Abstract

The project selection and scheduling model has been one of the most attractive topics for research in the last three decades. So far, many models have been presented that help organizations have the best portfolio of project selection, in addition to maximizing income, to achieve other goals they have in mind with project selection. In this research, a comprehensive model for project selection and scheduling is presented so that organizations can use it to maximize their income. In this research, each project is divided into several phases and each phase has a specific cost and income. Prerequisite and incompatibility relationship between projects is also considered. In addition to these, it is possible to adjust the project and the project can be updated or sold for a certain amount. The positive point is that pre-existing projects can be easily considered in this model and it is possible to adjust them. Finally, by adding the second objective function, an attempt has been made to minimize the average delay from the project delivery time. This second objective function helps to increase the efficiency of the model and organization managers can reach a balance point between revenue and delay.

Research aim:

Providing a model for project selection, adjustment and scheduling projects considering reinvestment

Research method:

A mathematical model (operational research) and GAMS software have been used for modeling. The method of solving the model is by using the CPLEX algorithm and after adding the objective function with the help of the epsilon method of reinforcement constraint. Findings: The results of the model show that the possibility of adjustment in the project significantly increases the income and reduces the restrictions. In addition, it was shown in several aspects that there is a certain threshold for investment and the number of selected projects.

Findings:

Adjustment helps organizations to make better decisions for investment and there is a threshold for inversting

Conclusion:

The results of solving the model in different modes show that there is a certain point for investment and investing more than that may not be profitable. Furthermore, organizations are better off committing themselves to a certain number of projects unless there are managerial reasons and insights that cannot be represented by the

model.

Keywords:

Project Selection, Project Scheduling, Project Adjustment, Project Portfolio Optimization

3. Modeling and solution method

3-1- Assumptions of the model

1- A number of projects are available, and it is possible to select and schedule a number of them.

2- Each project consists of a certain number of different phases, each phase having a prerequisite relationship with the next phase.

3- It is possible to interrupt the project at the end of each phase (it is not possible to interrupt it during the implementation of a specific phase) and one or more periods of the project can be postponed.

4- Each project can be adjusted (upgrade or abandoning the project) at most once, and otherwise it can continue without changes until the end.

5- Adjusting or continuing projects without change is known as the mode of doing the project.

6- mode zero is used to run the project in normal mode, mode 1 is used to display the upgrade, and mode 2 is used to display the abandonment of the project.

7- If we abandon the project at the end of each phase, the project will be sold with its value at that moment.

8- Prerequisite or incompatibility between projects is considered.

9- The planning horizon is divided into several time periods.

10- Project scheduling is based on implementation phases.

11- The source of implementing projects is money and at the beginning of zero time, it is available in the form of an initial budget.

12- There is a certain constraint for the initial budget.

13- The cash flow related to each phase of each project includes an expense at the beginning of the phase and an income at the end of it.

14- The cost and income related to different modes are considered in the parameters of the model.

15- The budget surplus of each period can be invested in a period with a risk-free interest rate.

16- It is possible to finance by selling projects.

17- The interest rate is constant during the time horizon.

3-2. Notation

In general, there are four groups of notation, which are:

- indices
- parameters
- Binary Decision variables
- Non-negative decision variables

1- The indices are as follows:

i, j: project indices ($i, j = 1,2, \ldots, N$)
k: index of each phase of project ($k = 1,2, \ldots, K$)
m: mode index (running the project in normal mode, upgrading or abandoning the project , $m = 0,1,2$)
t: index of period ($t = 0, \ldots., T$)

2- The parameters are as follows:

I: Set of all projects
H_i: set of prerequisite projects of i ($H_i \subset I$)
E_i: set of incompatible projects with i ($E_i \subset I$, $E_i \cap H_i = \emptyset$)
T: Length of the horizon
f_i: number of project i phases
R_{ikm}: final income of phase k of project i in mode m ($i \in I$)
c_{ikm}: initial cost of phase k of project i in mode m ($i \in I$)
d_{ikm}: time required to complete phase k of project i in mode m ($i \in I$)
SV_{ik}: value of project i at the beginning of phase k
v: initial budget at the beginning of the period
r: periodic interest rate
L: A very large number

3- Binary variables are:

$$x_{ikmt} = \begin{cases} 1 & \text{If phase } k \text{ of project } i \text{ starts in mode } m \text{ in period } t \\ 0 & \text{Otherwise} \end{cases}$$

$$y_i = \begin{cases} 1 & \text{If the project } i \text{ is selected} \\ 0 & \text{Otherwise} \end{cases}$$

4- Non-negative decision variables are also:

