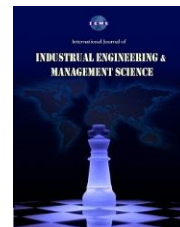




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## Multi-mode Capital-Constrained Project Payment Scheduling Problem with Discounted Cash Flows

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### Keywords:

- 1 Scheduling, Multi-mode Problem
- 2 Genetic algorithm
- 3 Capital-Constrained
- 4 Discounted Cash Flows

### ABSTRACT

Project scheduling is to determine the start time of each project activity, due to the constraints contained in it then determine a timing sequence to perform a series of related activities according to their precedence.

So that there is a balance between time completion and total cost of the project and it is to achieve one or more objectives. To achieve these objectives, the options examined and finally, the best option is selected. Despite numerous research on schedule projects, there is lacking in the area of project scheduling with considering financial goals that these problems can be relieved with a good estimation of the costs and expected income. Therefore, in this study, we intend to develop a model for scheduling project performance purposes, including time, cost and financial (income, payment, etc.) with the aim of maximizing profits by right setting of the resources and activities and creating of the optimum cash flow program to prevent financial failure of the project. Where the resources used to implement activities and project incomes represent negative and positive cash flow respectively. As well as various financial factors such as interest rates, payment terms and credit limits not only effect on the cash flow of the project, but the amount and timing of resources affects too.

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## Introduction

Project scheduling is to determine the start time of each project activity, due to the constraints contained in it and determining a timing sequence to perform a series of related activities according to their precedence [12]. So that there is a balance between time completion and total cost of the project and it is to achieve one or more objectives. To achieve these objectives, the options examined and finally, the best option is selected [2, 3]. To schedule all projects, there are precedence constraints between activities, but in addition there are other constraints, including resource constraints. Resources are created based on the needs of the activities and execution time and the cash flows involved in the construction. This means the resources used to carry out activities represent the costs of contractors in the construction and cash flow of the project. In general, financial aspects of project are remarkable than project scheduling. Different financial factors, such as interest rates, payment terms and credit limits, affect not only the cash flow of a project, but also the amount and timing of the use of resources, therefore, with regard to the scheduling problem with the resources and cash flow profits, the goal of the project is to maximize profits by properly regulating resources and activities and establishing a reliable cash flow forecasting program to prevent project financial failure [12].

One of the common problems in project management is the disruption of scheduling due to inefficient factors during project implementation, so project manager often run into difficulties in adhere their obligations. Therefore, the project scheduling, in addition to the short completion time, should be minimized during the operation [12]. Time management in the project requires a standard rule due to the temporary and non-repetitive nature of the projects and the essence of project management that is risk management and uncertainty [10].

### Categorization of project scheduling problems in terms of objective functions

In project scheduling problems, different objective functions are considered, the most common of which in most researches is to minimize project implementation time. The start time of the project is usually considered at  $t = 0$ ; however, according to the zero equation, the objective function is to minimize the maximum time that the project activity ends [12].

$$\min C \max = \min(\max(s_j + p_j)) \quad (0)$$

$s_j$  And  $p_j$  are the start time and operation time of the J activity.

The preparation of classic project planning usually specifies an optimality criterion, such as minimum length or minimum delay. Such criteria tend to implicitly maximize the use of equipment during the planned horizons. While management usually seeks to minimize costs and maximize the use of equipment and resources [10].

Other goals in project scheduling problems include maximizing the net present value of the project, cash flow of budget constraints and resource leveling, along with the function of the traditional goals, reducing the completion time of the project.

In fact, the project faces a negative cash flow during the project and payment at the end of it, Cash flow management and objective functions based on time value of money are important and the critical path of the project is identified in terms of cash flow [6].

In problems with an executive mode, there is a unique way to carry out each project activity that determines the operating time and the amount of resource consumption that is assumed to

be constant. In problems with multi executive modes, each activity can be done in one of the mods, and each mode has the cost, time, and amount of its own resources [12].

### **Project scheduling problem with resource constraints and monetary criteria**

In general, we can classify the criteria in the scope of project scheduling into non-monetary and monetary criteria. Minimizing the duration of a project implementation is the most common non-monetary criterion used by researcher project scheduling. At the time of completion of the whole project, the project is scheduled according to the critical path.

When specific cash flows are paid during the project to carry out activities and ongoing payments are made to complete project components, the current net present value criterion is a very important and practical criterion for project scheduling. Based on this criterion, the scheduling of the project is based on the critical cost path.

The scheduling of the project with resources constraints is rich in literature. . This category of problems has been considered for two reasons. First, considering the different functional and industrial conditions in terms of the objective function, the characteristics of activities, resources, and types of precedence relationships are very diverse, and secondly, with regard to their NP-hardness, researchers have always sought to provide more effective solutions to these problems.

A regular objective function is called a function whose value does not deteriorate by reducing the time it takes to perform an activity without increasing the time of doing other things, and the irregular objective function violates this property. These functions include minimizing early-delayed activities in relation to deliverables, maximizing net present value and resource leveling, which can be divided into the following sub-models:

1. Capital Constrained Project Scheduling Problem (CCPSP)
2. Resource constrained cost-time trade-off problem
3. Resource constrained net present value maximizing problem
4. Resource constrained and discounted cash flows project scheduling problem
5. Project Payment Scheduling Problem (PSP)

### **Various methods for solving project scheduling problems**

In the late 1950s, the development of critical paths and project appraisal and review led projects to be able to be described by network diagrams, so that activities are defined by the network structure. However, in these techniques, only the time of the project was considered and the limited use of resources was not considered and resource constraints are one of the main problems in project planning in the real world. In this section, we discuss the algorithms proposed to solve the project scheduling problem. As this is a matter of NP-hard, so many algorithms have been proposed by the researchers to solve it. The algorithms are divided into two parts: precise algorithms and approximate algorithms (Heuristic and Metaheuristic algorithms).

