Journal of Computer Science

Original Research Paper

An Optimal Portfolio Selection based on a Hybrid Approach to improve Projects Oriented Organizations

Driss El Hannach, Rabia Marghoubi and Mohamed Dahchour

National Institute of Posts and Telecommunications, Cedoc "2ti", "STRS" Laboratory, "Seeds" Team, Allal Al Fassi Avenue, Rabat, Morocco

Article history
Received: 01-07-2018
Revised: 24-10-2018
Accepted: 02-11-2018

Corresponding Author:
Driss El Hannach
National Institute of Posts and Telecommunications, Cedoc "2ti", "STRS" Laboratory, "Seeds" Team, Allal Al Fassi Avenue, Rabat, Morocco
Email: elhannach@inpt.ac.ma

Abstract: Nowadays, managing and allocating resources to the project portfolio is one of the most critical decision-making processes in project-oriented organizations. To achieve the most value in terms of profitability, these companies should consider taking advantage of ongoing projects and optimal management of their resources allocated to the most optimal project portfolio. Project Portfolio Selection (PPS) and resource allocation are critical problems in project portfolio based companies. These organizations are required to evaluate, prioritize and select their projects in accordance with the strategic and operational mission and objectives. In this study, we propose a three-stage hybrid approach for prioritizing and selecting an optimal project portfolio. We obtain the maximum economic contribution (maximum fitness) between the final PPS and the projects initial prioritizing while considering various organizational criteria and objectives. The proposed approach is composed of three stages with several steps. We use information entropy for the initial prioritizing, the branch and bound algorithm for generating combination of project portfolios and Integer Linear Programming (ILP) for selecting the most suitable project portfolio according to strategic and operational objectives. At the end, a case study is used to demonstrate the applicability and the merits of the proposed approach.

Keywords: Projects Prioritization, Project Portfolio Selection, Information Entropy, Branch and Bound, Integer Linear Programming

Introduction

Employees are confronted with decisions in their professional life. A manager in an organization needs to evaluate suppliers to develop partnerships with the best. A decision-maker is faced with the problem of prioritizing projects to only introduce the best projects to the portfolio. In addition to the problems of classification and choice, there are also problems with classification. The practices often performed in a company classify the projects into categories based on their priorities. This shows that the important problems (problems of classification, choice and sorting) of decision making are frequently encountered. These decision problems are complex because they involve several criteria. Generally, there is no single solution to meet all the criteria. A compromise must be found by the decision makers to solve the multi-criteria decision problems. They can use conventional approaches such as the weighted sum. This approach is not refined because it assumes a linearity of preferences that does not reflect the preferences of decision makers. Multi Criteria Decision Analysis (MCDA) methods have been developed to support decision-makers in their decision-making processes. MCDA methods provide techniques for finding compromise solutions. These are not methods that lead to the same solution for all decision-makers, but they take into account subjective information also called preference information provided by decision makers. These MCDA methods constitute a discipline composed of mathematics, management, computer science, psychology, social sciences and economics. Their fields of application are broader and can be used to solve several types of problems related to decision-making. Decisions can be tactical or strategic, depending on the time perspective of desired outcomes.

On a daily basis, decision-makers face a multitude of decision-making problems. However, (Roy, 1981;

Roy and Bouyssou, 1993) identified three main types of decisions:

1) Problems with the choice: The goal is to prioritize the alternatives to select the best option. For example, a manager selects the right project from a list of projects for inclusion in the project portfolio
2) Problems concerning sorting: Alternatives are sorted into ordered categories. The goal is to group them according to behaviors and similar characteristics through descriptive, organizational and predictive criteria. For example, projects in an organization can be classified into different categories such as "high performing projects", "medium performance projects" and "low performing projects". The sorting methods are used as initial sieving to reduce the number of alternatives to be considered for a later stage
3) Ranking problems: Alternatives are ranked from best to worst using scores or pairwise comparisons

Many other decision-making problems exist, generally combining the problems mentioned above.

A large number of organizations face the challenge of allocating scarce and limited resources (financial, human, material, etc.) to introduce projects to the portfolio. Each organization releases a more or less fixed budget for the financing of projects in a given period. The budgets allocated are generally insufficient to finance all the projects. The objective is to select, after prioritization, the portfolio of projects that can be financed under the budget constraint. Project prioritization is a multi-criteria decision problem that is difficult to manage. The evaluation of projects often requires the use of more or less detailed technical knowledge. Policy makers will sometimes have to rely on project proponents to determine project needs and judge how well projects will meet those needs. However, these promoters may exaggerate claims in order to increase the likelihood of adequate funding. Projects to prioritize have costs and benefits. So choosing among them the best requires difficult comparisons. It is possible to delay some projects, which would significantly increase their costs. Some projects may be riskier than others, which may make them less attractive. Probably, there may be interdependencies between projects that make it more difficult or sometimes impossible to set strict priorities. If there are a large number of proposed projects, identifying the right portfolio of projects can be a difficult problem to solve. In our work, we propose hybrid approach to first prioritize projects using information entropy and second generating feasible portfolios and finally build the optimal portfolio using mathematical programming while respecting the constraints of the resources put at our disposal.

