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A Mathematical Model for Balancing (Cost-Time-Quality and Environmental Risks) in Oil and Gas Projects and Solving it by Multi-Objective Bee Colony Algorithm

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ABSTRACT

Today, in large projects such as constructing oil, gas and petrochemical refineries, it is inevitable to use modern management methods and project timing. On the other hand, in classic scheduling case, the focus is on balance between time and cost of carrying out projects, which in such a situation, one of possible solutions to shorten time of implementing project is to accelerate activities. This acceleration can affect the quality of conducting projects and environmental impacts, in addition to impose more costs. Hence, in such studies, environmental impacts and quality of activities were also considered as new indicators in case of project time-cost balance. There has been proposed a new mathematical model with four indicators: cost, time, quality and environmental impacts. The provided model is a multi-objective mathematical model of zero-and-one programming type that despite traditional models, in which there is only considered an implementation mode for carrying out activities and a pre-conditional relationship between activities, modes of implementing activities are as multi-form and the dependence relationship between the activities is a generalized pre-requisite. Including the relationships brings the problem closer to the real world. Because of NP-hard of the problem in large dimensions and the necessity of using meta-heuristic Algorithms, we used MOBEE algorithm to solve the model.

1 Introduction

Gas industries, have an important role in the world economy because they supply the necessary products to sustain the world energy supply [25]. Today, in oil projects and large infrastructure projects such as constructing oil, gas and petrochemical refineries, it is inevitable to apply new methods of project management. Therefore, the importance of managing such projects is more than before due to scale, complexity and diversity of the projects in these industries [22]. However, it should be taught that project managers have considered to some extent applying new ways to manage projects. It seems that the most important reasons for delays to implement large oil projects are lack of planning in projects and using non-project knowledge, in addition to the project nature [7]. In classic issue of project scheduling with resource constraints, the goal is to minimize project length by considering resource constraints and

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prioritizing activities [15]. In classic scheduling case, the focus is on balance between time and cost of carrying out projects, which in such a situation, one of possible solutions for shortening time of implementing project is to accelerate activities.

Therefore, in the present research, to bring the matter closer to the real world, in addition to time and cost, the environmental effects and quality of activities were added to the issue of project cost-time balance as new indicators. There was provided a new mathematical model with four indicators; cost, time, performance and environmental effects. There were considered modes of implementing activities as multi-modality rather than monogamy, and the relationship between activities was considered as generalized pre-requisite relations. In addition to the relationship of end-start, there were also included three types of other time communication (beginning to beginning, beginning to ending and ending to ending) in the activities.

2 Literature Review

Studies show that the issue of balancing the main criteria of project was originally introduced in 1691 in relation to two criteria, time and cost. Gradually, with the advent of quality in modern engineering contracts, a cost-quality balance was considered in the project. In the last few decades, various methods have been proposed to optimize the time and cost of project activities, which can be divided into three categories: heuristic, mathematical, and meta-heuristic. The integer programming is an example of the proposed mathematical methods by researchers in which the problem of time-cost balance is optimized with a mathematical programming model, and because of these methods, it is possible to choose a combination of different options There are activities to do at any time for the project to be done, optimized for hybrid optimization methods and among the very hard issues (NP-Hard) [4]. Conventional optimization techniques or fast computational methods have been reduced at the right time, and thus it was very difficult to achieve optimal solutions in these situations. The comprehensive and successful development of hyper-optimization algorithms for solving single-objective optimization problems attracted the attention of researchers to investigate the possibility of using these algorithms in solving multi-objective optimization problems. Multiple approaches for the proper use of these algorithms, their classification, the application of each of these approaches in a specific category of optimization problems, as well as their verification are the problems and complexities facing the users of these algorithms.

In the past few years, the issue of project scheduling with resource constraints has been considered due to its scientific significance and computational challenges encountered in the models. Of course, despite previous efforts, which have been provided in line with the baseline modification, today, most of studies are conducted to develop a better solution with more diverse goals [25]. As the summary of studies in the following tables shows, most conducted studies in recent years have considered minimizing completion time of projects, and they only have created innovation in methods of solving problem.

3 Research Methodology

This research is a type of applied development study that is included in the quantitative study group (mathematical modeling). The methods of collecting data are library and field information. In order to review the literature and the background of the research, the library method has been used and the field method has been used to collect quantitative and statistical data. The research subject is a project of N activity, for which only one executive mode is considered for each activity. This research seeks to accomplish four objective functions: minimize project scheduling, minimize the cost of completing a project, and maximize the quality of the work activities and minimization of environmental degradation effects due to different constraints.