### **Development of a timeline for functional goals**

Given the importance of the completion time of projects and completion of the project in a timely manner, without delay, the goal most often used in most studies is to minimize the completion time of the project. . This goal is achieved when the duration of all project activities is well estimated and scheduled optimally. Also, in project scheduling problems, one can consider different objective functions, one of these problems, considering the cash flow of the project, which tries to maximize the net present value of the project. Obviously, the use of such problems occurs when the cash flow of the project is clear from the beginning. The important point in these problems is that by finding the optimal answer, the actual project path is identified as a cash flow (and not a time). Effective Cash Flow Management is a strategy for dealing with project risks and adjusting payments based on progress. Since payments are usually the same as completing work, it determines the timing of activities, the frequency of payments, and their amount and time. Even in high-risk projects, with reasonable timing of payments based on advancement, there are opportunities to increase profitability. This will give rise to payment scheduling problems, as this will determine the amount, time, and place of payments on the progress of the project.

### Scheduling Model

Different models of the payment scheduling problem to the contractor allow the analysis of marginal profit balances and other parameters (such as the number of progress payments, their amount and time) under different scenarios. Then, these models can be presented as decision support tools for contractor suggestions and capital budget decisions.

The contractor negotiates with the employer the total amount received for the project, the number of payments and the proportion of the costs repaid in each payment. Then all project activities can be selected as a search box to specify the location of payments. The time and amount of each payment is determined by specifying the location of the payments and the timing of the activities.

Sato and Hirao (2013) checked the balance between project budgets and critical risks [8]. The mathematical modeling approach is used with metrics called RPV. The researcher considers the process of responding to project risks in two broad categories:

1. Preventive: this approach is used in cost-dependent risk and is the source of the balancing problem.
2. Adoptive: this approach is used in cost-independent risk, which is considered as a precautionary budget for this kind of risk.

In the following, a general relationship between cost-risk is presented, then the optimization methods are used using operational research methods, and then the conditions where the addition of additional funds will increase the value of the project, explain and ultimately produce a tool for decision making practical help in project management. The basic hypothesis of this research is that the inputs and outputs of the project can be evaluated in the form of cash flow. According to [figure 1](#), RPV is the total cash flow from operations and expected cash flows from future activities that is reduced by their probable completion.

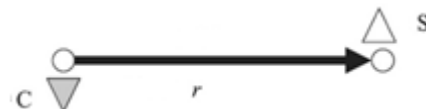


Fig.1. RPV for a project with an activity

In most researches conducted by researchers, maximizing the current net worth of a project or reducing the completion time of a project is considered solely and quantitative research on the balance between time-cost and the consideration of income and payments, in order to maximize the value of the project is done purely. Therefore, this research aims to maximize the current net present value of the project to the employer, following the objective function, according to the various constraints and conditions. In the subject literature, this problem has not been checked so far, and it is part of the suggestions for future research that is referred to in Zhengwen article [12].

In the problem of project scheduling based on income patterns, payment, and consideration of resource constraints, a new problem called MCCPPSP-DCF<sup>1</sup> with critical resource constraints is designed to integrate CCPSP<sup>2</sup> and PPSP<sup>3</sup> problems, which includes the scheduling problem of incomes and payments to maximize the employer's NPV. And activities can be implemented in several separate forms.

Project scheduling problems involve allocating scarce resources to activities over time that are processed at any time on any activity that requires resources. However, due to different project requirements, multiple constraints and parameter settings (such as resource constraints and payment terms) are considered in scheduling models.

The MCCPPSP-DCF problem for an employer is defined as follows: a project is considered with  $N$  Activities as AOA, and each activity consists of two inputs and outputs that occur at the time of its completion. The employer receives  $f$  incomes and provides  $k$  installments for the contractor during the implementation of the project. Activity  $n$  can be done in  $z_n$  modes, that the cost and execution time of the  $Z$  runtime are equal to  $d_{nz}$  and  $c_{nz}$ . The expenditures of  $n$  activity is equal to  $e_n$  and the profit margin of the employer and the contractor is equal to  $\zeta_e$  and  $\zeta_c$ , with the share of contractor payment called  $\theta$ . When earnings and payments occur, they should not be less than  $\lambda_e$  and  $\lambda_c$ . The interest rate of each period and the project completion time is equal to  $\alpha$  and  $D$  respectively. According to the above conditions, the purpose of this study is to determine the time and amount of incomes and payments, the method of implementation and the completion of the activities in order to maximize the employer's NPV.

## Model Assumptions

The following assumptions are considered in problem modeling:

- The activities of the problem are non-interruptible. That is, if an activity started, stopping is not allowed until the end of the activity, but the procedure can be changed.
- The maximum number of predecessor and successor activities is three.
- The duration of the activities is definite.
- Resource constraints in this project are only critical sources, which are definite and their amount is specific.

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<sup>1</sup> Multi-mode capital-constrained project payment scheduling problem with Discounted Cash Flows

<sup>2</sup> Capital-constraint project scheduling problem

<sup>3</sup> Project payment scheduling problem

- The activity network is a graph without cycles, and the duration and cost of activities are known in three ways.
- In the payment method, the number of continuous payments in the negotiation process is determined by both sides of the contract before the start of the project.
  - The contractor receives a fixed amount for the project.
  - The start time of the receipt of the earnings and their number is determined before starting the project.

## Variables and Parameters

The variables and parameters used in the model are as follows:

$n$  : Number of activities

$s_f$  : Amount of  $f$  income

$p_k$  : Amount of  $k$  payment

$f$  : Number of project incomes (for employer)

$k$  : Number of Contractor Payments

$q_n$  : The implementation method of  $n$  Activity

$\lambda_n$  : Minimum earnings

$\lambda_q$  : Minimum payments

$d_{nq}$  : The time of doing the  $n$  activity in the  $q$  execution mode

$c_{nq}$  : The cost of doing the  $n$  activity in the  $q$  execution mode

$e_n$  : The costs of  $n$  activity

$\zeta_n$  : The margin of profit of the employer

$\zeta_q$  : The margin of profit of the contractor

$\theta$  : The share of contractor payment

$ST_n$  : The start time of  $n$  activity

$FT_n$  : The completion time of  $n$  activity

$EF_n$  : The earliest completion time of the  $n$  activity

$LF_n$  : The latest completion time of the  $n$  activity

$OF_n$  : The optimal completion time of the  $n$  activity

$R$  : Number of critical resources

$R_k$  : The number of available units of the  $k$  source

$r_{jkt}$  : The number of units needed for the  $k$  source for the  $n$  activity during the time of  $t$