In this study, we propose a hybrid method for PPS problem. We obtain the maximum economic contribution between the final results and the project portfolio's initial sorting taking into consideration various criteria and objectives. Our approach consists of three stages and each stage is developed with several steps and procedures. We use information entropy for initial prioritizing, branch and bound algorithm for generating possible portfolios and finally ILP for deciding of the optimal portfolio in an uncertainty environment.

The rest of this paper is organized as follows: In section 2 the project portfolio selection is discussed. The proposed approach is introduced in section 3. In section 4, a case study is used to demonstrate the applicability of the proposed approach in the organizations. Finally, in section 5, basic conclusions and further research directions are proposed.

Project Portfolio Selection

The complexity of the business environment, the constraints related to the availability of scarce resources and the diversity of projects initiated by organizations make project funding a very important operation and the time spent on this task becomes very valuable (Didem, 2018). The process of project assessment and selection is usually done before the investment decision, habitually using the technical information. The main objective of this project selection process is to analyze the feasibility of projects in order to approve or reject project proposals on the basis of established criteria, following a set of structured steps with checkpoints (Amiri, 2010). The selection and assessment of the candidate projects take into account several criteria that have been studied in several previous works (Roychaudhuri *et al*., 2017; Atal *et al*., 2016; Jun and Cheng, 2017; Kaiser *et al*., 2015; Minken, 2016; Nassif *et al*., 2013; Novoselov *et al*., 2017; Park *et al*., 2015; Xu *et al*., 2015). In general, the aim of the PPS is to select a project portfolio from among several alternatives taking into account the existing limitations and facilities in order to achieve an optimal objective function (Tofighian and Naderi, 2015). One of the most important and commonly used objective functions in the field of PPS is the maximization function of projects profit (Liu and Wang, 2011).

Previously, it was tried to answer the questions related of PPS problem by studying the project selection and scheduling problem. Chen and Askin (2009) proposed a Mixed-Integer Programming (MIP) model with a Net Present Value (NPV) maximization objective function and used an implicit enumeration procedure to solve the problem. Liu and Wang (2011) developed an optimization model for the project selection and scheduling problem based on the Constraint Programming (CP) method using time-dependent resource constraints. Huang and Zhao (2014) studied this problem in the absence of historical

DOI: 10.3844/jcssp.2018.1454.1464

data for the problem parameters. They also developed a Genetic Algorithm (GA) to solve the suggested model.

Tavana *et al*. (2015) proposed a method for selecting an optimal combination of projects. They use respectively in a fuzzy environment the Data Envelopment Analysis (DEA), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and ILP. They use a case study to exhibit the efficacy of the algorithms and procedures. Archer and Ghasezade (1999) have classified methods of PPS into five specific areas including: Ad hoc methods, comparative approaches, scoring methods, portfolio matrices and optimization methods. In the same extension, (Iamratanakul *et al*., 2008) so categorized the PPS models into groups including: Scoring methods, economic methods (payback period, NPV and Internal Rate of Return (IRR)), mathematical programming, real options, simulation modeling and heuristics methods.

There is a considerable body of literature describing an abundant variety of models designed for the project portfolio selection problem. In short, each one methodology only does not cover all of the aspects of the PPS. El Hannach *et al*. (2014) conducted a comparative study of different projects prioritization approaches, through which they deduced that no methodology is complete to solve the PPS problems. Furthermore, the authors conclude that our approach will overcome all the problems and limitations found on the previous approaches as mentioned in the Table 1. In fact, our approach will use information entropy, branch and bound algorithm and mathematical programming which will prevent scalability, time consumption and the difficulty of implementation. From this comparative study, we can deduce that our approach has a positive impact on time, ease of implementation and reducing the complexity of the PPS problem.

Models of PPS capture the various characteristics: Interdependencies, uncertainty and the ability to partially fund or the requirement to either not fund or fully fund projects. They may be complicated mathematically. These characteristics can lead to complicated mathematical programs that include one or more objectives that may be linear or nonlinear, deterministic or stochastic and with variables that are real, integer, or binary. Appropriate solution procedures for these complex mathematical programs are also needed. We will present these in this work.

Table 1: Drawbacks of previous PPS problem

Approaches	Limitations
Analytical Hierarchy Process (AHP)	Is not scalable
Machine learning	Problem of updating FPS
Bubble sort, fuzzy logic	Time consumption
Hierarchy AHP	Difficulty of implementation

Proposed Methodology

Our approach is to generate all the feasible portfolios through a mathematical formulation. Our problem can be written as a non-linear multiobjective program:

$$Max : f_k^{(x)} \quad (1)$$

$$Under\ constraints : C_{ik} \le R_i \quad (2)$$

Where:

$f_k^{(x)}$: The total score (outputs) achieved by the portfolio k

C_{ik}: The total amount of resources i (inputs) needed for the portfolio k

R_i: The total amount of available resources i

This problem is complex because it includes nonlinearities in the objective function, as in the constraints and the variables are binary variables (0, 1). Therefore, the use of an exact resolution method is impractical. To get around this problem, we used a three-level hybrid approach: (1) Reduce the size of the problem through the prioritization of projects; (2) generate efficient portfolios; and (3) find the optimal portfolio.

