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Multi objective project portfolio selection

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The Project Portfolio Selection is a complex process that involves many factors and considerations since the project is proposed until the project portfolio is finally selected. Project Portfolio Management is the iterative process of assessment, selection and implementation of projects, and the most important part of that is to select projects for portfolio where the organization is required to identify and prioritize projects with the most objective alignment to its objectives. Since the selection of a suitable projects is very important, it is necessary to develop mathematical models to lead the organization towards the final goal. To achieve this goal, these models should reflect the organization's position, goals and priorities as much as possible. In this paper, we propose a multi - objective model for selecting the project portfolio that maximizes efficiency, quality while minimizes the risk involved in project execution.

1. Introduction

Given the competitiveness of global markets, the selection of the project portfolio is one of the most important decisions related to all firms (Lin & Hsieh, 2004). Since it is not possible to compare two projects, the projects should be compared with the group, so the problem of the project portfolio selection is critical for all companies (Chien, 2002). The project portfolio consists of a number of projects that are in the same vein and run with a single management and compete with respect to the limited resources they have (Archer & Ghasemzadeh). The use of this technique is a powerful strategic tool to enhance competitiveness and economic value (Shenhar et al., 2001). Important criteria that are used to optimize the project portfolio include available resources and related constraints, the relationship between projects in the portfolio, strategic alignment of projects and organization and the benefit of portfolio performance. Problems that exist in the project portfolio include:

1- Goals that are not in one line are conflicting; some have access and some are unavailable, so some of these projects are not easy to execute (Archer & Ghasemzadeh, 1999).
2- There are unknown contacts between cost parameters and project risk (Medaglia et al., 2007).

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3- Some projects are connected and organizations are unable to measure only one project, but must also measure a set of projects (Radulescu & Radulescu, 2001).

In Project Portfolio Management a series of processes will be made to increase the portfolio productivity, one of which is the process of selecting the project for the project portfolio (Martinsuo & Lehtonen, 2007). The strategy includes the processes of preparing project plans, assessing projects, assessing the risk of project, determining the degree of project compliance with the organization's strategy, the amount of resources needed for the project, the prioritization of projects and the selection of projects (Dietrich & Lehtonen, 2005; Ghorbani & Rabbani, 2009).

The wrong decisions in selecting the project have negative consequences, the first is that the resources available in unsuitable projects are consumed, and the second is that the organization loses benefits that could benefit from using resources in suitable projects (Martino, 1995). The selection of the right project is involved with the critical success factors of the organizations (Cleland & Ireland, 1994; Hemmatizadeh & Mohammadi, 2019). Archer and Ghasemzadeh classify the prevalent methods related to the issue of project selection and suggested two groups. The first group is mainly on social issues, grouped based on qualitative criteria and experts perspectives. The second group is based on operational researches that is divided into two multi- objective decision- making and multi- criteria decision making.

Two categories are suggested for selecting projects, the first involves capital budgeting problems, development and research (R&D) and Information Technology (IT), the latter includes the means and methods used for the project selection (Rabbani & Bajestani, 2010). Many mathematical models have been developed to help organizations select the appropriate project. Many people studied the dependency of volunteer projects and proposed nonlinear programming model that considers profit, revenues, costs, resources and they used branch and bound algorithm to solve the proposed model (Schmidt, 1993). Projects related to available resources and constraints are aimed at maximizing the current net value, while the return of each project depends on the completion of the project and projects that have been executed before the project (Kyparisis et al., 1996).

Consider a multi-objective mathematical model that maximizes profit with respect to quantitative and qualitative criteria, which formulated important and critical factors in the choice of the R&D Project portfolio (Rabbani et al., 2006). Liu and Wang (2011) proposed a general model for profit maximization by considering the budget and resource constraints for the project selection, where CP is used to solve the problem.

Gutjahr and Froeschl (2013) proposed a multi-objective optimization model that maximizes the productivity of human resources to choose the project portfolio. Shou et al. (2014) used a multi - factor evolutionary algorithm aimed at maximizing the current net value for the selection and planning of the project portfolio.

Tofighian and Naderi (2015) proposed a mixed integer linear model that aims at maximizing the expected profit and diversifying resources for the selection and planning of the project. In order to resolve the model, they implemented the colony optimization method and surveyed the initial capital of investors and net cash flow using a portfolio optimization model in which the combined risk return index was defined for optimal investment in selecting an investment strategy. Zhang et al. (2011) presented a model using a novel genetic algorithm for optimal investment and consumer decision-making to choose the project portfolio with flexible time, where a series of constraints in controlling the risk of bankruptcy, project initiation time, capital reimbursement strategies were considered.

Since projects are always a major problem, organizations need to select the best projects among competitive projects. By reviewing the literature, it became clear that a few of the previous studies considered the subject the several times in the project portfolio selection. In most techniques that are used to select the project, only one or more independent criteria are considered. Due to the low

number of contractors in the past, the companies were forced to submit their projects to any contracting. But in today's issues, quality is considered as an important factor in project control.

