# Project Selection Based on Project Scheduling with Renewable Resource, Nonrenewable Resource and Budget Constraints

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***Abstract-*** In this paper, the joint problem of the project selection and scheduling is formulated, analyzed, and solved to optimize total expected benefit (NPV) with renewable resource, nonrenewable resource and budget constraints. In this study, a situation of multiple constrained projects are subject to implementation. Decision makers should select and then schedule a subset of these projects, considering their constraints. Different types of project selection models generally ignore the projects scheduling as part of their selection process. At first a general mathematical formulation is presented. Then, Project portfolio of a given Company is introduced as a case study to show the validity of the proposed model.

***Keywords-*** Project selection, Project scheduling, NPV, renewable and nonrenewable resource constraint, budget constraint

## I. . Introduction

PROJECT selection is one of the most important strategic decisions in real world competitive markets, and is one of the biggest concerns and important issues that each enterprise may deal with ([11], [8], and [12]). The economic nature of many projects causes that more benefit can be achieved if a project is completed earlier [3]. Also one of the most prominent phases of the project management is project selection and scheduling problem. The resource-constrained project portfolio selection and scheduling problem can be described as a problem to select an optimal portfolio of projects and schedule them to maximize an organization's stated objectives. The project portfolio selection (PPS) problem may consider various objectives but maximum benefit is always considered as a crucial objective. Many studies have considered this objective function ([3], [11]). Inclusion of project activity scheduling as a sub problem of the project portfolio selection helps to improve the overall organization performance even though it increases the complexity of the decision making problem. This combined problem is termed as RCPPSSP.

Early studies used integer linear programming or dynamic techniques to support decision making about project portfolio selection, some studies extended these models and took account of factors that occur in practice, thus they had a more realistic perspective. For example, [4] used a goal programming model for information system project selection, and [10] prepared a multi objective integer optimization model with distributions of costs probability. More recently, new studies were done on project selection and scheduling. [9] also offered a scenario tree approach for multi-period project selection problems using the real option valuation method. [1] introduced a comprehensive model for the portfolio of several objectives, and [14] presented the multi agent evolutionary algorithm for project portfolio selection and scheduling to maximize the NPV.[12] for joint problem of the project selection and scheduling problem used ant colony optimization and their objective functions are maximizing NPV and balancing resource usage. [8] for optimizing risk, cost and NPV, used particle swarm optimization. Also [7] proposed two algorithms (genetic and simulated annealing) for maximizing NPV. [15] for this problem with uncertain net income and investment cost, proposed a model. Last but not least, [13] proposed the multi-objective decision analysis for competence oriented project portfolio selection [6]. A review of the project portfolio selection studies revealed that project scheduling was not taken into consideration in a majority of them [5]. Yet, a few studies such [2]. From the perspective of the project portfolio selection and scheduling, if we consider only selection aspects and eliminate scheduling, we cannot make efficient use of resources. Therefore, to tackle the problem of the simultaneous selection and scheduling, projects need to be prepared with more flexibility with respect to the use of resources and facilities. Recent studies conducted by [13] and [14], therefore, considered new models for project portfolio selection and scheduling.

In this paper the decision maker aims at selecting a subset of these projects and scheduling their activities. The objective function of the problem is to maximize total benefit. The problem is first mathematically formulated by a mixed integer

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linear programming model then by using numerical example effectiveness of the presented model is evaluated.

## II. Problem Definition and Proposed Mathematical Formulation

The problem of the project selection and scheduling can be described as follows. There are a set of N projects where each project has its own benefit. To perform each project a set of j activities has to be operated. There are some precedence relationships among the activities of a project. Type of the precedence relationships are assumed to be finish-start relationship. An activity can be started only if all of its predecessors completed and it does not need setup time. This is regardless of the dependencies between the projects. Candidate projects are considered based on their net present values and finally a subset of them are selected. It is assumed that cash inflow is achievable only when a project be completed. To operate each activity, some constrained resources are required. Both renewable and nonrenewable resources are included, therefore there is budget constraint in the model. The goal is to find a project portfolio such that the net present value of the portfolio is maximized. In the joint problem of the project selection and scheduling, a small subset of the projects are chosen from the larger set of the projects based on the set of desired criteria and the given set of limitations. The first phase of studying such an optimization problem is developing mathematical formulation.

### *Mathematical model*

In this section, the proposed model is described. In the model, the following indices and parameters are used:
Parameters:

| | |
|---|---|
| $N$ | Total number of the available projects |
| $T$ | Number of time periods (make span) |
| $i$ | Indices of the projects |
| $j$ | Indices of the activities |
| $d_{ij}$ | Duration of the activity *j* from project *i* |
| $r_{ijkt}$ | Quantity of resource *k* required by activity *j* from project *i*, in time period *t* for its execution |
| $R_{kt}$ | Capacity of renewable resource *k* in time t |
| $P_{ijt}$ | Benefit of the activity *j* from project *i*, in time period *t* |
| $S_{ij}$ | The set of the prerequisite activities of the activity *j* from project *i* |
| $C_{ijkt}$ | Cost of the renewable resource k of activity *j* from project *i* in time period t |
| $C_{ijv}$ | Cost of the non-renewable resource v of activity *j* from project *I* |
| $M_{ijv}$ | Quantity of the resource *v* required by the activity *j* from project *i*, for its execution |
| $B_v$ | Capacity of the non- renewable resource *v* |
| TB | Total budget |

Decision variables:
$X_{ijt}$: Takes value one if activity *j* from project *i* is finished in time period *t* and otherwise zero.
$Y_i$: Takes value one if project *i* is selected and otherwise zero.

