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Time-Cost-Quality Trade-Off in Project with Using Invasive Weed Optimization Algorithm

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ABSTRACT

The most important aims in choosing the best choice for the constituent parts of a project are time, cost and quality, in which the project time and final cost contain the least minimum, and the final quality includes the most maximum. In today's competitive world, simultaneous reduction of the project cost, its performing time and the high quality are so essential. Therefore, due to the asymmetry of the three factors above (i.e. the reduction of two factors and the increase of a factor), it is necessary to create a balance between cost, time and quality. To solve this model, a meta heuristic and heuristic IWO (invasive weed optimization) algorithm is introduced. This algorithm makes a search strategy using a mechanism inspired by the natural behavior of weeds in colonizing suitable place for growth and reproduction. Ina case study, the achieved computational results of this algorithm, Genetic Algorithm (GA) according to the model flexibility and capability by attending the Analysis of Variance (ANOVA) are compared and shown for the decision making by managers.

KEYWORDS: decision making, optimization, time-cost and quality of project, invasive weed growth algorithm, ANOVA.

INTRODUCTION

By the development of different systems for the completion of the projects, project managers no longer take into account only the reduction in project costs, given the fact that time is a crucial factor in the evaluation and processes of the construction. Compression of the time project gradually increases the final costs of the project. Critical Path Method (CPM) is one of the most common methods and existence techniques in determining of the project schedule.

In this method, we cannot make changes in the schedule. On the other hand, the assumption of unlimited resources determines the duration of the project. However, this is not the case in the real world, sometimes the stakeholders trend towards reducing the cost and time, and increasing the quality(an important factor). Therefore, the emergence of the time-cost-quality trade-off technique is the most important results of these efforts to address these shortcomings.

Lots of mathematical methods and investigations are applied for solving the problem of time, cost and quality balance (Fondahel 1961; Azaron and Perkgoz 2005). These methods generally depend on the problem, and do not guarantee the optimal solution {1}; and on the other hand, the increasing dimension and complexity of the problem cause the loss of performance. Although this approach would ensure the optimal solution {2}, conversion and use of these methods, which include conversion of heuristic methods into objective functions, may be associated with the error.{3}

During recent decades, various methods have been given for the simultaneous optimizing of time, cost and quality ,considering the fact that very serious attention has recently been paid to the quality as a criterion of optimization in the choice of methods for implementing the project. Most articles have been devoted to the simultaneous optimizing of time and cost. Given methods in related projects and time-cost -quality optimizing in performing the projects are categorized into three groups: 1) investigative 2) mathematics 3) ultra investigative. Some investigative methods are the given methods by Fondahel (1961), Prager (1963), Moslehi (1993), Siemens (1971).

These models are mentioned for the mathematical method: Linear programming method (Kelly 1961), Integer programming model (Mayer 1963), Operational programming model (Robinson 1975) and the collective model of linear and integer programming (Liu & Burns 1995). Investigative methods are related to the problem kind for achieving the response and do not guaranty the optimizing response achieving. Although the mathematical methods are able to optimize the response, if they can solve the problem but by increasing the number of variation, they aren't practical any more. Thus by increasing dimension and complexity of the problems, there will no possibility of solving mathematical optimization techniques. Recently, the complete progress of an ultra investigative algorithm in solving the optimizing problems has taken lots of researchers interest. According to the mentioned subjects and the importance of the three indicators, time- cost- quality, the necessity of a more practical algorithm is felt completely.

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The algorithm of Invasive Weeds Optimization (IWO) is inspired by invasive weeds growth by the point of numerical likely optimizing, which was pointed by Mehrabian and Locus (2006). IWO algorithm isan adaptive algorithm based on the biological evolution of the growth of weeds in the appropriate places for the objective function. Invasive weeds are too strong.

With the ability of invasive growth that makes them a serious problem for agricultural plants, the weeds are adopted and strong against the changes.

This algorithm as an Evolutional Algorithm tries to imitate the adopting power and accidental growing of the invasive weeds. This investigation expresses the problem of cost-quality for the linear relation between time-cost and time-quality; however, like other studies is not looking for Pareto (Zheng et al 2005) responses. Compared to other investigations, this article has two major differences in modeling and creativeness problem for solving the sample, comparing the response of problem and the quickness in achieving the problem's answer by GA algorithm (Eshteharian et al 2008).