BS_t: budget surplus in period t
w_0: Initial budget

3-3. Mathematical model

$$Max\ Z = BS_T \qquad (1)$$

s.t:

$$\sum_{m=0}^{1}\sum_{t=0}^{T} t x_{i1mt} + L(1 - y_i) \geq \sum_{m=0}^{1}\sum_{t=0}^{T} x_{j.f_j.mt}\left(t + d_{j.f_j.m}\right) \qquad i = 1 \dots .N \quad \forall j \in H_i \qquad (2)$$

$$\sum_{m=0}^{1}\sum_{t=0}^{T} x_{i1mt} \leq L(1 - \sum_{k=1}^{K}\sum_{t=0}^{T} x_{jk2t}) \qquad i = 1 \dots .N \quad \forall j \in H_i \qquad (3)$$

$$\sum_{m=0}^{1}\sum_{t=0}^{T} x_{i1mt} + \sum_{m=0}^{1}\sum_{t=0}^{T} x_{j1mt} \leq 1 \qquad i \in I \quad \forall j \in E_i \qquad (4)$$

$$\sum_{m=0}^{2}\sum_{t=0}^{T} t x_{ikmt} \geq \sum_{m=0}^{1}\sum_{t=0}^{T} x_{i.k-1.mt}(t + d_{i.k-1.m}) - \sum_{g=1}^{k-1}\sum_{t=0}^{T} x_{ig2t} \qquad i = 1 \ldots . N \quad k = 2.3 \ldots . K \tag{5}$$

$$\sum_{k=1}^{K}\sum_{t=1}^{T} x_{ik2t} \leq y_i \qquad i = 1 \ldots . N \tag{6}$$

$$\sum_{m=0}^{2}\sum_{t=0}^{T} x_{ikmt} \leq y_i \qquad i = 1 \ldots . N \quad k = 1 \ldots . K \tag{7}$$

$$\sum_{k=u+1}^{K}\sum_{m=0}^{2}\sum_{t=0}^{T} x_{ikmt} \leq L(1 - \sum_{t=0}^{T} x_{iu2t}) \qquad i = 1 \ldots . N \quad u = \{0.1. \ldots . K - 1\} \tag{8}$$

$$\sum_{t=0}^{T} (x_{ik1t}) \geq \sum_{t=0}^{T} x_{iu1t} - L \sum_{t=0}^{T}\sum_{u'=1}^{u-1} x_{iu'2t} \qquad i = 1 \ldots . N \quad \forall\, k \quad \forall\, u > k \tag{9}$$

$$\sum_{i=1}^{N}\sum_{m=1}^{2} x_{i1m0}\, c_{i1m} + BS_0 \leq w_0 \tag{10}$$

$$BS_{t-1}(1+r) + \sum_{i=1}^{N}\sum_{k=1}^{K}\sum_{m=0}^{1} x_{ikm.t-d_{ikm}+1}R_{ikm} + \sum_{i=1}^{N}\sum_{k=1}^{K} x_{ik2t}SV_{ik} = BS_t + \sum_{i=1}^{N}\sum_{k=1}^{K}\sum_{m=0}^{1} x_{ikmt}c_{ikm} \qquad \forall\, t \qquad (11)$$

$$\sum_{k=1}^{K}\sum_{m=0}^{2}\sum_{t=0}^{T} x_{ikmt}(d_{ikm}+t) \le T \qquad i = 1 \dots . N \qquad (12)$$

$$w_0 \le v \qquad (13)$$

$$w_0 \ge 0 \qquad (14)$$

$$BS_t \ge 0 \qquad \forall\, t \qquad (15)$$

$$x_{ikmt} \,.\, y_i \in \{0.1\} \qquad i = 1 \dots . N \qquad (16)$$

Expression 1: Objective Function

Expression 2: Ensuring prerequisites between projects. If project i is not selected, the constraint will be omitted.

Expression 3: If project j (prerequisite) is sold (not completed), project i will not be implemented.

Expression 4: Ensuring incompatibility of projects

Expression 5: Meeting the prerequisites between different phases of a project. If the project is abandoned, this constraint will be omitted.

Expression 6: Each project can be abandoned only once, if ever selected.

Expression 7: If a project is not selected, the variables corresponding to the start of its different phases as well as the abandonment of the project will be zero.

Expression 8: If a project is abandoned in a certain phase, subsequent phases cannot be completed.

Expression 9: If a project is upgraded, subsequent phases will be implemented upgraded (if the project is not abandoned)

Expression 10: How to allocate the initial budget. In order to make the solution space feasible, “less–than or equal to” is used instead of “equal”.

Expression 11: Budget balance equation in different periods

Expression 12: It ensures that the project is completed within the planned horizon.

Expression 13: Compliance with the upper limit of the available initial budget

Expression 14: The initial dedicated budget will not accept a negative value.

Expression 15: The budget surplus of each period will not accept a negative value.

Expression 16: Decision variables accept only values 0 and 1.