The problem formulation is as follows:

$$\max E\{\sum_{i=1}^{I}\sum_{j=1}^{J_i}\sum_{t=1}^{T} P_{ijt}X_{ijt}\}$$

$$\sum_{l=1}^{t} X_{ijl} \le 1 \qquad \forall i,t,\forall j = 1,2,\dots,J_i \tag{1}$$

$$\sum_{l=1}^{T} X_{ijl} = Y_i \quad \forall i,\forall j = 1,2,\dots,J_i \tag{2}$$

$$\sum_{t=0}^{T} tX_{iht} - \sum_{t=1}^{T}(t-d_{ij})X_{ijt} \le 0 \quad \forall i = 1,2,\dots,I, j = 1,2,\dots,J_i - 1, ih\epsilon S(ij) \tag{3}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J_i} r_{ijkt} \sum_{l=\max\{0,t-d_{ij}+1\}}^{t} X_{ijl} \le R_{kt} \quad \forall k = 1,2,\dots,k, t = 1,2,\dots,T \tag{4}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J_i}\sum_{t=1}^{T} M_{ijv}.X_{ijt} \le B_v \qquad \forall v = 1,2,\dots,V \tag{5}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J_i}\sum_{t=1}^{T}\sum_{\forall k\in K} C_{ijkt}.r_{ijkt}.X_{ijt} + \sum_{i=1}^{I}\sum_{j=1}^{J_i}\sum_{t=1}^{T}\sum_{\forall v\in V} C_{ijv}.M_{ijv}.X_{ijt} \le TB \tag{6}$$

$$X_{ijt}\epsilon\{0,1\} \tag{7}$$

$$Y_i\epsilon\{0,1\} \tag{8}$$

The objective function of the problem is to maximize the total profit of the selected project portfolio. Constraint (1) ensures that each activity of the projects only at one time can be done. Constraint (2) ensures that all activities of a selected project are completed. It also enforces that every activity of the unselected projects is not executed. Constraint (3) describes the precedence relationships among activities which requires an activity to start only after all its predecessors have been completed. Constraints (4) and (5) consider the renewable and nonrenewable resources constraints, respectively. Constraint (6) describes the budget Constraint. Constraints (7) and (8) declare the decision variables.

## III. Numerical Example

For showing the effectiveness of the proposed model, information of a given case study are shown in table 1. There are 20 projects that each project have several activities, benefits and times of the projects are based on the time period, each period is 3 months or 90 days. The number of the periods is equal to 15.

TABLE I
INFORMATION OF THE CANDIDATE PROJECTS

| Project | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| time | 4 | 4 | 4 | 3 | 4 | 6 | 2 | 4 | 6 | 4 |
| benefit | 8 | 6 | 10 | 3 | 2 | 6 | 8 | 6 | 4 | 8 |
| cost | 125 | 75 | 100 | 65 | 185 | 85 | 175 | 225 | 200 | 75 |
| Project | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| time | 4 | 2 | 8 | 4 | 5 | 3 | 4 | 5 | 4 | 4 |
| benefit | 6 | 1 | 7 | 9 | 10 | 1 | 5 | 3 | 5 | 6 |
| cost | 75 | 300 | 175 | 100 | 300 | 220 | 175 | 80 | 75 | 100 |

## IV. RESULTS

This section gets the results of the solved problem in the certain condition. To solve the nominal model, we insert all problem data in an Excel Worksheet and link between the Excel Worksheet to export problem data to GAMS. This is implemented on a PC workstation with a 500 MHz CPU and 284 MB memory. The optimal objective is equal to 67.
The results of the nominal model are shown in table 2.

TABLE II
SELECTED PROJECTS IN NOMINAL MODEL

| Project | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Selection state | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| Start time period | 1 | 1 | 1 | 2 | - | 1 | - | - | - | 2 |
| Project | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Selection State | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| Start time period | 3 | - | - | 4 | - | - | - | - | 1 | 2 |

As seen in the above table, among the candidate projects, ten of them are selected for execution and in addition to the project selection, the activities of the selected projects are scheduled so that the maximum benefit is meet.

## V. CONCLUSION

Project selection is one of the important issues in industrial, governmental nonprofit and commercial organization. If project selection be a smart selection with considering the organization conditions, they cause empowering of the organizations in the competitive environment. This paper studied the problem of the project selection and scheduling with renewable and nonrenewable resources and budget constraints. Each project requires a set of the activities. The decision maker should select and schedule a subset of the available projects that maximize the total profit. The results showed that the proposed model is effective for organizations in the case of decision making about project selection problem based on project scheduling by considering going constraints.

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