Difference in modeling is because of that the project managers do the activities shortening for achieving the acceptable quality, So the given model in this article is specialized just for this real problem and solving the pattern concludes achieving the optimized point in three dimensions space. The project manager can achieve another optimized point by changing the amount of acceptable quality of the determined time. So by having this optimized point, decision making for the project managers will be easier compared to the time that we have all Pareto responses.

In this article creativity, creativity in the model solving, is introduced for solving the pattern that, in comparison with GA algorithm, is more practical. High speed, being fast, being inspired by the nature and simplicity help this algorithm to converge on the responses. The solving algorithm of this model for huge projects reduces the speed and time of achieving the optimized answer remarkably.

In the given model of this article, the enriched invasive weeds algorithm is applied for solving the time, cost and quality optimizing in this problem. The enriched invasive weeds algorithm is suitable for solving the discrete or separated problems which are spread in the responses of searching space in a real form. By applying the method of enriched invasive weeds growth in this pattern has been attended to solving the time, cost and quality problem and the conclusions have been compared to the GA in the ANOVA method.

This paper is organized as follows. In the next Section, we present the problem definition and the problem formulation. Then, a solution procedure is introduced. We develop an algorithm, namely EIWO. To illustrate the proposed approach, a number of examples are presented and the related results of this algorithm are analyzed by the ANOVA method. Finally, the remarking conclusion is given.

Problem Formulation

In this paper, a project has been defined by Direct acyclic graph, G=(V,E), where V is the set of nodes and E the set of arcs. Arcs show the activities, and nodes indicate the events. G(V,E) is shown as a matrix Amx3 that m is the number of Nodes and n is the number of Arcs.

The Amx3 matrix is called the node - arc incidence matrix for graph G(V,E) .

According to the number activities, Matrix, A contains m rows and 3 columns. The first column includes the activities number. The second one is the network model number for each activity which the activity has exited from that, and the third column is the model number that the activity in the network has entered to that.

$$\mathbf{A} = [\mathbf{a_{ij}}]$$

$$\mathbf{a_{ij}} = \begin{cases} \mathbf{i} & \mathbf{if\ j = 1} \\ \mathbf{q} & \mathbf{if j = 2}\ \boldsymbol{and}\ \boldsymbol{q}\mathbf{bethebeginningnodeofArc\ i} \\ \mathbf{q} & \mathbf{if\ \ j = 3\ and\ q\ be\ the\ ending\ node\ of\ Arc\ i} \end{cases} \quad i=1,\ldots,m \qquad j=1,\ldots,3 \qquad q=1,\ldots,n \quad (1)$$

In each activity of the project (Ej) includes a different execution mode of M_j that each $K \in M_j$ includes time t_{jk}, cost c_{jk} and quality q_{jk} of the activity j. It is assumed that if k and r are two modes for activity j and k <r, then tjk>tjr, cjk<cjr and qjk ≠ qjr. Although in the studies, it is assumed that the reduction in activities decreases the quality of each activity, it should be noted that in the real world of the projects, reduction in the duration of activity always decreases the quality of an activity. For example, if a new technology is used to reduce the time of activity, it can reduce the time and increase the quality and cost.

The aim is to find the optimal combination (tjk, cjk, qjk) for any activity to compress network project, so that the total costs of the project (direct costs + indirect costs) can reach the minimum by reducing the total project time; and total quality of the project cannot be lower than the optimal value.

$$\mathbf{Min.\ C_T} = \left(\sum_{j=1}^{n} \sum_{k \in M_j} \mathbf{c_{jk}} * \mathbf{y_{jk}}\right) + \mathbf{C_{Id}} * \mathbf{T_{cpm}^{k}} \quad (2)$$

St:

$$\sum_{j=1}^{n} \mathbf{w_j} \sum_{l=1}^{L} \mathbf{\acute{w}_{jl}} \sum_{k \in M_j} \mathbf{q_{jlk}} * \mathbf{y_{jk}} \geq \mathbf{Q_{allow}} \quad (3)$$

$$\sum_{k\in M_j} y_{jk} = 1 \qquad j = 1, 2, \dots, n \tag{4}$$

$$\sum_{j=1}^{n} w_j = 1 \tag{5}$$

$$\sum_{l=1}^{L} \acute{w}_{jl} = 1 \qquad j = 1, 2, \dots, n y_{jk} = 0 \text{ or } 1 \qquad \forall j, k \tag{6}$$