The propose methodology is composed of three steps. It begins with prioritizing projects proposals regarding their Final Prioritizing Score (FPS). This FPS is calculated by information entropy (Stage1). A branch-and-bound model is then applied to generate alternative portfolios as Decision Making Units (DMUs). The purpose is to generate portfolios for subsequent resources allocation (Stage2). Finally, mathematical programming is performed to demonstrate and validate the desirable portfolio (Stage3). In what follows we describe the methodology in details.

Stage 1: Prioritizing Projects

The main objective of this step is to prioritize projects proposals by applying the method of information entropy. The concept described below is related to our previous work (El Hannach *et al*., 2016) in that we assume the information entropy is like a measure that can be used to model the uncertainty in the steps of evaluating project portfolios in various decision-making problems. The information entropy is a great extent in the process of decision making based on the quality and quantity of information. The concept of information entropy was introduced by Shannon and Weaver (1947) in the field of communication theories. He considers the information entropy as equivalent to the uncertainty. This method has been extended to other disciplines such as statistics, decision theory, economics and social sciences (Wang and Yu, 2011). Its mathematical definition is as follows:

$$E = -\sum_i^n P_i \log P_i \quad (3)$$

where, P_i is the probability of project number ***i*** in the portfolio and ***i*** is the index of this project.

This method is based on qualitative evaluation criteria (high dependence on subjective judgments of managers) and quantitative (values calculated by mathematical models). The information entropy is as weights to evaluate the criteria in order to avoid uncertainty and subjective judgments of decision makers. Several criteria can be combined: Strategic, profitability, resources, management difficulty, risk level and more. Two types of criteria can be distinguished: Positive and negative. The implementation of the information entropy includes ***m*** projects waiting for prioritization and ***n*** evaluation criteria. The problem is represented by a matrix $\boldsymbol{m} \times \boldsymbol{n}$:

$$X = \left[x_{ij}\right]_{m\times n}\left(i = 1,2\ldots\ m \text{ and } j = 1,2\ldots n\right) \quad (4)$$

Which: x_{ij} indicates the performance degree of project number ***i*** against the criterion number ***j***. The information entropy method applied for prioritizing projects is described in the following steps:

1) Standardize the values of the matrix:

- The optimal solution:

$$x_j^* \quad (5)$$

- For the positive criteria:

$$x_{j\max}^* = \max\left(x_{ij}\right) with i = 1,2,\ldots,m \quad (6)$$

- For the negative criteria:

$$x_{j\min}^* = \min\left(x_{ij}\right)\ with\ i = 1,2,\ldots,m \quad (7)$$

- The matrix x'_{ij} represents the weight of proximity:

$$X = \left\lfloor x'_{ij}\right\rfloor_{m\times n} \quad (8)$$

- For the positive criteria:

$$x'_{ij} = \frac{x_{ij}}{x_{j\max}^*} \quad (9)$$

- For the negative criteria:

$$x'_{ij} = \frac{x_{j\min}^*}{x_{ij}} \quad (10)$$

2) Information Entropy E_j and information utility D_j:

$$Compute\ E_j = -k\sum_{i=1}^m x'_{ij}\ \log x'_{ij}$$
$$with\ k = \frac{1}{\log m} and\ 0\ \le E_j \le\ 1 \quad (11)$$

$$Compute\ D_j = 1 - E_j \quad (12)$$

3) Compute the weighting of evaluation criteria:

$$W_j\ = D_j\ /\sum_{j=1}^n D_j \quad (13)$$

4) Compute the value of each R&D projects:

$$f_i\ = \sum_{j=1}^n f_{ij}\ with\ f_{ij} =\ W_j \times x'_{ij} \quad (14)$$

The best project is one that has the greatest value f_i. In the multi project selection, prioritize projects based on this value to select the right projects to form the optimal portfolio.

Stage 2: Generation of Portfolios

After the prioritizing projects with the information entropy method explained above, we focus in this step to generate possible portfolios. For constructing alternative projects, Eilat *et al*. (2006) define a portfolio as an union of smaller portfolios combined with the possible categories of candidate projects.