3-3-2. Developed mathematical model

Additional notation and constraint:

$TD(i,k)$: Total deviation from the delivery time of phase k of project i

$Due\_date(i,k)$:Delivery time of phase k of project i

$$TD(i,k) = \max\{0, \sum_{k=1}^{K} \sum_{m=0}^{1} (t+d_{i,f(i),m})\, x_{i,f(i),m,t} - Due\_date(i,k)\} \qquad \forall\, i$$

$$Min\ Z2 = \sum_{i=1}^{N} \frac{TD(i)}{N'}$$

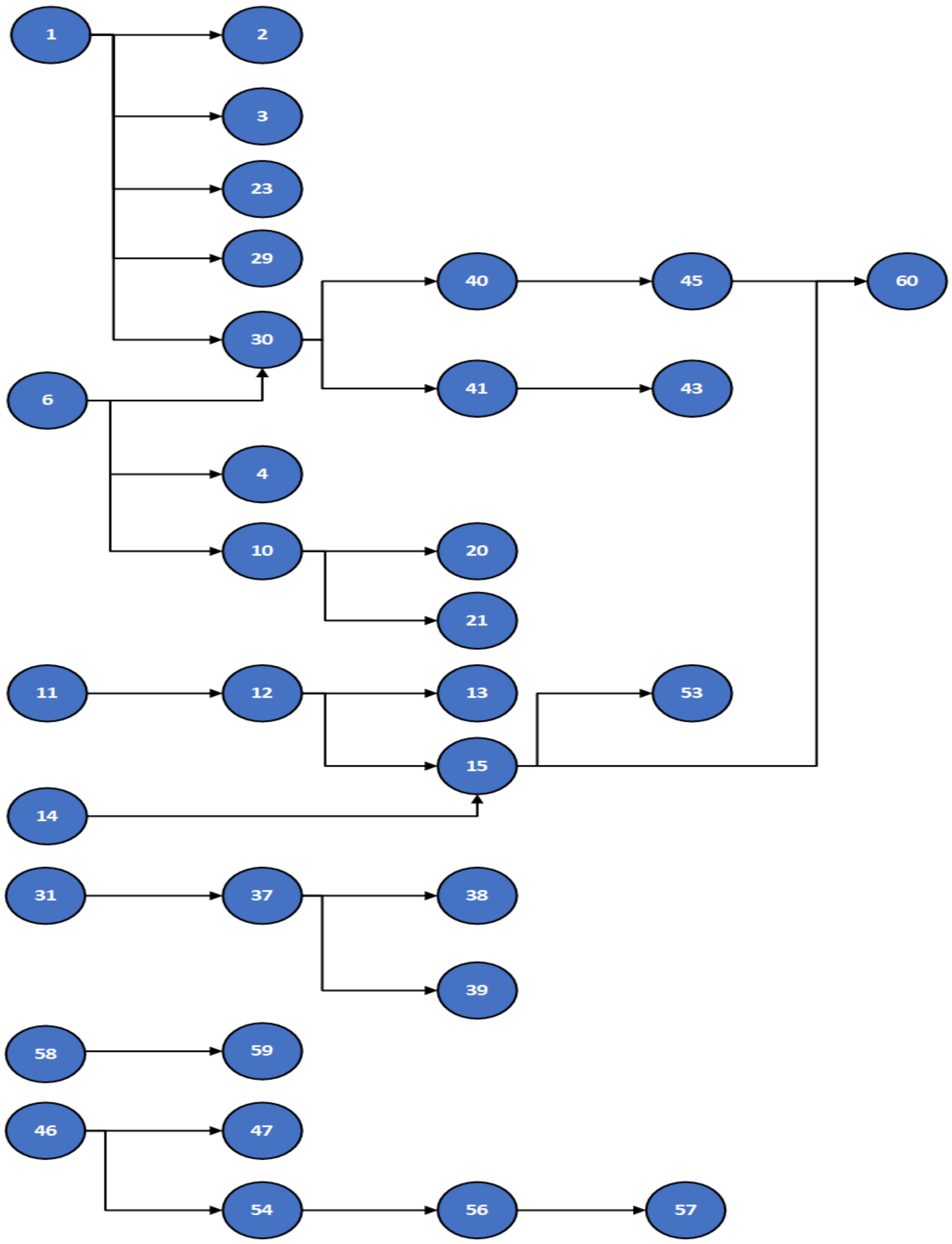

Figure 1- Prerequisite relationship between projects

Table 3- Characteristics of sensitivity analysis scenarios

possibility of sale	Possibility of upgrading	Normal execution	The name of the scenario	Scenario number
has it	has it	has it	Complete	1

			execution	
has it	does not have	has it	Run without upgrades	2
does not have	does not have	has it	Execution without Adjustment	3