Table 1: The conducted studies

Row	Objectives	Model hypotheses	Solving method	References
1	Maximizing weight value of doing activity modes	Multivariate performance of activities; general pre-requisite	Precise methods	[8]
2	Minimizing Project Length	Hierarchical variables; random loss limits	Algorithm for discrete algae	[19]
3	Minimizing project time	Renewable and non-renewable resources; multi-state activities	Routing algorithm	[13]
4	Minimizing project time	Flexible resources	Genetics algorithm	[10]
5	Minimizing project time	Multimode; resource constraints	Evolution multi-objective algorithm	[20]
6	Minimizing project time	Multi-Project; multi-mode	Monte Carlo and Memetic algorithm	[18]
7	Minimizing total time; Minimizing project delay time	Renewable resources	Binary Search	[21]
8	Minimizing project time	Total pre-requisite of renewable and non-renewable resources; non-interruptible activities	Integrated linear integration model	[15]
9	Minimizing costs; maximizing program stability	Uncertainties during activities and costs; considering possible boundaries in violation of restrictions	Genetic algorithms and multiple objective differential evolution	[1]
10	Minimizing project time; minimizing project cost	Secondary pre-requisite; multi-mode activities	NSGA-II algorithm	[12]
11	Minimizing project time	Each resource is a skill; assigning some resources to a specific activity throughout the project	Developing two new concepts: weight value of resources and grouping activities; innovative method	[3]
12	Minimizing project time	Renewable resources; single-mode activity	Population-based evolution algorithm (differential evolution)	[2]
13	Minimizing project length and delay time	Renewable resources	NSGA-II	[9]
14	Minimizing project length and costs	Under risk aversion; multi-mode activities	Integer planning	[24]

The problem of project scheduling with multiple objective functions is placed in the category of very difficult problems (NP-hard), and because of the computational complexity, solving them in large dimensions is not possible through linear programming and existing software, or to the time So many need to be used; for this reason, meta- heuristic methods are used to solve such problems. Since the problem of multi-objective optimization is sought, it first seeks to find a suitable approximation of the unpicked front, and secondly, the answers can cover all of that Pareto. There are two ways to solve a multi-objective objective function. One is the transformation of a multi-objective problem into a single objective and solving it using single-objective algorithms, in which case it must obtain a set of answers with several repetitions and, of course, some of the points of the unpicked front are not considered in this way. The second method is to solve it directly through multi-objective algorithms; therefore, we use multi-objective algorithms to solve the problem.

Table 2: Model Parameters

Title	Parameter description
I	Activity ith
M_i	Set run mode to activity I
A	Total of activities
L	Quality indicators set
ls_i	The most delay start time of ith activity
q_{iml}	Quality of l index in doing activity i on executable mode m
w_i	Weight of activity i
w_{il}	Weight of quality index l for activity i
σ_i	Don limit of quality of activity i
es_i	Earliest start time of ith activity
C_{im}	The cost of doing activity i in executable mode m
E_{SS}	Total activities that their relationship prerequisite is as start-start
E_{SF}	Total activities that their relationship prerequisite is as start-end
E_{FS}	Total activities that their relationship prerequisite is as end-start
E_{FF}	Total activities that their relationship prerequisite is as end-to-end
SS_{IJ}	Delay time of start-start mode of activity i and j
SF_{IJ}	Delay time of start-end mode of activity i and j
FS_{IJ}	Delay time of end-start mode of activity i and j
FF_{IJ}	Delay time of end-end mode of activity i and j
d_{im}	Time of running activity i in executable mode m
r_{imk}^{rr}	Activity i intake in executable mode m from kth renewable source
$a^{rr}{}_k$	Access level to kth renewal source in each period
r_{imk}^{nr}	Activity i intake in executable mode m from kth non-renewable source
α_k^{nr}	Access level to new kth renewable resource in whole project
P_{im}^{EI}	Environmental effect of activity i in executive mode m for environmental index m
P^{EI}	The threshold of environmental impact for the environmental index NO M
T	The time of project completion
t_i	Time interval between esi and lsi
es_i	The earliest possible start time for activity ith
ls_i	The earliest possible start time for activity ith, until no delay in project final completion
H	A set of pairs of activities with perquisite relationships

By investigating multi-objective meta- heuristic algorithms, the Bee Colony Algorithm was selected for this problem. To control the sensitive parameters of the Bee Colony Algorithm, Taguchi experiments were used to operate the Taguchi experiments and implement the Bee Colony Algorithm using the Minitab and Matlab software respectively. To validate the problem, we tested the model with real data part of a project at the Ilam Gas Refining Company, which can be said that our target group was the National Iranian Gas Company, which described the Ilam gas refinery as an example of this industry.