The CPM problem can be viewed as the reverse of the shortest network path, so T_{cpm}^{k} according to the network matrix has been formulated as below:

$$T_{cpm}^{k} = \text{Max} \sum_{j=1}^{n} x_j \sum_{k\in M_j} t_{jk} * y_{jk} \tag{7}$$

St:

$$\sum_{j=1}^{n} a_{ij} * x_j = b_i i = 1, 2, \dots, m x_j = 0 \text{ or } 1 \tag{8}$$

$$b_i = \begin{cases} 1 & i = 1 \text{if} \\ -1 & i = m \text{if} \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

where:
C_T: Total Cost of Project (Direct costs + Indirect Costs)
C_Id: Project indirect cost per time unit
c_jk: Direct cost of activity j when performed the kth execution mode.
direct cost of doing activity I in mode k
t_jk: Duration of activity j when performed the kth execution mode
q_jlk: Performance of quality indicator (l) in activity j performed the kth execution mode
y_jk: Stands for the index variable of activity j when performed the Kth execution mode.
If yjk=1 then the activity j performed the Kth mode.
whileyjk=0 means not.
x_j: The index variable of activity j that …… of flow on the arc j.
ifxj = 1 the activity j is in the path.
While xj = 0 means nota_ij
b_i: the available supply in ith node
M_j: Set of available execution modes for each activity j
w_j: Weight of activity j compared to other activities in the project
w´_jl: Weight of Quality indicator (L) compared to other(L) indicator, in activity j
Q_allow: Lower bound for Project quality

Solution Procedure

For each activity, there are some execution modes for choosing in the Discrete Time-cost Quality Trade-off Problem (DTCQTP) (Shahsavari Pour et al 2010; Shahsavari Pour et al 2012). If n be the project activities and each activity k has the execution mode, then there will be Kn series of justified responses ,which indicate the extremely huge space of searching for solving the problem. Therefore it is essential to apply Evolutionary Algorithm for solving the problemand achieving the optimized responses.

Invasive Weed Optimization (IWO)Algorithm

IWO is a likely numerical optimizing algorithm which is inspired by the invasive weeds growth. IWO was discussed in an article by Mehrabian and Locus (2006). IWO is an adaptive algorithm based on the natural biological evolution of invasive weeds growth and extending in the suitable position of the objective function. Invasive weeds are strong, and their invasive growth has made them as a serious problem for the agricultural plants. The weeds have shown that they are strong and adopted against the sudden environment changes (Mehrabian and Lucas 2006; YIN and WEN 2012). This algorithm as an evolutionary algorithm simply imitates the invasive weeds power of adopting and sudden growth. The algorithm details are explained in the flowchart of figure below. The following figure 1 shows the stages of growthing seeds.

Fig1: The stages of graoathing seeds.