$\alpha$  : Discount rate

$D$  : Project completion time

$NPV$  : Net present value of the project

$$W_{fn} = \begin{cases} 1 & \text{If } f \text{ income is paid for } n \text{ activity} \\ 0 & \text{OW} \end{cases}$$

$$X_{kn} = \begin{cases} 1 & \text{If K payment is paid for n activity} \\ 0 & \text{OW} \end{cases}$$

$$Z_{nq} = \begin{cases} 1 & \text{If the n activity is performed with the execution method of q} \\ 0 & \text{OW} \end{cases}$$

Also, for the convenience of expressing the values of decision variables, the following symbols are defined:

W : The occurrence vector of incomes ( $W = (w_{fn}; f = 1, \dots, F)$ )

X : The occurrence vector of payments ( $X = (x_{kn}; k = 1, \dots, K)$ )

Y : The occurrence vector of activity completion time ( $Y = (OF_n; n = 1, \dots, N)$ )

Z : The vector of the operational method of activity ( $Z = (q : z_{nq}; n = 1, \dots, N)$ )

I : Vector of incomes ( $I = (s_f; f = 1, \dots, F)$ )

U : Vector of payments ( $U = (p_k; k = 1, \dots, K)$ )

V : The scheduling of activity ( $V = \{Z, Y\}$ )

A : The scheduling of project cash flow ( $A = \{W, X, V, I, U\}$ )

### Proposed mathematical model

Max NPV

$$= \sum_{f=1}^F \left\{ s_f \sum_{n=1}^N \left[ w_{fn} \sum_{EF_n}^{LF_n} \exp(-\alpha \cdot OF_n) \right] \right\} - \sum_{k=1}^K \left\{ p_k \sum_{n=1}^N \left[ x_{kn} \sum_{EF_n}^{LF_n} \exp(-\alpha \cdot OF_n) \right] \right\} \quad (1)$$

s. t.

$$EF_n \leq OF_n \leq LF_n \quad (2)$$

$$\sum_{n=1}^{N-1} w_{fn} = 1, \quad f = 1, 2, \dots, F \quad (3)$$

$$\sum_{n=1}^{N-1} x_{kn} = 1, \quad k = 1, 2, \dots, F \quad (4)$$

$$w_{FN} = 1 \quad (5)$$

$$x_{KN} = 1 \quad (6)$$

$$\sum_{f=1}^F [w_{fn}] \leq 1, \quad n = 1, 2, \dots, N \quad (7)$$

$$\sum_{k=1}^K [x_{kn}] \leq 1, \quad n = 1, 2, \dots, N \quad (8)$$

$$\sum_{q=1}^{Q_n} z_{nq} = 1, \quad n = 1, 2, \dots, N \quad (9)$$

$$\sum_{ES}^{LS} ST_n + \sum_{q=1}^{Q_n} (d_{nq} z_{nq}) \leq \sum_{EF}^{LF} FT_n, \quad n = 1, 2, \dots, N \quad (10)$$

$$(\lambda + \zeta_\lambda) \sum_{n=1}^N \left( e_n \cdot \sum_{f=1}^F w_{fn} \right) \leq \sum_{f=1}^F \left\{ s_f \sum_{n=1}^N [w_{fn}] \right\} \quad (11)$$

$$\theta (\lambda + \zeta_\lambda) \sum_{n=1}^N \left( e_n \cdot \sum_{k=1}^K x_{kn} \right) \leq \sum_{k=1}^K \left\{ p_k \sum_{n=1}^N [x_{kn}] \right\} \quad (12)$$

$$s_f \geq \lambda_\lambda, \quad f = 1, 2, \dots, F \quad (13)$$

$$p_k \geq \lambda_\lambda, \quad k = 1, 2, \dots, K \quad (14)$$

$$\sum_{EF}^{LF} FT_n \leq D \quad (15)$$

$$\sum_{f=1}^F s_f = (\lambda + \zeta_\lambda) \sum_{n=1}^N e_n \quad (16)$$

$$\sum_{k=1}^K p_k = (\lambda + \zeta_\lambda) \sum_{n=1}^N e_n \quad (17)$$

$$\sum_{n=1}^N r_{nkt} \leq R_k, \quad \forall_{k,t} \quad (18)$$

$$s_f \geq \lambda; p_k \geq \lambda; w_{fn}, x_{kn} \in \{0, 1\}; \lambda \leq z_{nq} \leq \lambda; \quad (19)$$

$OF_n, z$  as integer

The equation (1) of the objective function indicates the NPV of the employer from the implementation of the project, and includes all the receipts (incomes) and payments (expenses), which should be maximized, according to one of the payment methods.

Constraint (2) sets the completion time of the  $n$  activity in the  $[EF_n, LF_n]$  time window.

Constraint (3) connects  $f$  ( $f = 1, 2, \dots, f - 1$ ) income to a specific activity.

Constraint (4) connects  $k$  ( $k = 1, 2, \dots, k - 1$ ) payment to a specific activity.

Constraint (5) assigns the last income  $F$  to the final activity of  $N$ .

Constraint (6) assigns the last payment  $K$  to the final activity of  $N$ .

Constraint (7) ensures that income can earn in the one of the specific activities.

Constraint (8) ensures that payment can do in the one of the specific activities.

Constraint (9) selects an implementation state for each activity.

Constraint (10) relates to the precedence and Successor between project activities. So that no activity can begin before the completion of all of its precedence activities.

Constraint (11) restricts the minimum total amount of income during the project to the cumulative amount of project costs plus the profit margin of the employer.

Constraint (12) restricts the minimum total amount of payments during the project to the amount of the contractor's cumulative expense plus its margin, which is multiplied by the payment rate.

Constraint (13) ensures that the amount of each income is at least equal to  $\lambda_i$ .

Constraint (14) ensures that the amount of each payment is at least equal to  $\lambda_p$ .

Constraint (15) ensures that the project is completed before the project planning horizon.

Constraint (16) indicates that the total income is equal to the total project expenditure and the marginal interest of the employer.

Constraint (17) indicates that the sum of the total payments is equal to the total contractor's expense and its marginal interest.

Constraint (18) is critical for restricting critical resources, and in each period, all activities that are still in progress are to be considered for each source.

Constraint (19) is used to define decision variables.