4 Problem Formulation

4.1 Model Hypotheses

In designing the problem mathematical model, the following hypotheses were presented, by considering applicable features and conditions:

- ✓ Data are definite and distinct;
- ✓ Project activities have multi-mode nature; in other words, there are several methods for carrying out each activity;
- ✓ Project activities are not interrupted; in other words, after starting any activity, it is not allowed to stop;
- ✓ Capacity of resources is limited;
- ✓ There is no need for preparation time for activities;
- ✓ Pre-requisite relationships of activities are general pre-requisite relationship type.

4.2 Model Parameters

The presented parameters of mathematical model in this study are defined as Table 2. For activity i in the project, M_i is considered as set of different modes of activity I that there is introduced a fourfold combination (t, c, q, e) for each run mode such as mi, they represent time, cost, quality and environmental effects of an activity in that mode respectively.

4.3 Decision Variables

The decision variable in the proposed model is decision-making variable (Ximt) that is binary. If activity i in executable mode m start in time t, its value will be 1; otherwise its value will be 0. x_{im_it} is the decision variable in the proposed model is decision-making variable (X_{imt}) that is binary? If activity i in executable mode m start in time t, its value will be 1; otherwise its value will be 0. The decision variable in the proposed model is decision-making variable (X_{imt}) that is bi-nary. If activity i in executable mode m start in time t, its value will be 1; otherwise its value will be 0.

$$x_{im_it} \in \{0,1\} \tag{1}$$

$$i = 0,1,2, \dots, n+1 \tag{2}$$

$$m_i = 1,2, \dots, M_i \tag{3}$$

$$t = es_i, \dots., ls_i \tag{4}$$

Because the problem is a multi-mode one, there are considered three counters for decision variable. The first counter (i) represents counter of the relevant activity; the counter m also indicates operating mode of activity i; and finally, counter t refers to the start time of activity i that this is the time between the earliest and the shortest start time of activity i. When activity i is started in time t, {Ximit= 1 and Ximit= 0}.

$$\begin{cases} X_{im_it} = 1 \\ , \\ X_{im_it} = 0 \end{cases} \tag{5}$$

5 Target Functions

There are four objectives in this study which are defined as follows:

First objective: minimizing costs of the project completion

The first considered objective, both in project timing and in context of sustainable development is costs of the project completion. According the following equation, in this target function, there have been ignored other project costs such as resources.

$$\text{Min } Z_1 = \sum_{i \in A} \sum_{m \in M_1} \sum_{t=es_i}^{ls_i} c_{im_i} \times X_{im_it} \tag{6}$$

Second Objective: Minimizing Time of the Project Completion

One of the most important considered goals in scheduling all projects is the completion time of the project. Since the math model is written according to the project activity network, if the completion or start time of the last project activity (that is usually a virtual activity) is minimized, overall project time will be minimized too; therefore, in accordance with the following equation, the research mathematical model will minimize completion time of the project in the second objective function.

$$\text{Min } Z_2 = \sum_{t=es_{n+1}}^{ls_{n+1}} t.\, x_{(n+1)1t} \tag{7}$$

Third Objective: Maximizing Quality of the Whole Project

The third objective function maximizes quality of the whole project, in terms of quality indicators, weight of these indicators, as well as the importance of each activity [5]:

$$\text{Max } Z_3 = \left(\sum_{i=1}^{n} w_i \sum_{l=1}^{L} \sum_{m=1}^{M_i} w_{il} q_{im_il} X_{im_it} \right) \tag{8}$$

Fourth objective: Minimizing environmental impacts of the project

The fourth objective function is to distinguish the presented model with models of balancing and time-cost-quality in this field. In this function, there are considered minimization environmental impacts involved with the project. Since each project depends on its nature and implementation environment can have many environmental consequences, in general, these can be classified into the following three categories [23]:

- Environmental effects of the project on air;
- Environmental impacts of the project on soil;
- Environmental impacts of the project on water

In order to maintain totality of the proposed model, all three categories of these effects are taken into account and the ultimate target function is obtained from sum of the effects of each category. In the proposed math model, there have been considered three environmental effects for each activity in each mode that are represented by EI. Final contamination of the project will be obtained by summing three upper classes of pollution for the selected implementation mode in the activities. Therefore, the fourth objective function will be as follows:

$$MinZ_4 = \frac{\sum_{i=1}^{I}\sum_{m=1}^{M_i}\sum_{t=es_i}^{ls_i} p_{im}^{EI^{(1)}} . x_{imt}}{P^{EI^{(1)}}} + \frac{\sum_{i=1}^{I}\sum_{m=1}^{M_i}\sum_{t=es_i}^{ls_i} p_{im}^{EI^{(2)}} . x_{imt}}{P^{EI^{(2)}}} + \frac{\sum_{i=1}^{I}\sum_{m=1}^{M_i}\sum_{t=es_i}^{ls_i} p_{im}^{EI^{(3)}} . x_{imt}}{P^{EI^{(3)}}} \tag{9}$$

6 Constraints of the Model

There are seven categories of constraints, which are defined as follows:

Choosing a Run-Mode for Each Activity

The first limitation of the presented mathematic model guarantees just one run-mode for each activity in the final schedule. In this sense and according to the fact that this study supposes multiple modes for each activity of the project, the mentioned limitation of necessity for choosing guarantees just one mode of activity in order not to be interrupted.

$$\sum_{m_i=1}^{M_i}\sum_{t=es_i}^{ls_i} X_{im_it} = 1 \qquad i = 1, \dots, n+1 \tag{10}$$

Constraints of General Pre-Requisites Relations

The next limitation of this mathematic model is because of the nature of Four-prerequisite relationships (beginning - beginning, beginning – end, end-beginning, end-end) among the project's activity. But, the ith activity cannot be performed before the end of all pre-requisite activities as being determined by the H set. Accordingly, the limitations do not allow the activity's start before the end of all pre-requisite activities.

$$\sum_{m_i+1}^{M_i}\sum_{t=es_i}^{ls_i} (t + ss_{ij}) X_{im_it} \le \sum_{m_j=1}^{M_j}\sum_{t=es_j}^{ls_j} t.x_{jm_jt} \qquad \forall(i,j) \in E_{ss} \tag{11}$$

$$\sum_{m_i+1}^{M_i}\sum_{t=es_i}^{ls_i} (t+SF_{ij}) X_{im_it} \le \sum_{m_j=1}^{M_j}\sum_{t=es_j}^{ls_j} \left(t.d_{jm_j}\right) x_{jm_jt} \qquad \forall(i,j)\in E_{sf} \tag{12}$$

$$\sum_{m_i+1}^{M_i}\sum_{t=es_i}^{ls_i} (t+d_{im_i}+FS_{ij}) X_{im_it} \le \sum_{m_j=1}^{M_j}\sum_{t=es_j}^{ls_j} t.x_{jm_jt} \qquad \forall(i,j)\in E_{fs} \tag{13}$$

$$\sum_{m_i+1}^{M_i}\sum_{t=es_i}^{ls_i} (t+d_{im_i}+FF_{ij}) X_{im_it} \le \sum_{m_j=1}^{M_j}\sum_{t=es_j}^{ls_j} \left(t+d_{jm_j}\right) x_{jm_jt} \ \forall(i,j)\in E_{ff} \tag{14}$$

Constraints of renewable resources

This constraint which is that of renewable resources is present in the basic project scheduling issue. All of the resources which can be applied at maximum use in each period have been considered in this constraint. Renewable constraints like manpower, equipment, etc have also been included in this limitation.

$$\sum_{i=1}^{n}\sum_{m_i=1}^{M_i} {r^{rr}}_{im_ik} \sum_{s=Max\{t-d_{im},es_i\}}^{Min\{t-1,ls_i\}} x_{im_is} \leq {a^{rr}}_k \; k=1,\dots,K, t=1,\dots,T \tag{15}$$