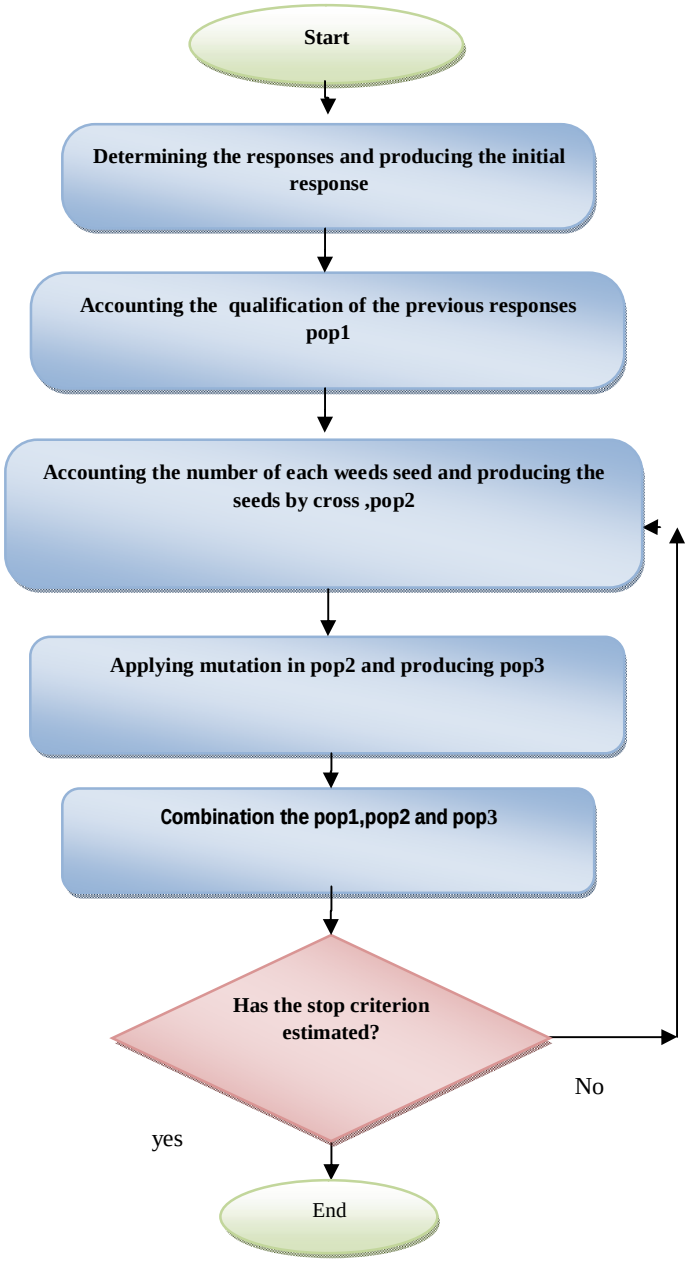

Fig. 2 Flowchart of IWO

The IWO execution steps for solving the investigative problem are as below :
Step 1: At first the problem data are recognized, then by coincidence N seeds with right gene as initial responses are produced. The problem data include the project data and IWO parameters.
The project data include:
project Network matrix ($A_{mx3}=[a_{ij}]$)
available Execution modes for each activity j and their expected impact on the activity cost, time and quality .
(M_j)and (c_{jk},t_{jk} ,q_{jk})
Weight of activity j compared to other activities in the project. (W_j)
Project indirect cost per time unit . (C_{Id})
Lower bound for Project quality . (Q_{allow})
The required IWO Parameters include :
string size (n)

Number of generation (G).
Population size (N).
weight of EXP function.(W_{exp})
weigh to Linear function. (W_{lin})
crossover Rate
Mutation Rate.
Step 2: For each of N produced seeds, the total direct cost($DC_{(s)}$) , the total project time($\mathbf{T_s^{cpm}}$) and the total project quality $Q_{(s)}$ are accounted as below:
The project direct cost: the sum of the direct costs of all project activities

$$\mathbf{DC_{(s)} = \sum_{j=1}^{n} c_{sj}\ s = 1, 2, \dots, N} \qquad (10)$$

The Total project time: Total time of activities on the critical path

$$\mathbf{T_s^{cpm} = Max \sum_{j=1}^{n} x_j * t_{sj}} \qquad (11)$$

St:

$$\mathbf{\sum_{j=1}^{n} a_{ij} * x_j = b_i i = 1, 2, \dots, m x_j = 0 \text{ or } 1} \qquad (12)$$

The Total project quality: the weighted sum of qualitative values of different indicators of activities.

$$\mathbf{Q_{(s)} = \sum_{j=1}^{n} w_j * q_{sj}} \qquad (13)$$

$$\mathbf{q_{sj} = \sum_{l=1}^{L} \acute{w}_{jl} * q_{sjl} s = 1, 2, \dots, N} \qquad (14)$$

Although, in a random seed production, the seeds have the right gene and each activity just be able to choose its execution mode, in this step in order to being sure of the seed rightness, the calculated quality for seed shouldn't be less than the quality allow (Q_{allow}).
Step 3: Determining the Fitness Function and the possibility of choosing P_s for each of S seeds by using bellow formula:

$$1)\mathbf{F_{(s)} = DC_{(s)} + T_s^{cpm} - \left(DC_{min} + IC * T_{min}^{cpm}\right) + 1} \qquad (15)$$

$$2)\mathbf{P_{(s)}} = \frac{\frac{\sum_{s=1}^{N} F_{(s)}}{F_{(s)}}}{\sum_{s=1}^{N} \frac{\sum_{s=1}^{N} F_{(s)}}{F_{(s)}}} \qquad (16)$$