### Method of solving the model

As discussed in the literature review section, the problem of project scheduling with desirable cost patterns with constrained resources considerations is due to computational complexities in the family of NP-hard problems, and their solving in large dimensions is impossible through linear programming and available software and require a long time. For this reason, meta-heuristic methods are used to solve such problems.

In general, the use of an meta-heuristic method for solving problems is taken by evaluating two conditions, that is, the solving time constraint (due to the breadth of the optimal search solution space) and the acceptance of the near-optimal (and not necessarily optimal) solution of the risk.

Also, the meta-heuristic methods have high efficiency with respect to precise algorithms and many heuristic methods for solving the combination of the optimization problems.

In MCCPPSP-DCF for Employer,  $s_f$  and  $p_k$  are independent decision variables, that is, if the execution method and the end time of activities, occurrence of incomes and payments are determined, then they can be calculated using the constraints (11) to (14).

Therefore, for solving model, similar to the MPPSP solving method, the MCCPPSP-DCF problem for the employer is also divided into two sub-problems:

1. Sub problem 1: How to determine the incidence of incomes ( $W$ ) and payments ( $X$ ), as well as the vector of the executive procedure ( $Z$ ), using the vector of the occurrence of the end time of fixed ( $Y$ ) activities.
2. Sub problem 2: How to determine the occurrence of the end time of activities ( $Y$ ) by using the incidence vector ( $W$ ) and payments ( $X$ ) as well as the vector of the executive method ( $Z$ ).

An elaborate algorithm and genetic algorithm is developed for solving sub-problem 1 and sub-problem 2 respectively, which will solve with the main processes as follows:

- Step 1- Enter the initial answer,  $A^0 = \{W^0, X^0, V^0, I^0, U^0\}$  and calculate  $NPV^0$ .
- Step 2- Fixing  $Y^0$  and searching for  $Z^*$ ,  $X^*$  and  $W^*$  with genetic algorithm.
- Step 3- Fixing  $Z^*$ ,  $X^*$   $W^*$  and searching for  $Y^*$  with the proposed heuristic algorithm.
- Step 4- Calculate the value of the objective function  $NPV^*$  with values  $A^* = \{W^*, X^*, V^*, I^*, U^*\}$

- Step 5- Gaining Output of  $A^*$  and NPV\*

An initial response to start the algorithm and a display method for the solution of the problem is required to solve problems using meta-heuristic algorithms. The problem of project scheduling is not excluded from this rule. Below is an example of how to display the answer and how to generate the initial answer for the proposed solution.

**Solution Representation Method**

The purpose of this section is to link the main problem with the structure of the genetic algorithm, that is, to build a communication bridge between the main problem and the problem-solving space in which the interaction occurs. In all meta-heuristic algorithms, due to the need to feasible solving at the start of the task, we need to store it according to a specific structure, which is called the method of displaying the answer. A feasible solution for given problem is shown in figure 2 as a single-dimensional matrix with  $4n$  dimensions.

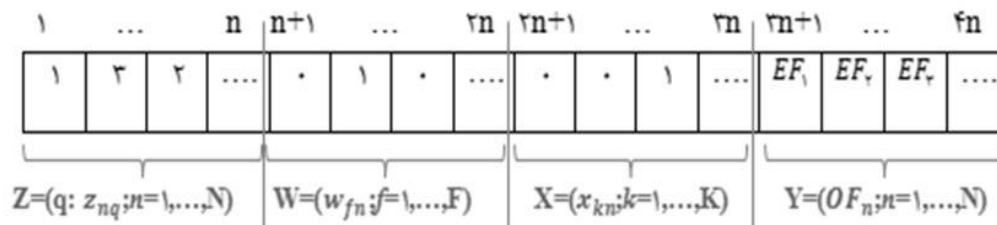


Fig.2. Solution Representation Method

**Solution Initialization Method**

To produce the initial answer, a method is used that called the production method of scheduling. This method plays a very important role in most of the heuristic and meta-heuristic methods and scheduling problem solving. This method takes a display list, such as activity list, random key or priority rule display, and converts it into a scheduler. There are two different types of this method, parallel method and serial method. Most of the evolutionary meta-heuristic methods use a random approach to generate initial answers. However, the quality of the final solutions obtained from these methods depends directly on the quality of the initial generated responses [12].

- Step 1-  $Z^o$  is selected for each activity randomly
- Step 2-  $Y^o$  is calculated by considering the precedence constraints and calculating  $V^o = \{Z^o, Y^o\}$
- Step 3- Random selection of  $F-1$  and  $K-1$  activity (without n) for  $W^o$  and  $X^o$
- Step 4- Calculation of  $I^*$  and  $U^*$  with 11 and 12 constraints and by using  $W^o$ ,  $X^o$  and  $V^o$
- Step 5- If the constraints 13 and 14 are met, the initial response is equal to  $A^o = \{W^o, X^o, V^o, I^o, U^o\}$ , otherwise, repeat steps 3 to 5.

**Structure of Optimization Method for Genetic Algorithm**

- Step 1- Inclusion of input parameters
- Step 2- Creating a Primary Population

- Step 3- Functional fitness assessment
- Step 4- Parent selection for reproduction
- Step 5- Performing intersection operations for the production of children
- Step 6- Perform mutation operations to produce mutated people
- Step 7- Integration of population (primary population, intersection population, mutated population)
- Step 8- If the number of iterations has reached the specified limit, finish and otherwise go back to step 3
- Step 9- Stop and exit results

**The structure of proposed heuristic algorithm**

An overview of the proposed algorithm for solving the sub problem 2 is shown in figure 3.