Constraints related to non-renewable resource

This limitation is that of the non-renewable recourses whose total amounts are specified from the beginning of the project. It can be said that their use will reduce their amount. Resources like project's budget, types of supplies and consumable materials etc. are among the mentioned materials. Since the cost of doing activities is minimized by the cost-target function and the project's budget can also be regarded as a kind of non-renewable resource, presenting a new limitation for preventing extra cost spending has been ignored. Besides, Project budget limitation has been included in this limitation.

$$\sum_{i=1}^{n}\sum_{m_i=1}^{M_i} r^{nr}_{imk} \sum_{s=es_i}^{ls_i} x_{ims} \leq a^{nr}_k \quad , \qquad k=1,2,\dots,K \tag{16}$$

Constraints Related to Quality

This limitation ensures that the quality for doing each activity is not less than the predetermined level that is intended.

$$\sum_{m=1}^{M} \boldsymbol{q_{im}} \sum_{t=es_i}^{ls_i} \boldsymbol{x_{imt}} \geq \boldsymbol{\sigma_i} \tag{17}$$

Constraints related to deadline of the project's completion

This limitation ensures that the time of project's completion does not exceed the target time (T)

$$\sum\nolimits_{m=1}^{M_i} \sum\nolimits_{t=es_I}^{ls_I} t.x_{im_it} \leq T \tag{18}$$

Constraints related to decision variables

This limitation shows the same binary without the Xmit decision variable.

$$X_{imt} \in \{0,1\}$$
$$m_i = 1,2,\dots,M$$
$$i = 0,1,2,\dots,n+1$$

$$t = 1,2, \dots, T$$
$$l = 1,2, \dots, L$$

7 Methods of Solving and Evaluation Criteria

Methods of solving multi-objective are divided into classical and evolutionary methods. Achieving only one optimal answer at each step and not finding all multi-objective optimization solutions are considered as weaknesses of classical methods. In order to overcome this, researchers use evolutionary methods that can find several optimal solutions in one implementation. Multi-objective Bee Colony Algorithm (MOBEE) has higher efficiency in solving multi-objective problems, due to lower computational complexity [3]. In the following, we describe the used methods to solve this problem.

7.1 Bee Algorithm

Heuristics are used for difficult problems that are not practical to be solved to optimality. Instead of optimal solutions, heuristics aim for satisfactory solutions that can be obtained more easily with short computation time [11]. The process of designing and implementing meta-heuristic algorithms has three successive stages, each of which has different steps. In each step, activities must be done to complete that step. Step 1 is preparation, in which a clear understanding of the problem we want to solve should be got, and the objectives of the design of the meta-heuristic algorithm for it must be clearly identified in terms of the solutions available for this problem. The next step is called construction. The most important goals of this stage are choosing a solution strategy, defining performance measurement metrics, and designing an algorithm for the selected solution strategy. The final stage is implementation, in which the algorithm designed in the previous step, including parameter setting, performance analysis, and, finally, the compilation and preparation of the results report should be done [16]. Bee algorithm is based on search algorithm that was developed in 2005 for the first time. This algorithm simulates behavior of bee honey for food search. The process of feeding a colony starts by guardian bees that are sent to search for promising rose gardens (with high amount of nectar or pollen). The observer bees randomly move from a rose garden to another one. During agronomy season (flowering), colony continues its search by ready a number of colony population as leading bee (observer bee). After ending all rose gardens, every observer bee takes a special dance on top of a rose garden which a memorable quality of nectar and pollen. This dance, known as rotational dance, translates information about direction of the rose garden (towards the hive), distance to the rose garden and quality of the rose garden to other bees. This information sends additional and follower bee toward the rose garden. Most follower bees follow go toward rose gardens with more promising and have more hope for finding nectar and pollen in them. In the following, there are described steps of implementing this algorithm in general terms.