This step consists in generating the possible portfolios from the candidate projects. Let: $GCP = \{1, 2, 3, \ldots, n\}$ be the set of any Group of Candidate Projects (GCP) and let GP_k the group of projects included in the portfolio k chosen from GCP ($GP_k C\ GCP$). Let the vector V_k representing the selection of projects in the portfolio k ($V_{jk} = 1$ if the project j is included in the portfolio k, otherwise $V_{jk} = 0$). This procedure for generating potential portfolios is based on the availability of inputs made available to the organization to supply projects with the necessary resources. Let x_{ij} be the value of the entry i necessary for the project j and R_i be the total availability of the entry i. the value of the input i allocated to the portfolio k is noted by: $\widehat{x_{ik}}$; it is calculated by the following formula:

$$\widehat{x_{ik}} = \sum_{j=1}^n x_{ij} v_{jk} \quad (15)$$

In order to build the portfolios from the GCP group, we use the branch and bound algorithm as shown in Fig. 1. We start at node number *0* representing the empty project portfolio. We use the following notation: We denote by v_k

DOI: 10.3844/jcssp.2018.1454.1464

the corresponding portfolio and the vector = { $\widehat{x_{ik}}$, $\boldsymbol{i}$ = 1, …,$\boldsymbol{m}$} representing entries for the portfolio. In order to represent graphically the result of the application of the Branch and bound algorithm, we consider in this example four candidate projects (for demonstration reason): $P1$, $P2$, $P3$, $P4$ which need to consume respectively the units of the following resources related to resource R_1: 7, 7, 3 and 8 (R_1 = 16 *units*). Let $\boldsymbol{m}$ = 1 denotes the resource R_1.

Stage 3: Choice the Optimum Portfolio

In this step, after generating the portfolios as virtual DMUs, we apply mathematical programming to the portfolios selected in the second step of our methodology, to choose the project portfolio that produces the maximum benefits, within the limits of available resources.

The standard mathematical model of resources allocation problem is defined as follows: Suppose there are independent candidate projects; that is, we can choose any combination of projects. In addition, the costs and benefits of any project do not depend on other projects included in the portfolio. We define, for each project $\boldsymbol{i}$ = 1, 2, ...,$\boldsymbol{m}$ the variable zero-one x_i. The variable x_i is equal to one if the project is accepted and zero if the project is rejected. Let b_i be the incremental value (profits) of the project $\boldsymbol{i}$ and c_i its costs. Let $\boldsymbol{C}$ be the total available budget.

The objective is to select among the available projects the subset of projects whose total cost is less than or equal to $\boldsymbol{C}$ and which produces the greatest possible value. This problem is expressed mathematically as follows:

$$Maximize \sum_{i=1}^{m} b_i x_i \quad (16)$$

$$Subject\ to: \sum_{i=1}^{m} c_i x_i \leq C$$
$$and\ x_i = 0\ or\ 1\ for\ i = 1, 2, ..., m. \quad (17)$$

Let:

- $\boldsymbol{m}$: number of projects (projects are independent = any combination of projects)
- For each project $\boldsymbol{i}$ = 1,…, $\boldsymbol{m}$ we define zero-one variable x_i
- x_i = 1 if project $\boldsymbol{i}$ is accepted
- x_i = 0 if project $\boldsymbol{i}$ rejected
- b_i is the incremental value (benefit) of the ith project
- c_i is the cost value of the ith project
- C is the total available budget

The goal of this formulation is to select from the available projects, the subset DMU with a total cost less than or equal to $\boldsymbol{C}$ that produces the greatest possible total value