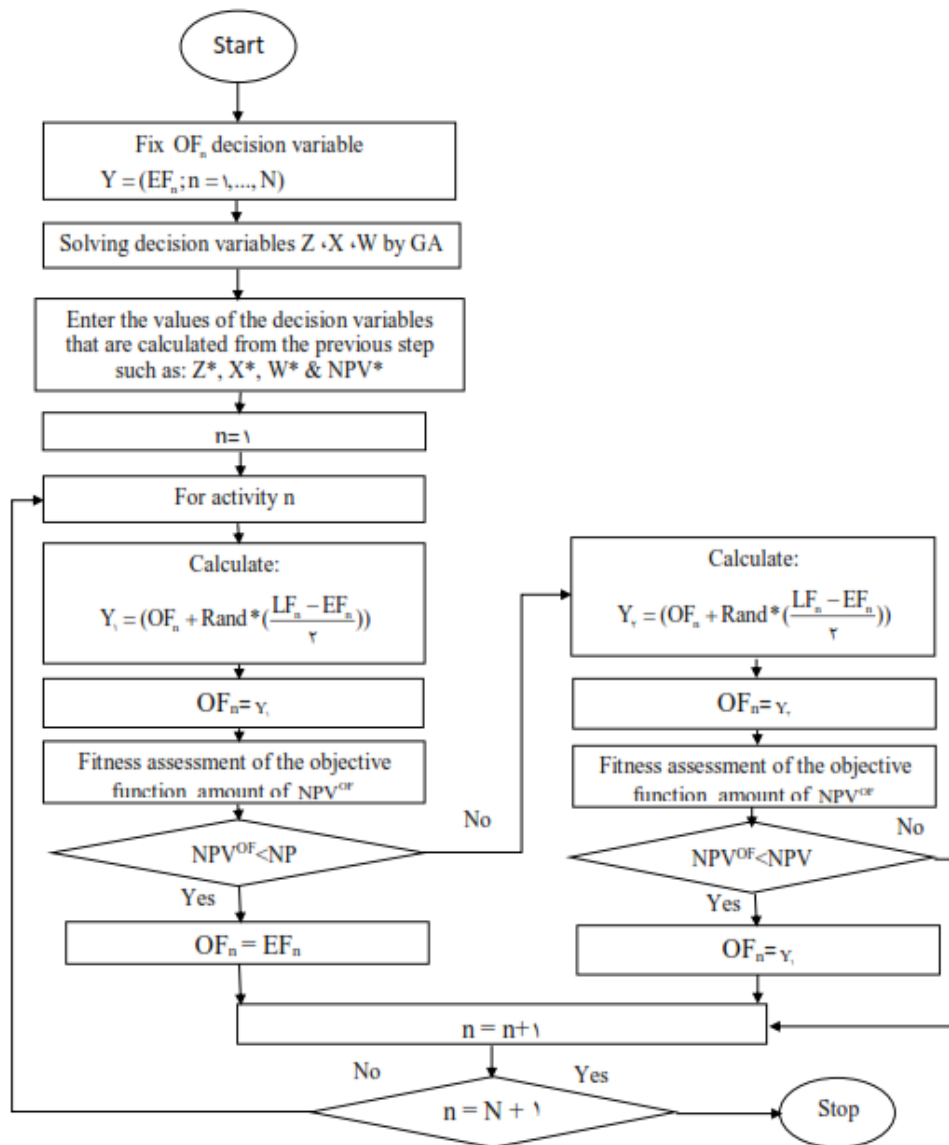


Fig.3. Outline of the proposed heuristic algorithm for solving the sub problem 2

### The general features of project

The failure structure is the only pivot point that can be considered as an important channel in integrating a comprehensive project management system with other sub-systems such as risk management. At high levels of the WBS, you can undo the effects of delays without properly executing running activities; otherwise, it can create many potential problems, and researchers believe this is the only way. The typical example of this research is the project of building a commercial and office complex (given that all data such as revenues and payments, etc. are real, mention of the name of the project and the partner company is forbidden) which has a large number of activities (more than 500 Activity). The information of this study is analyzed to the third level of the WBS and is avoided to enter the lower levels. The project sample item included 58 activities. Project information includes the time of activities, precedence relationships, the number of resources required to carry out the activities and positive and negative cash flows (according to the resources used) is obtained from the project managers and planners. In the project, only critical resources constraints are considered, which include two types of renewable and non-renewable sources.

### The optimal scheduling of operational objectives

The mathematical model presented in this study is coded with the use of genetic algorithm and proposed algorithm in Excel and VBA. In this section, the model is first validated and then the input parameters of the problem and the solution results are discussed. To validate the model, the Solver tool in Excel and the sample project presented in the Hegazy article [7] have been used. The supplementary information is given in [figure 4](#).

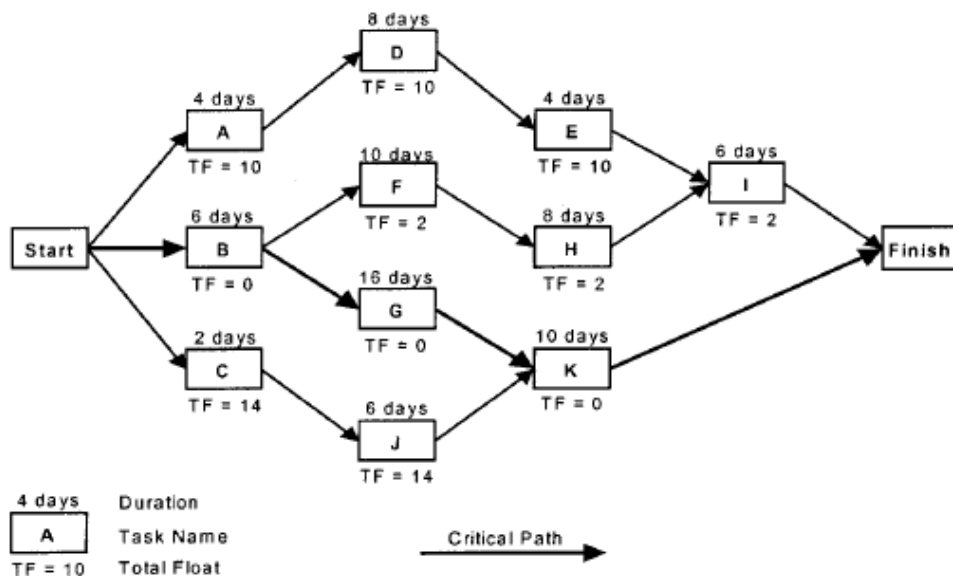


Fig.4. Project activities network

After entering the project information in Solver and solving the model, the project's profit margin is 40,189 \$ and the end time is 27 days. The results obtained for decision variables and the results of solving the model with solver are shown in [Table 1](#) and [Table 2](#) respectively. Also, the project information and the solution results with the proposed genetic algorithm, with a project profit value of 42,275\$ and a 27-day end time, are shown in [Table 4](#) and [Table 4](#)

respectively. By comparing the Solver solution with the results, it can be concluded that the method of solving and coding made for it yields better results and its logic is correct.

