMENT

The authors would like to thank AES-Tietê for their technical support and real data releases, and the National Agency for Electrical Energy (ANEEL) for their financial support (grant PD 0064-1021/2010).

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