Companies and industries want to use project management to increase quality, enhance customer satisfaction, maintain and improve their position, and increasing productivity in the competitive world. On the other hand, because of the variability in the rate of return of the project and changes such as political, economic, market position, competitors, the project risk is due to the lack of fulfilment of our predictions for the future.

In this paper, a multi-objective model with three simultaneous objective functions is considered which includes quality, return and risk of the project. Regarding the problems that exist in the project selection, the dependence and relationship between projects is also considered. The main objective of this paper is to find the best solution for the project selection, considering the quality, return and risk of all projects.

The remainder of this paper is organized as follows: Section 2 presents a multi-objective model for selecting the project portfolio with regard to risk, return and quality. Section 3 contains a case study (In about one sentence write about the case study of this paper) and concludes with the implementation of this model.

2. A model for project portfolio selection

The assumptions are as follows:

1. Quantitative and qualitative objectives are considered.

2. All selected projects should be completed at the end of the planning horizon.

3. The planning horizon of multiple time periods is considered.

4. The rate of resource consumption and the amount of resources are pre - determined for each period of time.

5. The selected project will be done only by a contractor.

6. The dependence and relationship between projects is considered.

2.1. Problem symbols

A project selection problem is considered from *N* project, *C* contractors and T time period. Each project has its own returns, risks and qualities, all depending on the start time of the project and the contractor. It is assumed that $\mathrm{B_{ict}}$, Q_{ict}, and R_{ict} refer to efficiency, quality, and risk ,respectively. The resource consumption rate and the amount of resources for each period are considered by a_i and r_t respectively. The duration of the project done by the contractor is shown by $\mathrm{d_{is}}$. The proposed model is a multi-objective planning model that aims to maximize returns and quality and minimize risk. The main question here is: which project should start with the contractor to achieve the goals?

Indexes:

i, j	Indexes for projects; i, j={1,2,….n}
c	Indexes for contractor; c={1,2,….c}
t, h	Indexes for time period; t={1,2,….T}
k	Indexes for objective function; k={1,2,3}

Parameters:

$\boldsymbol{T}$	Number of time periods
$\boldsymbol{r_{ict}}$	Risk of project *i* in time *t* with contractor ***c***
$\boldsymbol{q_{ict}}$	Quality of project *i* in time *t* with contractor ***c***
$\boldsymbol{b_{ict}}$	Return of project *i* in time *t* with contractor ***c***
$\boldsymbol{d_{ic}}$	Duration of project *i* with contractor ***c***
$\boldsymbol{w_k}$	Target factor *i* in the final objective function
$\boldsymbol{a_i}$	Required amount of resource for project ***i***
$\boldsymbol{r_t}$	Available amount of resource in time ***t***
$\boldsymbol{M_{ij}}$	1 if projects *i* and *j* are interdependent, 0 otherwise

Variable:

$\boldsymbol{X_{ict}}$	1 if project i starts in time t with contractor c, 0 otherwise

$1 \leq t \leq T - d_{ic}+1$

2.2. Objective function

The deterministic model can be formulated as follows:

$$zz = \sum_{k=1}^{3} z_k * w_k \tag{1}$$

Equation (1) is the final objective function, which is the sum of the three objective functions risk, quality and profit.

$$min\ R = \sum_{i=1}^{n} \sum_{t=1}^{T-d_{ic}+1} \sum_{c=1}^{c} r_{ict} * X_{ict} \tag{2}$$

$$max\ B = \sum_{i=1}^{n} \sum_{t=1}^{T-d_{ic}+1} \sum_{c=1}^{c} b_{ict} * X_{ict} \tag{3}$$

$$max\ Q = \sum_{i=1}^{n} \sum_{t=1}^{T-d_{ic}+1} \sum_{c=1}^{c} q_{ict} * X_{ict} \tag{4}$$

The Eqs. (2) - (4) are the objective function that is to minimize the risk and maximize profits, quality of the project.

$$\sum_{i=1}^{n} \left(\sum_{c=1}^{c} \sum_{j=\max\{1,t-d_{ic}+1\}}^{\min\{t,T-d_{ic}+1\}} X_{ich} \right) a_i \leq r_t \qquad \forall t \tag{5}$$

The set constraint (5) ensures that resource constraints are not violated and always resources required by contractors should be less than the amount of resources available in this period.

$$\sum_{t=1}^{T-d_{ic}+1} X_{ict} + \sum_{t=1}^{T-d_{jc}+1} X_{jct} * M_{ij} \leq 1 \qquad \forall i, j, c \in H_i \tag{6}$$

The set of constraint (6) shows the interdependence between projects and dependent projects that should not be initiated by a contractor in a period of time.

$$\sum_{t=1}^{T-d_{ic}+1} \sum_{c=1}^{c} x_{ict} \leq 1 \qquad \forall i \qquad (7)$$

The set of constraints (7) determines when each project will start and with which contracting.

$$\sum_{c=1}^{c} x_{ict} = x_{it} \qquad \forall i, t \qquad (8)$$

The set constraint (8) determines that each project can be done by a contractor in a period of time.

$$x_{ict} \in \{0,1\} \qquad (9)$$

The set constraint (9) defines the decision variables.