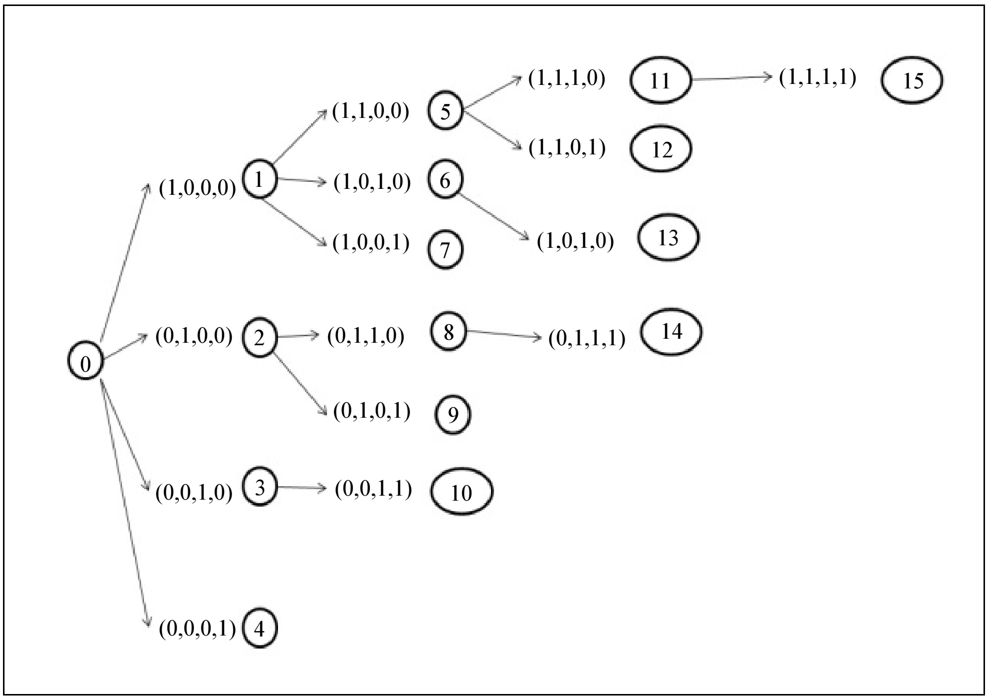

Fig. 1: The branch and bound algorithm illustration

Case Study

We use the following example to illustrate some of the numerical aspects of the proposed methodology. We will take the case of 30 R&D projects extracted from the work done by Eilat *et al*. (2006). These projects are evaluated by five dimensions as shown in Table 2: The economic contribution of projects expressed in monetary terms (US $), the scientific contribution measured on a scale of 0 to 100, the social contribution also measured on the scale from 0 to 100, human resources allocated to projects measured in Full-Time Equivalent (FTE) and material resources calculated in monetary terms (US $). In addition, resources dedicated to the project portfolio are limited and will not allow all projects to be carried out: No more than 300 FTE for human resources and 60,000$ for material resources. To solve this prioritization and selection problem of project portfolio, we apply our methodology explained in the previous chapter.

Stage 1: Candidate Projects Prioritization

In this stage, we prioritize the projects to apply them a filter to reduce the size of the portfolio to compare and also it is not useful to ask the decision-makers to give their in-depth opinions on the projects which are not interesting to priori.

Using the information entropy method (Equation (4) through Equation (14)) on the candidate projects in Table 2, we obtain the projects prioritized by their FPS as indicated by the result of Table 3.

Stage 2: Possible Portfolios Generation

In this stage, we proceed of a sieving to reduce the size of the portfolio to compare on the one hand and it is not wise to ask decision-makers and stakeholders to thoroughly evaluate projects that are not interesting during the first step. Using the result of Table 3, we will calculate the accumulations of the two resources R1 and R2 as presented in Table 4 from which will be retained the first seven projects (representing the threshold of exceeding resources R1 and R2) to build the possible projects portfolios: This problem is complex because with these 30 projects, there would be a possible combination of 1,073,741,824 of different projects portfolios. On the other hand, with 7 projects, we will have to generate 124 of different projects portfolios.

Table 2: Projects extracted from work done by Eilat *et al*. (2006)

Project number	Economic contribution (1000$)	Scientific contribution	Social contribution	Human resources (FTE)	Material resources (1000$)
Project 1	158	30	40	10	8
Project 2	3101	90	95	11	18
Project 3	1240	70	20	114	5
Project 4	137	10	20	13	7
Project 5	1312	90	40	54	21
Project 6	429	95	25	63	7
Project 7	785	95	20	49	20
Project 8	276	15	10	19	4
Project 9	85	10	10	11	13
Project 10	107	90	95	111	3
Project 11	985	35	90	99	15
Project 12	382	25	15	35	9
Project 13	516	70	95	74	14
Project 14	218	20	10	22	8
Project 15	25	20	15	36	9
Project 16	111	24	22	42	14
Project 17	24	21	16	35	20
Project 18	200	37	54	88	12
Project 19	117	11	45	38	23
Project 20	20	25	16	15	21
Project 21	115	12	43	40	14
Project 22	250	19	56	50	15
Project 23	99	20	25	55	9
Project 24	75	13	10	32	15
Project 25	111	13	64	67	19
Project 26	220	18	85	98	13
Project 27	80	9	45	20	20
Project 28	60	12	13	20	25
Project 29	70	13	34	25	15
Project 30	22	18	46	15	20

Table 3: Projects prioritized regarding their FPS

Project number	Economic contribution (1000$)	Scientific contribution	Social contribution	Human resources (FTE)	Material resources (1000$)	FPS
Project 2	3101	90	95	11	18	0,738284
Project 10	107	90	95	111	3	0,707138
Project 1	158	30	40	10	8	0,499984
Project 13	516	70	95	74	14	0,468323
Project 6	429	95	25	63	7	0,422649
Project 3	1240	70	20	114	5	0,406659
Project 5	1312	90	40	54	21	0,393603
Project 8	276	15	10	19	4	0,392526
Project 11	985	35	90	99	15	0,381412
Project 4	137	10	20	13	7	0,371252
Project 7	785	95	20	49	20	0,353023
Project 30	22	18	46	15	20	0,344209
Project 26	220	18	85	98	13	0,326077
Project 9	85	10	10	11	13	0,325922
Project 18	200	37	54	88	12	0,302368
Project 20	20	25	16	15	21	0,287922
Project 27	80	9	45	20	20	0,284564
Project 14	218	20	10	22	8	0,281388
Project 22	250	19	56	50	15	0,276982
Project 29	70	13	34	25	15	0,257423
Project 25	111	13	64	67	19	0,256028
Project 12	382	25	15	35	9	0,255333
Project 21	115	12	43	40	14	0,245229
Project 23	99	20	25	55	9	0,236867
Project 15	25	20	15	36	9	0,235089
Project 19	117	11	45	38	23	0,227804
Project 16	111	24	22	42	14	0,219252
Project 28	60	12	13	20	25	0,208568
Project 17	24	21	16	35	20	0,190859
Project 24	75	13	10	32	15	0,181496