If (($\mathbf{DC_{min}}$ +$\mathbf{IC*T_{min}^{cpm}}$)) won't be 1 in this pattern, then f_s will be large numbers and in consequence P_s get closer and finally the selection process loses the essential practicality.
If Fsequals 0, the P_s accounting will be impossible, so +1 exists in the first equation.
Since the seeds with lower Fs are better, the P_s should be somewhat that has less F_s ,whatever the F_s becomes less the possibility of choosing S seed that is P_s will increase, so the equation 2 achieved for P_s.
Step 4: Computing the numbers of produced seeds by each plant, according to the amount of its fitness. In this step, each plant produced some seeds that its quantity is related to the fitness of the plants. It means that the plants with the high fitness will introduce more seeds in comparison with those which have less fitness. For computing the number of each plant seed, a linear function in relation to the fitness has been used.
A linear function is used to obtain the number of seeds:

$$NOS=C* \mathbf{F_{(s)}} \qquad (17)$$

Where $F_{(s)}$ is the amount of S fitness and C is a constant in which is used for balancing. The seeds should be produced after determining the seeds number for each plant. The seeds operators have designed in a way that we gain right seeds after the execution. Some point crossover, and steady crossover has been used in this problem (Hansancebi and Erbatur 2000). And according to the activities number one or some point mutation has been applied. For example, in a project with 9 activities, 3 random seeds by right gene could be as below:

$$\mathbf{Parent_1 = [2, 1, 5, 3, 2, 4, 1, 5, 3]}$$
$$\mathbf{Parent_2 = [4, 3, 2, 5, 4, 1, 3, 2, 5]}$$
$$\mathbf{Parent_3 = [1, 4, 3, 2, 3, 5, 4, 1, 2]}$$

In this example, because of the small number of activities, one- and multi-point mutation and multi-point crossover operators were used. By the effect of operator execution, the produced seeds from the above parents are like these:

$$\mathbf{Offspring_1 = [2, 3, 3, 3, 4, 5, 1, 2, 2]}$$

One–two & three point mutation with Random point (E=6)

$$\mathbf{Offspring_1 = [2, 3, 3, 3, 4, 3, 1, 2, 2]}$$

It should be mentioned that using one, two or three-point mutation depends on the fitness of seeds. A seed with high fitness takes fewer mutation (one point) and a seed with lower fitness takes more mutation (three points).
In addition, the mutation rate is also a decreasing one, and uses the function 4 so that the mutation rate will be zero in the last generations.

$$\mathbf{F_{MuRate}} = \mathbf{1} - \frac{\mathbf{n_G}}{\mathbf{G}} \tag{18}$$

The fitness calculation of seeds and their production will continue as long as we reach the maximum number of plants to grow. Thus, the produced seeds are added to the initial population.

Step 5: repeating the steps 2 to 4 until the seeds do not change from one generation to the next.

Application Example

The applied example in this article includes 9 activities. Each activity contains different modes that have the time, cost and quality of the activity (table2). Also the effective weight of each activity is indicated in the table2. Figure 3 shows the related network of the example. For achieving the time and critical path. The network matrix has been distinguished in the table