Table 1. Results for decision variables

Project time (day)=27,0 NPV=40,189\$				Predecessor			successor			CPM Calculation											
Code	Name	Runtime	cost x\$ 1000	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Delay	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	ES	EF	LS	LF	TF
1	A	3,00	2,20				4				0,0	0,0	0,0	11,0	27,0	27,0	0,0	3,00	8,00	11,0	8
2	B	3,00	16,6				6	7		0	0,0	0,0	0,0	5,0	3,0	27,0	0,0	3,00	0,0	3,00	0
3	C	1,00	5,20				10				0,0	0,0	0,0	11,0	27,0	27,0	0,0	1,00	10,0	11,0	10
4	D	8,00	18,0	1			5			0	3,0	0,0	0,0	19,0	27,0	27,0	3,00	11,0	11,0	19,0	8
5	E	4,00	20,0	4			9			0	11,0	0,0	0,0	23,0	27,0	27,0	11,0	15,0	19,0	23,0	8
6	F	10,00	15,0	2			8			0	3,0	0,0	0,0	15,0	27,0	27,0	3,00	13,0	5,00	15,0	2
7	G	14,00	12,4	2			11				3,0	0,0	0,0	17,0	27,0	27,0	3,00	17,0	3,00	17,0	0
8	H	8,00	16,0	6			9				13,0	0,0	0,0	23,0	27,0	27,0	13,0	21,0	15,0	23,0	2
9	I	4,00	14,2	5	8					0	15,0	21,0	0,0	27,0	27,0	27,0	21,0	25,0	23,0	27,0	2
10	J	6,00	9,30	3			11				1,0	0,0	0,0	17,0	27,0	27,0	1,00	7,00	11,0	17,0	10
11	K	10,00	7,30	7	10					0	17,0	7,0	0,0	27,0	27,0	27,0	17,0	27,0	17,0	27,0	0

Table 2. Results from solving the model with solver

Decision variables					The cost and time information of three different methods of construction (Method 1 is the cheapest and method 3 is the most expensive method of construction)														
Changing executive method in	W	X	Y	Z	Optimum start time (OS)	Optimum Completion	Income Receipt Period (EF)	Contractor payments	Income Receipt Period (OF)	Contractor payments	Executive	cost 1 x 1000	Runtime 1	cost 2 x 1000	Runtime 2	cost 3 x 1000	Runtime 3		
	Yes	1	1	5	3	2	5	3	3	5	5	3	\$10,40	4	\$2,20	3	\$2,20	3	
Yes	1	1	3	3	0	3	3	3	3	3	3	\$10,00	6	\$18,5	4	\$16,6	3		
Yes	0	0	6	3	5	6	0	0	0	0	3	\$4,00	2	\$4,00	2	\$5,20	1		
Yes	1	0	13	2	2	10	11	0	13	0	2	\$18,00	8	\$18,0	8	\$7,30	5		
Yes	0	0	14	2	10	14	0	0	0	0	2	\$20,00	4	\$20,0	4	\$26,1	3		
Yes	0	0	13	2	3	13	0	0	0	0	2	\$15,00	10	\$15,0	10	\$15,0	10		
Yes	0	0	17	2	3	17	0	0	0	0	2	\$12,00	16	\$12,4	14	\$11,6	10		
Yes	0	0	22	1	13	21	0	0	0	0	1	\$16,00	8	\$16,2	6	\$17,0	2		
Yes	0	1	25	2	21	25	0	25	0	25	2	\$10,00	6	\$14,2	4	\$14,2	4		
Yes	0	0	15	2	9	15	0	0	0	0	2	\$9,30	6	\$9,30	6	\$9,30	6		
Yes	1	1	27	2	17	27	27	27	27	27	2	\$7,30	10	\$7,30	10	\$9,00	9		

Table 3. Project Information

Project time (day)=27,0 NPV=42,275\$				Predecessor			successor			CPM Calculation											
code	name	Runtime	cost x\$ 1000	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Delay	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	ES	EF	LS	LF	TF
1	A	3,00	2,20				4				0,0	0,0	0,0	15,0	27,0	27,0	0,00	3,00	12,0	15,0	12
2	B	4,00	18,5				6	7		0	0,0	0,0	0,0	11,0	4,0	27,0	0,00	4,00	0,00	4,00	0
3	C	2,00	4,00				10				0,0	0,0	0,0	12,0	27,0	27,0	0,00	2,00	10,0	12,0	10
4	D	5,00	7,30	1			5			0	3,0	0,0	0,0	20,0	27,0	27,0	3,00	8,00	15,0	20,0	12
5	E	3,00	26,1	4			9			0	8,0	0,0	0,0	23,0	27,0	27,0	8,00	11,0	20,0	23,0	12
6	F	10,0	15,0	2			8			0	4,0	0,0	0,0	21,0	27,0	27,0	4,00	14,0	11,0	21,0	7
7	G	14,0	12,4	2			11				4,0	0,0	0,0	18,0	27,0	27,0	4,00	18,0	4,00	18,0	0
8	H	2,00	17,0	6			9				14,0	0,0	0,0	23,0	27,0	27,0	14,0	16,0	21,0	23,0	7
9	I	4,00	14,0	5	8					0	11,0	16,0	0,0	27,0	27,0	27,0	16,0	20,0	23,0	27,0	7
10	J	6,00	9,30	3			11				2,0	0,0	0,0	18,0	27,0	27,0	2,00	8,00	12,0	18,0	10
11	K	9,00	9,00	7	10					0	18,0	8,0	0,0	27,0	27,0	27,0	18,0	27,0	18,0	27,0	0