7.1.1 Bee Algorithm Steps

Step 1

Generating and evaluating initial responses

Step 2

Selecting better sites (answers) and sending worker bees toward the sites

Step 3

Returning bees to the hive and perform a special dance (generate neighboring response) using the following formula

$$P_i = \frac{f_i t_i}{\sum_i^{SN} f_i t_n} \qquad f_i t_n = \begin{cases} \dfrac{1}{1+f_i} & if\ f_i > 0 \\ 1 + abs(f_i) & if\ f_i < 0 \end{cases}$$

Step 4

Comparing all bees in a site and select the best case

Step 5

Replacing unelected bees (sites) with random answers

7.1.2 Problem Solving by multi-objective Bee Algorithm

Step 1

Define function as a merit function in m files

Step 2

Define number of the proposed variables in model (nvar)

Step 3

Insert size of variables in matrix form: Var size= [1 $\quad nvar$]

Step 4

Set var_{min} and var_{max} values

Step 5

Determine the number of algorithm replication: Max It= 500

Step 6

Set number of guardian bees using Taguchi Tests on 50 bees; Nscout Bees=50

Step 7

Consider a fraction of leading bees to determine the areas:$Nselected\ site = round(nscout\ bee/2 * 0.5)$

Step 8

Select the elite areas based on relationship:$nelite\ site = round(0.4 * nselected\ site)$

Step 9

Assign bee to the found areas:$nselected\ site\ bee = round(0.5 * nscout\ bee)$

Step 10

Select bees for better areas:$nelite\ site\ bee = (2 * nselected\ site\ bee)$

Step 11

Produce neighborhood uniformly that is adjusted by Taguchi method:$r = 0.9$

Step 12

Produce primary population and duplication of primary bees

Step 13

Sorting population of bees using sort of Initial production and finally running solBest on sort

Final step

The termination condition in this model is to select the defined Maxit number that is considered here 500.

8 Data Analysis and Research Findings

In order to solve the modeled problem, setting parameters was first carried out with Taguchi method then the proposed model was solved by MOBEE. Meta-heuristic algorithms are very sensitive to their parameters, and changing these parameters significant affect their search styles. Taguchi method was used to set the parameters of the algorithms using the Minitab software, as shown in Table 3.

Table 3: Parameters of MOBEE algorithm according Taguchi experiments

Parameters tested for the algorithm of MOBEE			
Level	Npop	Number of bees	Neighbourhood rates
1	(400,450)	30	0.85
2	(450,500)	40	0.90
3	(500,550)	50	0.95

Taguchi experiments' design was tested in Mini-Tab software as orthogonal arrays L that its results are reported in Fig 1 and Fig 2. As you can see, the proper parameters for the two algorithms will be:

Fig. 1: M/M diagram of MOBEE

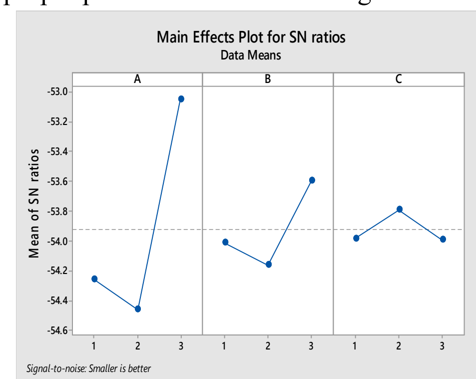

Fig. 2:S/N diagram of MOBEE

Table 4: The confirmed parameters for algorithms

Confirmed Parameters for MOBEE			
Level	N_{pop}	Number of bees	Neighbourhood rates
3	(500,550)	50	0.9

9 Solving Strategy

To solve the problem in a large-scale, there have been defined a number of sample issues in different dimensions and the problem solving problems for this sample are discussed below using the Matlab R2015a software in a 7-core computer with 2.45 GHz processor and 8 GB of RAM. In order to solve a large-scale modeling problem, there have been used MOBEE.

Then there was investigated achieving the optimal answer front, values of the target functions for each final solutions of the algorithms. In Pareto's diagrams, MOBEE algorithm is shown in Figures 4 to 9.