Fig. 3. Project network

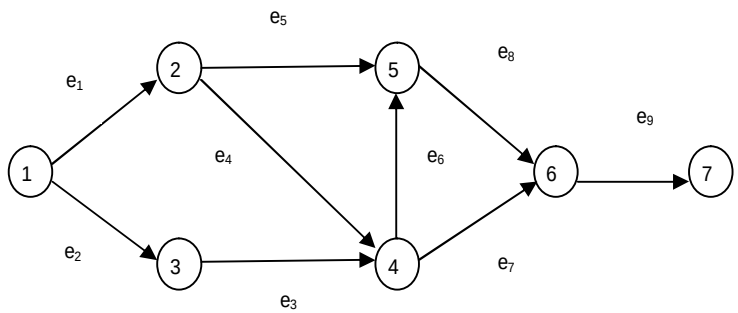

Table 1. Network matrix

$$\begin{array}{c} \mathbf{e_1} \\ \mathbf{e_2} \\ \mathbf{e_3} \\ \mathbf{e_4} \\ \mathbf{e_5} \\ \mathbf{e_6} \\ \mathbf{e_7} \\ \mathbf{e_8} \\ \mathbf{e_9} \end{array} \begin{bmatrix} \mathbf{1} & \mathbf{1} & \mathbf{2} \\ \mathbf{2} & \mathbf{1} & \mathbf{3} \\ \mathbf{3} & \mathbf{3} & \mathbf{4} \\ \mathbf{4} & \mathbf{2} & \mathbf{4} \\ \mathbf{5} & \mathbf{2} & \mathbf{5} \\ \mathbf{6} & \mathbf{4} & \mathbf{5} \\ \mathbf{7} & \mathbf{5} & \mathbf{6} \\ \mathbf{8} & \mathbf{5} & \mathbf{6} \\ \mathbf{9} & \mathbf{6} & \mathbf{7} \end{bmatrix}$$

Table 2. Activities executions modes

		Modes																			
		1			2			3			4			5			6				
		T	**C**	**Q**	**T**	**C**	**Q**	**T**	**C**	**Q**	**T**	**C**	**Q**	**T**	**C**	**Q**	**T**	**C**	**Q**		
Activities	$\mathbf{e_1}$	7	160	90	6	180	85	5	190	80	4	200	70	3	230	85				0.1	W_d
	$\mathbf{e_2}$	8	140	85	7	150	82	6	179	80	5	180	75	4	200	80				0.1	
	$\mathbf{e_3}$	8	110	90	7	120	85	6	140	84	5	150	80	4	170	90				0.14	
	$\mathbf{e_4}$	10	100	88	9	130	90	8	140	85	7	150	75	6	165	80				0.11	
	$\mathbf{e_5}$	14	160	92	13	170	90	12	180	86	11	200	70	10	230	80	9	240	90	0.12	
	$\mathbf{e_6}$	8	130	85	7	140	82	6	150	80	5	170	85	4	190	90				0.15	
	$\mathbf{e_7}$	11	150	87	10	180	90	9	190	85	8	200	90							0.08	
	$\mathbf{e_8}$	11	140	91	10	150	88	9	160	85	8	170	75	7	265	85				0.12	
	$\mathbf{e_9}$	11	150	90	10	170	88	9	180	85	8	200	90							0.08	

IWO Parameters are set as Follows

The presented model was implemented in the Microsoft Excel using the visual basic programming language, and the used parameters are as below:

N=100, G=100, mutation rate: 0.2, crossover rate: 0.8 The program was run on a Pentium 4 PCs with CPU 2.8 GHz, which took 24.46 seconds, and chromosome [*4,2,2,1,1,5,1,4,4*] and its corresponding project time, cost and quality (T_t=34, C_d=1440, Q=84.5) were obtained as the output. Also total cost of the project was obtained (C_t=2120).The project manager then obtained other optimal points by increasing Q_{allow}, which are presented in the results in Table 3 and Figure 4.

The table 3 includes some of the achieved responses by applying the algorithm. It is possible to make another balance between time, cost and quality by changing the related weight of them and achieve other responses. It should de stated that the execution time duration of the algorithm for achieving the responses was 24.46 seconds.

To demonstrate the performance of the proposed algorithm, we compare the responses obtained with the results of GA and NHGA methods (Shahsavari Pour et al 2012; Shahsavari Pour et al 2010). The WEED, NHGA and GA are implemented with the same parameters for thirty times. Their results are analyzed via the analysis of variance (ANOVA) method.

the below parameter has been used for the variance analysis and the conclusions of variance analysis are shown in Figure 4.

$$\mathbf{WRD} = \left(\mathbf{w_c} \times \frac{\mathbf{C_{alg}-C_{min}}}{\mathbf{C_{min}}} + \mathbf{w_t} \times \frac{\mathbf{T_{alg}-T_{min}}}{\mathbf{T_{min}}} + \mathbf{w_q} \times \frac{\mathbf{Q_{max}-Q_{alg}}}{\mathbf{Q_{max}}}\right) \tag{19}$$

where, C_{alg} and T_{alg} and Q_{alg} are the total project cost, duration and quality for a given algorithm, respectively. $\boldsymbol{C_{min}}$and T_{min} and $Q_{max}$are the best solutions obtained by each algorithm for a given instance. Whatever **WRD** be much less, the difference between the achieved response and optimized relative response will be less.

As it is shown in the graphs of figure 5, it can be concluded that the scatter of the introduced algorithm is less than the GA, NHGA and thereby is more optimized.