Table 4: Resources R1 and R2 accumulations

Project number	Economic contribution (1000$)	Scientific contribution	Social contribution	Human resources (FTE)	Material resources (1000$)	FPS	Cumul R1 human resources
Project 2	3101	90	95	11	18	0,738284	11
Project 10	107	90	95	111	3	0,707138	122
Project 1	158	30	40	10	8	0,499984	132
Project 13	516	70	95	74	14	0,468323	206
Project 6	429	95	25	63	7	0,422649	269
Project 3	1240	70	20	114	5	0,406659	383
Project 5	1312	90	40	54	21	0,393603	437
Project 8	276	15	10	19	4	0,392526	456
Project 11	985	35	90	99	15	0,381412	555
Project 4	137	10	20	13	7	0,371252	568
Project 7	785	95	20	49	20	0,353023	617
Project 30	22	18	46	15	20	0,344209	632
Project 26	220	18	85	98	13	0,326077	730
Project 9	85	10	10	11	13	0,325922	741
Project 18	200	37	54	88	12	0,302368	829
Project 20	20	25	16	15	21	0,287922	844
Project 27	80	9	45	20	20	0,284564	864
Project 14	218	20	10	22	8	0,281388	886
Project 22	250	19	56	50	15	0,276982	936
Project 29	70	13	34	25	15	0,257423	961
Project 25	111	13	64	67	19	0,256028	1028
Project 12	382	25	15	35	9	0,255333	1063
Project 21	115	12	43	40	14	0,245229	1103
Project 23	99	20	25	55	9	0,236867	1158
Project 15	25	20	15	36	9	0,235089	1194
Project 19	117	11	45	38	23	0,227804	1232
Project 16	111	24	22	42	14	0,219252	1274
Project 28	60	12	13	20	25	0,208568	1294
Project 17	24	21	16	35	20	0,190859	1329
Project 24	75	13	10	32	15	0,181496	1361

The selected projects are P2, P10, P1, P13, P6, P3 and P5. By applying the Branch and Bound algorithm represented graphically by Fig. 1 of the example given in the previous chapter, we obtain the result given in Table 5 which contains only the possible portfolios of the last two iterations of the algorithm.

The analysis of the results obtained, as shown in Table 5, makes it possible to select the portfolios that consume the available resources (mobilized human resources and material resources) as indicated in Table 6, with the exception of the portfolio N°110 which needs to operate, an additional allocation of 16 units of FTE and 5,000$ US.

Stage 3: Select Optimum Projects Portfolio

Each portfolio is considered as a DMU characterized by three outputs or objectives and two inputs or constraints. The selection of the optimal portfolio is a multiobjective optimization problem that will be solved by the application of Equation (16) and Equation (17) which will give us the following mathematical formula:

$$Max\ 3103*X1+107*X2+158*X3+516*X4+429*X5+1240*X6+1312*X7 \quad (18)$$

$(C1)$: $11*X1+111*X2+10*X3+74*X4+63*X5+114*X6+54*X7 <= 300$;
$(C2)$: $18*X1+3*X2+8*X3+14*X4+7*X5+5*X6+21*X7 <= 60$;
$(C3)$: $X1 <= 1$;
$(C4)$: $X2 <= 1$;
$(C5)$: $X3 <= 1$;
$(C6)$: $X4 <= 1$;
$(C7)$: $X5 <= 1$;
$(C8)$: $X6 <= 1$;
$(C9)$: $X7 <= 1$;

The corresponding matrix form is represented respectively by Fig. 2 and 3 as follows.

Foncion objectif:

$$Max = (3103 \quad 107 \quad 158 \quad 516 \quad 429 \quad 1240 \quad 1312 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0) \times \begin{bmatrix} X1 \\ X2 \\ X3 \\ X4 \\ X5 \\ X6 \\ X7 \\ s1 \\ s2 \\ s3 \\ s4 \\ s5 \\ s6 \\ s7 \\ s8 \\ s9 \end{bmatrix}$$

Fig. 2: Objective function relating to Equation (18)

Sous contraintes:

$$\begin{bmatrix} 11 & 111 & 10 & 74 & 63 & 114 & 54 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 18 & 3 & 8 & 14 & 7 & 5 & 21 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} X1 \\ X2 \\ X3 \\ X4 \\ X5 \\ X6 \\ X7 \\ s1 \\ s2 \\ s3 \\ s4 \\ s5 \\ s6 \\ s7 \\ s8 \\ s9 \end{bmatrix} = \begin{bmatrix} 300 \\ 60 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$$