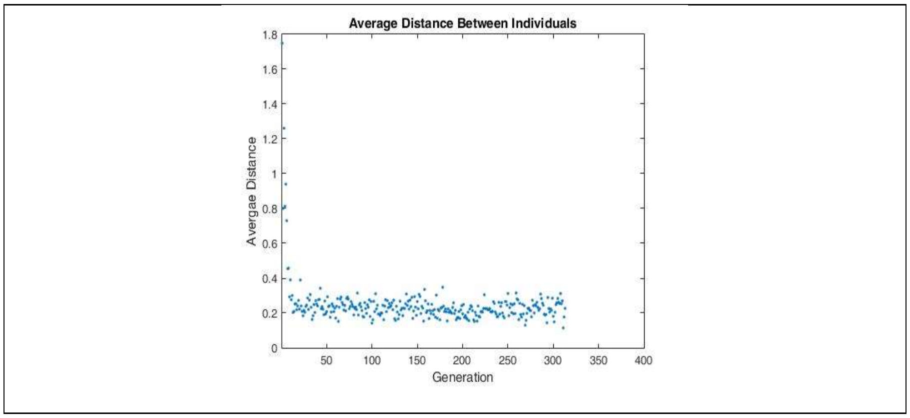

Fig. 3: The number of solving model repetitions for the proposed algorithms

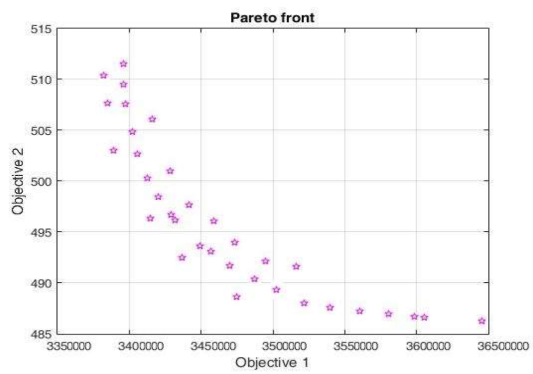

Fig. 4: Pareto front (compare of objectives 1&2)

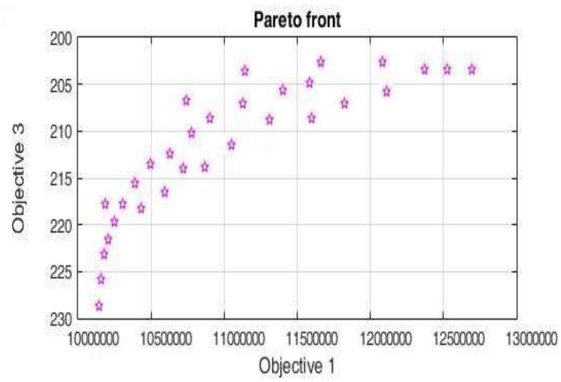

Fig. 5: Pareto front (compare of objectives 1&3)

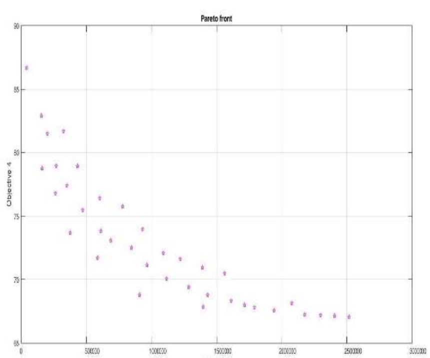

Fig. 6: Pareto front (compare of objectives 1&4)

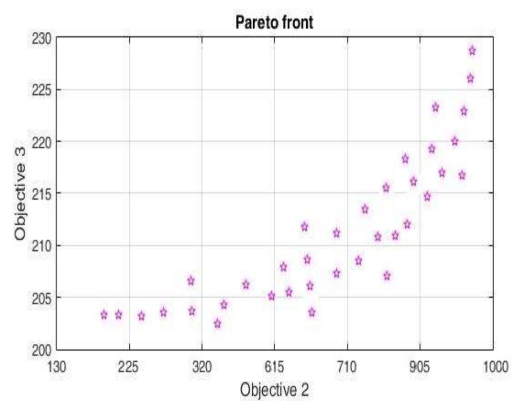

Fig. 7: Pareto front (compare of objectives 2&3)

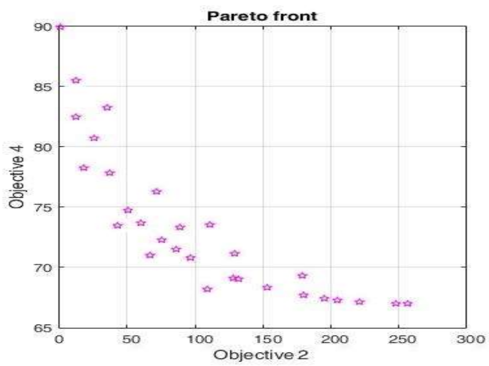

Fig. 8: Pareto front (compare of objectives 2&4)