However, since the execution time of the program (i.e., the time to get a result) is an important factor, we need an additional indicator for further improvement and higher effectiveness, and we would like to get the optimal solution in the least time. Related graphs are shown in figure 5:

$$\mathbf{WRD\&Run\_Time} = \mathbf{W_{WRD}} * \mathbf{WRD} + \mathbf{W_{run\_time}} * \mathbf{Runtime} \tag{20}$$

W_{WRD} and W_{run_time} are the specialized weights for the criterions of WRD and Execution Time ,which indicate these two parameters importance. According to the importance of the space degree and also the response achieving time, the amount of WRD is considered 0.9 and the Execution Time is considered 0.1 .

Less amount in this answer shows the optimizing being of the response in the least time. Figure 5 Analysis Graphs based on WRD and Execution time. As it is shown in the graphs of figure 5, all the responses are optimized as well as having less been scattering the introduced method and much few times has spent for computing the responses.

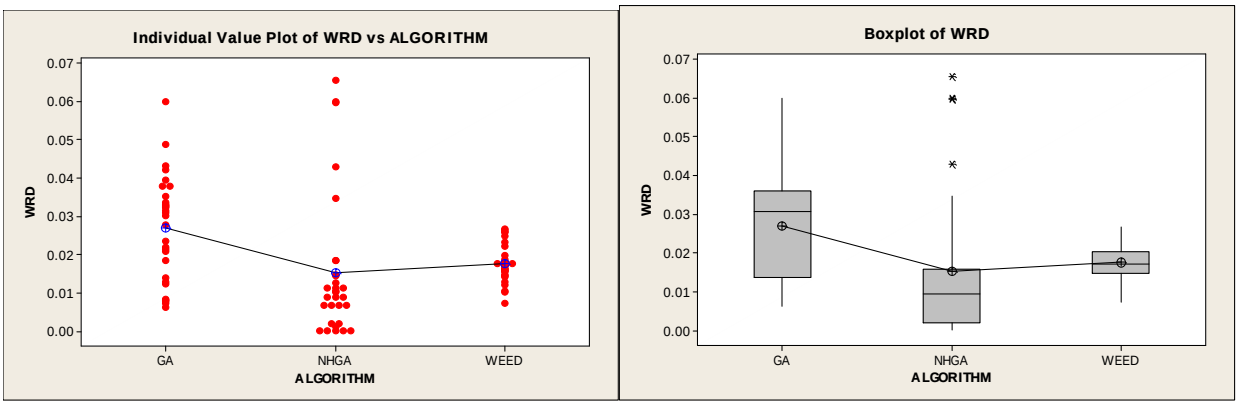

Fig. 4. Variance Analysis Graph based on WRD

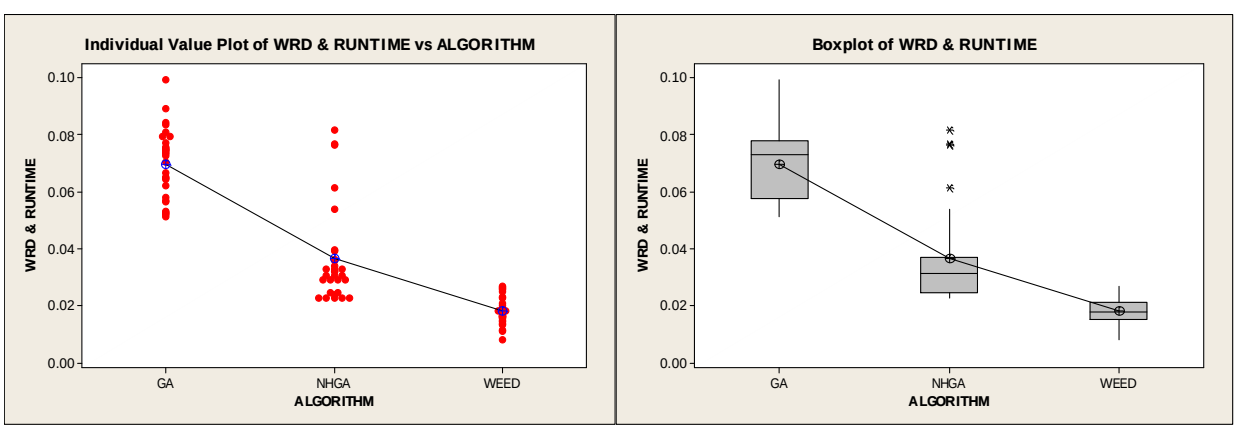

Fig 5. Analysis Graphs based on WRD and Execution time

Table 3.**Final outputs of the EIWO**

Solution	C_d	Q	T_t	Q_{Allow}
4 2 2 1 1 5 1 4 4	1440	84.48	34	84
4 2 2 1 1 5 1 4 4	1440	84.48	34	84
4 2 2 1 1 5 1 4 4	1440	84.48	34	84
4 2 2 1 1 5 1 4 4	1440	84.48	34	84
4 2 2 1 1 5 1 4 4	1440	84.48	34	84
3 2 1 1 1 5 1 4 4	1420	86.18	35	85
3 2 1 1 1 5 1 4 4	1420	86.18	35	85
3 2 1 1 1 5 1 4 4	1420	86.18	35	85
3 2 1 1 1 5 1 4 4	1420	86.18	35	85
3 2 1 1 1 5 1 4 4	1420	86.18	35	85
2 1 1 1 1 5 1 4 4	1400	86.98	36	86
2 1 1 1 1 5 1 4 4	1400	86.98	36	86
2 1 1 1 1 5 1 4 4	1400	86.98	36	86
2 1 1 1 1 5 1 4 4	1400	86.98	36	86
2 1 1 1 1 5 1 4 4	1400	86.98	36	86
3 2 1 1 1 5 1 3 3	1390	86.98	37	86
3 1 2 1 1 5 1 3 3	1390	86.58	37	86
2 2 1 1 1 5 1 3 4	1400	87.88	37	87
2 2 1 1 1 5 1 3 4	1400	87.88	37	87
2 2 1 2 1 5 1 2 4	1420	88.46	38	88
2 2 1 2 1 5 1 2 4	1420	88.46	38	88

Conclusions

This article presents a model of algorithms for solving the time, cost and quality problem. Compared to other existing models and algorithms, the advantage of this model is the use of the Invasive Weed Optimization Algorithm. One of the most important aims of this project is locating the Quality variation beside the Time and Cost. In order to place the model more closer to the reality, the problem was presented in a