Fig. 3: Constraints relating to our objective function

Table 5: Possible generated portfolios

Portfolio number	V_k	$\widehat{x_{1k}}$	$\widehat{x_{1k}}$	Portfolio number	V_k	$\widehat{x_{1k}}$	$\widehat{x_{2k}}$
97	1111100	269	50	111	111110	372	37
98	1111010	320	48	112	111101	312	53
99	1111001	260	64	113	111011	363	51
100	1110110	309	41	114	110111	352	44
101	1110101	249	57	115	101111	416	50
102	1110011	300	55	116	11111	315	55
103	1101110	373	47	117	1111110	383	55
104	1101101	313	64	118	1111101	323	71
105	1101011	364	61	119	1111011	374	69
106	1011110	272	52	120	1110111	363	62
107	1011101	212	68	121	1101111	427	68
108	1011011	263	66	122	1011111	326	73
109	1010111	252	59	123	111111	426	58
110	1001111	316	65	124	1111111	437	76

Table 6: Portfolios respecting available resources

Portfolio Number	V_k	$\widehat{x_{1k}}$	$\widehat{x_{2k}}$
97	1111100	269	50
101	1110101	249	57
102	1110011	300	55
106	1011110	272	52
109	1010111	252	59
110	1001111	316	65

Table 7: Optimal solution max = 6415,714

Variables	Values	Dual price
X1	1,00000	0,00000
X2	0,00000	3,57143
X3	0,00000	136,85714
X4	0,64286	0,00000
X5	1,00000	0,00000
X6	1,00000	0,00000
X7	1,00000	0,00000

We have used Linear Program Solver called RSS. It is an open optimization package intended for solving linear programming problems. It is an executable program (version 1.0.0.0) developed by the industrial engineering department of the National School of Engineering of Tunis. It works through its graphical interface on the windows platform. The RSS solver is based on the implementation of the simplex method to allow us to find the optimal solution as shown in Table 7.

This solution corresponds to the optimal portfolio (*P*2, *P*13, *P*6, *P*3 and *P*5) relative to the optimal V_{opt} = *(1001111)*, provided that the *P13* project is finished up to 64.286% of the resources R_1 and R_2.

Conclusion

Prioritizing project portfolio and optimizing scarce resources allocation to the best and optimal portfolio that better aligns with the organization's strategic and operational priorities is more difficult task. In our approach, we have proposed a three-stage hybrid method for PPS formulations. We have calculated the maximum economic contribution between the final project portfolio selection and the project portfolio's initial sorting while taking into consideration various criteria and objectives. The method proposed above is composed of three stages and each stage has been developed with several steps and procedures. We used information entropy for initial ranking, branch and bound algorithm for generating possible portfolios and finally linear integer programming for deciding of the optimal portfolio in an uncertainty environment.

The approach proposed in this work helps the Decision Makers (DMs): (1) Think systematically about complex PPS problems formulation; (2) decompose the PPS problems into manageable steps and integrate the solutions to attempt at a production consistent with organizational goals and objectives; (3) carefully take into account the parameter of uncertainty of judgment within a structured methodology; and (4) use for several both quantitative and qualitative goals, criteria constraints and DMs preferences. Managerial assessment and accurate information or data are integrated elements of PPS formulations. Our approach involves DMs assessments and data within a formal and scientist approach.

In addition, our approach gives the possibility to the DMs to apply sensitivity analysis to the optimal solution by selecting or removing some projects to verify the impact of these changes on the best solution and the limited resources available to consume by modified portfolio.

The proposed approach comprises a specific tools and techniques that need a high consensus of time and hard effort. This paper puts the focus on the design of our approach based on information entropy, branch and bound and ILP. The future work will be the application of an automated framework based on C++ or Java programming languages in order to implement and validate our approach. Moreover this framework will allow organizations to optimize time, efforts and improve the transparency in their DMs preferences. Ourfuture work will be to implement our approach as a Decision Support System (DSS), integrating the interdependence matrix between projects.

Acknowledgement

The authors thank the management of the doctoral school "CEDOC 2TI" of the National Institute of Posts and Telecommunications for the efforts made for the benefit of PhD students. Not forgetting to pay tribute to the teaching staff within the «SEEDS» team who, through their orientations, has achieved this work.

Author's Contributions

Driss El Hannach: Developed the main idea, proposed the approach, implemented it, analyzed the results and contributed to writing of the manuscript.

Rabia Marghoubi: Participated in the validation of the proposed approach, coordinated and supervised the work.

Mohamed Dahchour: Contributed to analyzing the results and writing of the manuscript.

Ethics

The authors confirm that this manuscript has not been published elsewhere and that no ethical issues are involved.