3. Experimental results

In this section, we tested the model with a real case study to determine the model.

3.1 Case study

In this section, we use a case study to describe model implementation and data is derived from a contract company in Mazandaran. We name all projects according to a series of privacy problems. MMG is a contracting company where many projects have been proposed to implement in the company. In MMG first the quality, efficiency, risk, and other parameters, such as available resources are estimated and the company selects better projects for implementation.

The risk of projects is determined by the contractor because it is generated by multiplying the possibility in intensity or risk empirically. The efficiency is considered as the severity and the probability is given by the contractor, but other parameters are estimated by the project manager, executive directors and consultants. Five projects have been offered to the company and horizon periods are 6 months. Also, return, quality, risk and constraints must be satisfied. The available resources are 45 items per each period of time. The selected project is only executed by a contractor and each time the selected project should be completed within the same time frame. Other data are shown in Tables (1-6).

Table 1
Required resource for each project

	i				
	1	2	3	4	5
$\mathbf{a_i}$	18	9	8	16	14

Table 2
Duration of projects

$\mathbf{d_{ic}}$		**c**	
		1	2
I	1	3	4
	2	2	2
	3	1	3
	4	2	1
	5	4	2

Table 3
Interdependencies between projects

		j				
M_{ij}		1	2	3	4	5
	1	0	1	0	1	1
	2	1	0	0	0	0
i	3	0	0	1	0	1
	4	0	1	0	0	0
	5	1	0	1	0	0

Table 4
Return of projects

		c_1						c_2					
		t						t					
b_{ict}		1	2	3	4	5	6	1	2	3	4	5	6
	1	30	22	27	22	17	17	26	22	25	18	19	18
	2	28	24	23	26	19	19	29	22	26	23	25	19
I	3	26	27	26	22	20	19	27	28	24	28	22	19
	4	29	27	25	28	17	16	27	28	24	24	20	18
	5	27	23	22	21	19	18	29	21	25	24	23	20

Table 5
Quality of projects

		c_1						c_2					
		t						t					
q_{ict}		1	2	3	4	5	6	1	2	3	4	5	6
	1	100	100	90	98	90	95	96	94	98	97	98	98
	2	92	95	94	95	99	100	85	86	95	92	92	97
I	3	85	82	83	88	92	95	87	87	95	92	92	97
	4	84	83	85	92	97	98	86	88	93	93	93	95
	5	86	94	96	94	98	100	85	88	91	95	99	95

Table 6
Risk of projects

		c_1						c_2					
		t						t					
r_{ict}		1	2	3	4	5	6	1	2	3	4	5	6
	1	10	11	15	18	13	11	21	15	15	12	12	12
	2	20	18	19	9	12	19	13	20	17	13	13	15
I	3	10	21	19	18	16	13	23	22	19	16	14	16
	4	22	24	18	14	14	14	25	15	19	13	13	14
	5	15	17	17	16	12	15	18	18	15	18	10	9

The model is solved by GAMS 24.1.3 on a personal computer based on 2.8 GHz at 0.016 seconds since the computer with the CPLEX solver. After solving the model with the software Gams, we conclude that projects 1, 4 are initiated with the contractor 1 in the 1, 5, and projects 2, 5 with the contractor 2 in the period 3, 5 and other projects are eliminated. The objective function value is equal to 308.4.

Table 7
Project *i* starts in time *t* with contractor *c*

		c_1						c_2					
		t						t					
X_{ict}		1	2	3	4	5	6	1	2	3	4	5	6
I	1	1	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	1	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	1	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	1	0

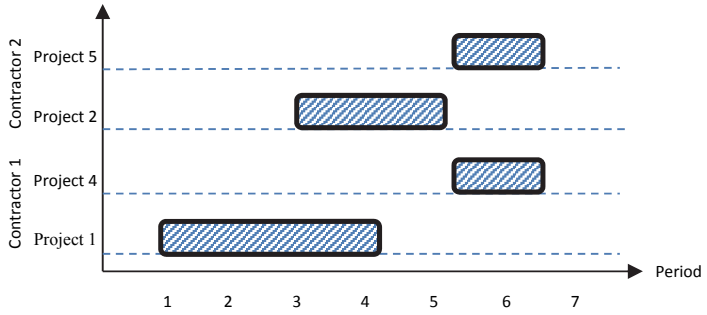

Fig. 1. Optimal scheduling of the project by contractors

Table 8
The objective function and their factors

Optimal Objective value	k			Multi objective result
	1	2	3	
Z	51	393	96	308.4
W	-0.1	0.7	0.4	

4. Conclusions

Decision makers usually face resources and budgets constraints to achieve expected profit, so they have to decide which projects to consider. The purpose of this paper is to help decision makers in the selection and planning of the project portfolio. The different goals that conflict with each other have the main role in the project selection. The issue of selecting the project may have different goals, but maximum benefit is always considered as the main purpose. This paper suggests how to select some projects among competing projects with respect to return, quality, risk and availability of resources and other technical constraints in the real world. It is also formulated in a given environment and then the effectiveness of the proposed model is evaluated by the case study.

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