Table 4. Results from solving the model with proposed method

Decision variables					The cost and time information of three different methods of construction (Method 1 is the cheapest and method 3 is the most expensive method of construction)														
Changing executive method in	W	X	Y	Z	Optimum start time (OS)	Optimum Completion	Income Receipt Period (EF)	Contractor payments	Income Receipt Period (OF)	Contractor payments	Executive	cost 1 x 1000	Runtime 1	cost 2 x 1000	Runtime 2	cost 3 x 1000	Runtime 3		
	Yes	0	0	3	2	0	3	0	0	0	0	2	\$10,40	4	\$2,20	3	\$2,20	3	
Yes	1	1	4	2	0	4	4	4	4	4	2	\$10,00	6	\$18,52	4	\$16,60	3		
Yes	1	1	2	1	0	2	0	2	0	2	1	\$4,00	2	\$4,00	2	\$5,20	1		
Yes	0	0	8	3	3	8	0	0	0	0	3	\$18,00	8	\$18,00	8	\$7,30	5		
Yes	1	0	11	3	8	11	11	0	11	0	3	\$20,00	4	\$20,00	4	\$26,11	3		
Yes	0	0	14	1	4	14	0	0	0	0	1	\$15,00	10	\$15,00	10	\$15,00	10		
Yes	0	0	18	2	4	18	0	0	0	0	2	\$12,00	16	\$12,40	14	\$11,60	10		
Yes	0	0	16	3	14	16	0	0	0	0	3	\$16,00	8	\$16,20	6	\$17,00	2		
Yes	1	0	20	2	16	20	20	0	20	0	2	\$10,00	6	\$14,20	4	\$14,20	4		
Yes	0	1	8	2	2	8	0	8	0	8	2	\$9,30	6	\$9,30	6	\$9,30	6		
Yes	1	1	27	3	18	27	27	27	27	27	3	\$7,30	10	\$7,30	10	\$9,00	9		

### Results

The input parameters of the problem include general parameters and control parameters of the algorithm. General parameters related to the characteristics of the activities and resources. The activity parameters are: the time of each activity, precedence activities, the number of activities, the resources required for each activity and the project cash flows. The parameters related to the critical resources shown in Table 5.

Table 5. Data on input parameters

matter	parameter	Data value or data generation method
Activity	Number of activities	58
	Time of activity	It is executed in three ways
	The set of precedence activities	There can be at most three precedence relationships
	The required resources of activity	$r_{ijk, \forall i,j,k}$ and According to the information available in the section on determining the methods of implementation, Figure (3,3)
	Project Cash Flow	$p_k, s_f$ And in accordance with the project timetable (5.3).
Critical resources	Number of resources	3
	Quantity available from any source	$L_1, E_3, M_1$ is equal to 50, 2 and 50 units respectively

The control parameters of genetic pattern, including the number of algorithms, the size of the population, the number of intersections and the parent selection method, are shown in [Table 6](#).

Table 6. Data on control parameters

<b>matter</b>	<b>parameter</b>	<b>Data value or data generation method</b>
<b>Program control</b>	Number of repetitions of the algorithm	100
	Population size	100
	Intersection number	2
	The parent's choice method of the stop principle	The number of generations generated in this research is equivalent to 100 generations

The genetic algorithm is performed 100 times and generates 100 populations. This set is the primary population, each member of the population has a fitness value, which represents the amount of matching with the objective function of the problem. Now we use an intersection operator to make improvements in the fitness of population members and population updates. According to the previous discussion, the intersection operation approach is a two-point operator, and then the mutated population is created by mutation. At each step of this approach, the amount of fitness of the goals is examined and the members of the population are compared with each other. In the second step, using the proposed algorithm, problem is solved the decision variable Y that was assumed to be constant in the previous step. In the second step, using the proposed algorithm, the decision variable Y, which was assumed to be constant in the previous step, was found. The proposed model has been executed in 10 times, the results of which are presented in [Table 7](#).

Table 7. Results from various solutions of the proposed problem

<b>matter</b>	<b>title</b>	<b>amount</b>
<b>Objective function</b>	maximum	2200,5
	minimum	1992,8
	average	2122,92
	Standard deviation	73,54
	Average solving time	25

Regarding the implementation of the algorithm, the genetic algorithm is first implemented after entering the general parameters of the problem, defining and initializing the control parameters and determining the initial response. To enter parameters and solve the interface problem, [Figure 5](#) is designed.

Finally, a set of answers that includes the time and amount of revenues and payments, the operating method, the start and end time of the activities and the maximum project completion time, and in proportion to the NPV of the project for the employer (as shown in Figure 6) and the value before Implementation of the optimization and the values of the initial program (in accordance with Figure 7) is introduced as the output of the algorithm and the final solution.

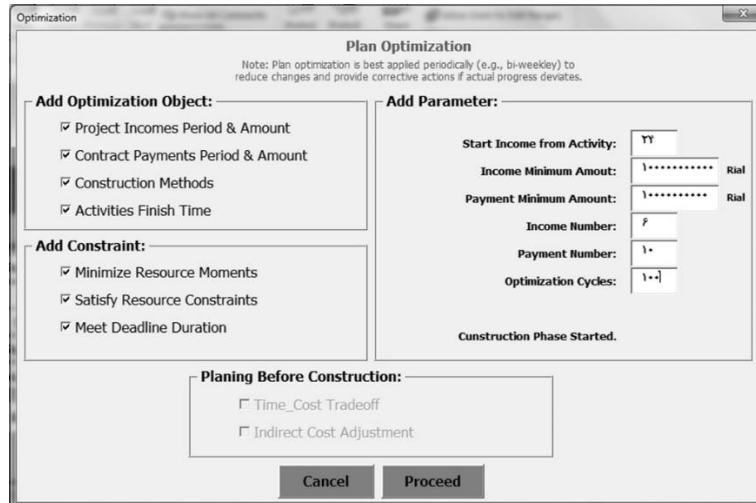


Fig.5. User interface for defining the parameters and constraints of the scheduling and solving model