References

Amiri, M.P., 2010. Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods. Expert Syst. Applic., 37: 6218-6224. DOI: 10.1016/j.eswa.2010.02.103

Archer, N.P. and F. Ghasezade, 1999. An integrated framework for project portfolio selection. Int. J. Project Manage., 17: 207-216. DOI: 10.1016/S0263-7863(98)00032-5

Atal, V., T. Bar and S. Gordon, 2016. Project selection: Commitment and competition. Game. Econ. Behav., 96: 30-48. DOI: 10.1016/j.geb.2016.01.011

Chen, J. and R.G. Askin, 2009. Project selection, scheduling and resource allocation with time dependent returns. Eur. J. Operat. Res., 193: 23-34. DOI: 10.1016/j.ejor.2007.10.040

Didem, Z., 2018. Assessment of techno-entrepreneurship projects by using Analytical Hierarchy Process (AHP). Technol. Society, 54: 41-46. DOI: 10.1016/j.techsoc.2018.02.001

Eilat, H., B. Golany and A. Sthub, 2006. Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology. Eur. J. Operat. Res., 172: 1018-1039. DOI: 10.1016/j.ejor.2004.12.001

El Hannach, D., R. Marghoubi and M. Dahchour, 2014. Étude comparative des différentes approches de priorisation de projets. Proceedings of the 4th International Workshop of Innovation and New Trends in Information Systems, (TIS' 14), pp: 87-100.

El Hannach, D., R. Marghoubi and M. Dahchour, 2016. Project portfolio management information systems (PPMIS) information entropy based approach to prioritize PPMIS. Proceedings of the 4th International Colloquium on Information Science and Technology, Oct. 24-26, IEEE Xplore Press, Tangier, Morocco, pp: 228-234. DOI: 10.1109/CIST.2016.7805048

Huang, X. and T. Zhao, 2014. Project selection and scheduling with uncertain net income and investment cost. Applied Math. Comput., 247: 61-71. DOI: 10.1016/j.amc.2014.08.082

Iamratanakul, S., P. Patanakul and D. Milosevic, 2008. Project portfolio selection: From past to present. Proceedings of the 4th IEEE International Conference on Management of Innovation and Technology, pp: 287-292.

Jun, M.A. and J.C.P. Cheng, 2017. Selection of target LEED credits based on project information and climatic factors using data mining techniques. Adv. Eng. Inform., 32: 224-236. DOI: 10.1016/j.aei.2017.03.004

Kaiser, M.G., F. El Arbi and F. Ahlemann, 2015. Successful project portfolio management beyond project selection techniques: Understanding the role of structural alignment. Int. J. Project Manage., 33: 126-139. DOI: 10.1016/j.ijproman.2014.03.002

Liu, S.S. and C.J. Wang, 2011. Optimizing project selection and scheduling problems with time-dependent resource constraints. Automat. Constr., 20: 1110-1119. DOI: 10.1016/j.autcon.2011.04.012

Minken, H., 2016. Project selection with sets of mutually exclusive alternatives. Econ. Transport, 6: 11-17. DOI: 10.1016/j.ecotra.2016.06.001

Nassif, L.N., J.C.S. Filho and J.M. Nogueira, 2013. Project portfolio selection in public administration using fuzzy logic. Proc. Soc. Behav. Sci., 74: 41-50. DOI: 10.1016/j.sbspro.2013.03.036

Novoselov, A., I. Potravny, I. Novoselova and V. Gassiy, 2017. Selection of priority investment projects for the development of the Russian Arctic. Polar Sci., 14: 68-77. DOI: 10.1016/j.polar.2017.10.003

Park, H., J. Lee and B.C. Kim, 2015. Project selection in NIH: A natural experiment from ARRA. Res. Pol., 44: 1145-1159. DOI: 10.1016/j.respol.2015.03.004

Roy, B., 1981. The optimisation problem formulation: Criticism and overstepping. J. Operat. Res. Society, 32: 427-436. DOI: 10.1057/jors.1981.93

Roy, B. and D. Bouyssou, 1993. Aide multicritère à la décision: Méthodes et cas. Economica, Paris.

Roychaudhuri, P.S., V. Kazantzi, D.C.Y. Foo, R.R. Tan and S. Bandyopadhyay, 2017. Selection of energy conservation projects through financial pinch analysis. Energy, 138: 602-615. DOI: 10.1016/j.energy.2017.07.082

Shannon, C.E. and W. Weaver, 1947. The Mathematical Theory of Communication. 1st Edn., The University of Illinois Press, Urbana.

Tavana, M., M. Keramatpour, F.J. Santos-Arteaga and E. Ghorbaniane, 2015. A fuzzy hybrid project portfolio selection method using data envelopment analysis, TOPSIS and integer programming. Expert Syst. Applic., 42: 8432-8444. DOI: 10.1016/j.eswa.2015.06.057

Tofighian, A.A. and B. Naderi, 2015. Modeling and solving the project selection and scheduling. Comput. Indust. Eng., 83: 30-38. DOI: 10.1016/j.cie.2015.01.012

Wang, Z. and Y. Yu, 2011. Information entropy method for project portfolio selection. Proceedings of the 8th International Conference on Fuzzy Systems and Knowledge Discovery, Jul. 26-28, IEEE Xplore Press, Shanghai, China, pp: 2618-2622. DOI: 10.1109/FSKD.2011.6020005

Xu, X., A. Chen, S.C. Wong and L. Cheng, 2015. Selection bias in build-operate-transfer transportation project appraisals. Transport. Res. Pol. Pract., 75: 245-251. DOI: 10.1016/j.tra.2015.03.026