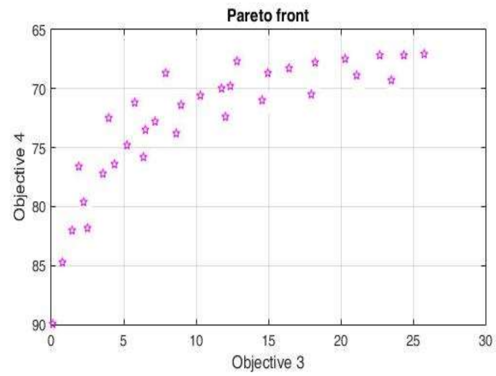

Fig. 9: Pareto front (compare of objectives 3&4)

As we can see, the provided Pareto answer set has an appropriate convergence in algorithm. In this part, 12 problems were generated in different dimensions and an average of five implementations of MOBEE algorithm was reported for the values of objective functions.

Table 5: Performance of MOBEE

PRPBLEM NUMBER	**MOBEE**				
	First goal	**2th goal**	**Third goal**	**Fourth goal**	**Run time**
1	2572419.9	297	87.828292	57.14502	750.121
2	2872046.1	314	98.155581	67.235492	759.23
3	2983247.3	336	113.73403	77.428928	780.14
4	3075914.9	366	142.39921	82.474164	803.33
5	3215900.8	400	163.36268	87.828292	875.4
6	3335260.6	435	165.05129	92.976492	930.22
7	35594521	458	170.23038	98.155581	1000.23
8	3696111.4	472	175.74925	101.21361	1125.23
9	4012976.9	492	180.52678	103.27289	1249.4
10	40741561	512	193.25313	106.25885	1311.12
11	42480780	530	196.00227	108.21516	1325.16
12	4384098.1	544	204.55858	113.56929	1496.5
Average		12413737	426	157.571	1033.840

10 Conclusion and Future Directions

In the present research, there was presented a binary mathematical model for problem of scheduling in oil, gas and petrochemical projects to minimize costs and time, maximizing quality of project and minimizing environmental risks. There were considered hypotheses for this optimization. In addition to limitation of resources in two types of renewable and non-renewable cases, there were considered some implementation methods for each activity. Then secondary pre-requisites were generalized to main ones. To validate the model, we extracted a number of large-scale examples of Ilam gas refinery projects and tested the model with these data. Because the exact methods available for activities above 20 at 1800 seconds are not defined in the GAMS software, the problem with activities of over 20 nodes is in the category of very hard problems (NP-hard). To solve the model, use of the meta-heuristic algorithm and the model was solved with multi-objectives bee algorithm. As shown in the Pareto graphs, the algorithm worked well to solve the problem. In most of the research on balancing project objectives detailed in the literature review, focus is on a particular type of resource. But in this study, a variety of resources (renewable and non-renewable) is considered, on the other hand, unlike most previous researchers who have considered the modes of implementation of activities in a single-mode, in this study, the methods of carrying out activities are multi-mode. We considered that the model would be closer to the actual situation in the real world, since it is possible to carry out the activities of each project in the realm of reality in different ways. The problem is also considered multi-objective and for the first time, the problem of project timing balancing has been modeled with four key objectives: time, cost, quality of implementation of activities and environmental impacts. Therefore, the difference can be this research with other researches and the changes made in the number of target functions, the resource constraints in both renewable and non-renewable, and the multi-mode of implementing project activities rather than single-mode, and the introduction of multi-objective Bee Colony Algorithm (MOBEE) to solve the large-scale model, it is considered as one of the innovations of this research. In order to carry out further research in this field, consideration of each parameter of the project scheduling problems under uncertainty conditions as well as other methods for solving the problem can be suggested. Meanwhile, the application of other meta-algorithms can be used to solve this model and compared their results with the results of these algorithms. Another issue that can be studied in future research is the consideration of a new resource constraint in the model of the problem of project scheduling with limited resources. The division of resources into two categories of renewable and non-renewable ones, albeit from the perspective of consumption and the time period determined It seems reasonable to divide, but what actually happens is that over time renewable resources such as machinery, human resources, etc., lose their initial efficiency and sometimes even as an inexhaustible source, they end up.

- As we have seen, due to the four objectives of the model presented in this study and the number of goals, the number of hotspots will be increased, in some cases the number of points in Pareto will be so high that the decision maker may in choosing the optimal option, you will be confused. Therefore, the inclusion of a multi-criteria decision-making method can be helpful in choosing the optimal option.
- In order to prevent over-allocation of resources, another objective function such as minimizing the resources used can be defined.

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