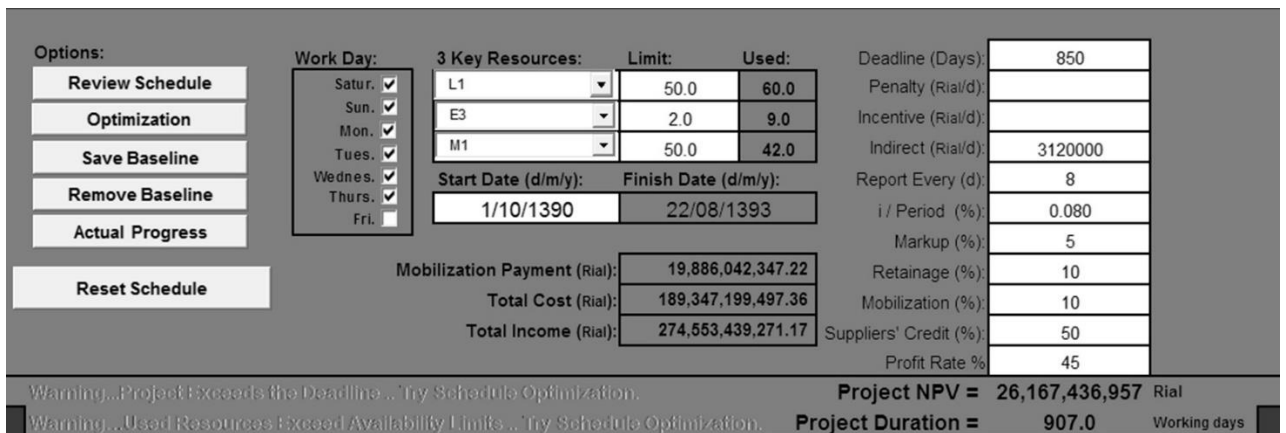


Fig.6. Overview of the project before optimization

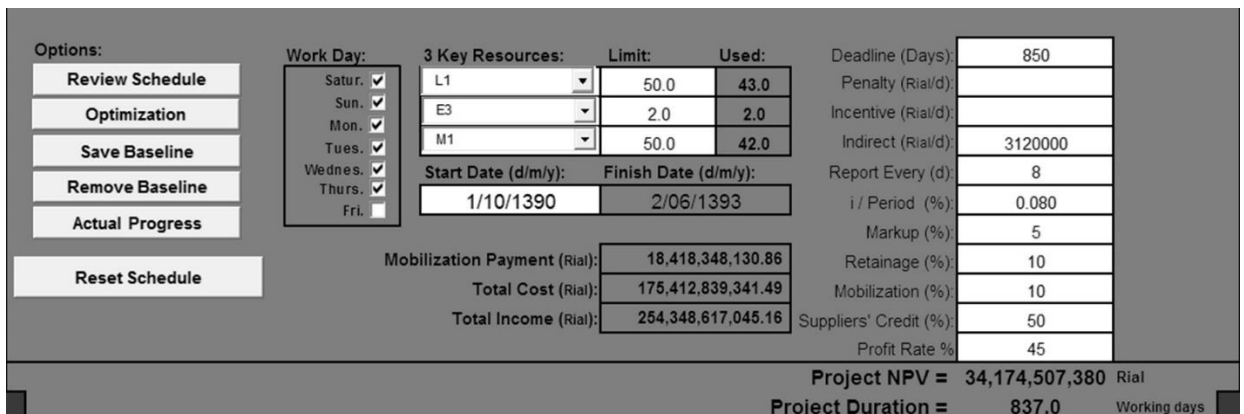


Fig.7. General Project information after optimization

## Discussion and Innovation

One of the most important problems that delayed the implementation of the projects is the lack of liquidity during the implementation of the project phases, which leads to undue delays. These problems can be largely addressed by an appropriate estimation of expected costs and expected incomes. Therefore, in this research, we tried to develop a model for scheduling of the project's goals in order to maximize profits by properly regulating resources and activities, and creating an optimal cash flow plan to prevent project financial losses.

The most important aspects of research innovation are:

- Providing a new mathematical model for scheduling payments, with constrained available capital and critical resources, and discounted cash flows, to maximize the current net present value of the project for the employer, in which several operational practices are considered (MCCPPSP-DCF).
- Development of a new innovative algorithm to solve part of the decision variables.

Also, suggestions that can be made to continue this research are as follows:

- Considering other goals such as the sustainability and quality of the project in the objective function of the mathematical model of the scheduling problem.
- Considering the time and cost of operating and consuming resources in a fuzzy mode in the scheduling model.
- Other algorithms can be used to generate and improve solutions. In other words, a hybrid meta-heuristic algorithm is considered to solve the scheduling problem.
- Considering the adjustment coefficients and the inflation rate in the objective function of the scheduling model.
- Considering rewards and fines for each time unit, in the scheduling objective function and the proposed performance evaluation model.

## References

- [1] Angela, H.L.C., Chiu-Cheng, C., 2008. A Memetic Algorithm for Maximizing Net Present Value in Resource-Constrained Project Scheduling Problem. IEEE Congress on Evolutionary Computation (CEC) 2041-2049.
- [2] Demeulemeester, E., Herroelen W., 2002. Project Scheduling: A Research Handbook. Kluwer Academic Publishers.
- [3] Hegazy, T., Petzold, K., 2003. Genetic optimization for dynamic project control. Journal of construction engineering and management 129, 396-404.
- [4] Kazemi, F.S., Tavakkoli-Moghaddam R., 2011. Solving a multi-objective multi-mode resource-constrained project scheduling problem with discounted cash flows. 6 th International Project Management Conference.
- [5] M.J, I., Wei, O.S., 2013. Project Scheduling Under Resource Constraints: A Recent Survey. International Journal of Engineering Research & Technology (IJERT) 2(2), 1-20.
- [6] Najafi, A.A., Akhavan Niaki, S.T., Shahsavar, M., 2009. A parameter tuned genetic algorithm for the resource investment problem with discounted cash flows and generalized precedence relations. Computers & Operations Research 36, 2994 – 3001.

- [7] Okada, et al., 2010. A Random Key-based Genetic Algorithm Approach for Resource- constrained Project Scheduling Problem with Multiple Modes. Proceeding of the Internatinal MultiConference of Engineers and Computer Scientists (IMECS), 17-19March 2010,Hong Kong.
- [8] Sato, T., Hirao., M., 2013. Optimum budget allocation method for projects with critical risks. International Journal of Project Management 31, 126–135.
- [9] Shu-Shun , L., Chang-Jung W., 2008. Resource-constrained construction project scheduling model for profit maximization considering cash flow. Automation in Construction 17, 966-974.
- [10] Turner, J.R., 2009. The hand book of Project-based Management:Leading Strategic Change in Organizations. McGraw-Hill,USA.
- [11] Zhengwen, H., 2012. Metaheuristics for multi-mode capital-constrained project payment scheduling. European Journal of Operational Research 223, 605–613.
- [12] Zheng-wen, H.E., 2009. Client Perspective Based Multimode Project Payment Scheduling Problem and Its Heuristic Algorithm. Systems Engineering Journal 29(2), 70-77.