discrete mode (DTCQTP). (Shahsavari Pour et al 2010; Shahsavari Pour et al 2012). Also it expresses that how quality as an effective factor can change the responses of the cost-time balanced problem in relation to the Cost, Time, Quality problem. By comparing the previous studies about the balance time, cost and quality problem, the ability of the proposed algorithm in finding out the set of optimized responses was proved and by having the optimized points decision making become much easier in comparison to the time that they just had the Pareto responses. Applying the proposed algorithm in this model significantly increased the speed to reach solutions to the problem so that less than 25 seconds was spent in the example above. High speed, the responses fast converging, extending the problem and solving that by the Fuzzy logic (Jin et al 2005) can be effective in the capability and practicality of the model for greater projects in macro scales.

In sum, the proposed model can greatly help the managers, decision-makers and programmers of construction in evaluating the effects of different consuming programs in the project process.

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The authors declare that they have no conflicts of interest in this research.

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Notation

The following symbols are used in this paper:

$\acute{w}_{jl}$= Weight of Quality indicator (L) compared to other(L) indicator , in activity j
C_{Id}= Project indirect cost per time unit
C_T= Total Cost of Project (Direct costs + Indirect Costs)
M_j= Set of available execution modes for each activity j
Q_{allow}= Lower bound for Project quality
T_{min}^{cpm}= minimum time of population
$a_{ij=}$ **The entry of incidence matrix, as defined before**;
b_i= the available supply in ith node
c_{jk}= Direct cost of activity j when performed the kth execution mode.
q_{jlk}= Performance of quality indicator (l) in activity j performed the kth execution mode
t_{jk}= Duration of activity j when performed the kth execution mode
w_j= Weight of activity j compared to other activities in the project
x_j= The index variable of activity j that of flow on the arc j .ifx_j = 1 the activity j is in the path. S While x_j = 0 means not
y_{jk}= Stands for the index variable of activity j when performed the Kth execution mode . If y_{jk}=1 then the activity j performed the K_{th}mode .whiley_{jk}=0 means not.
DC_{min} = minimum direct cost of population