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A stochastic model for project selection and scheduling problem

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Abstract

Resource limitation in zero time may cause to some profitable projects not to be selected in project selection problem, thus simultaneous project portfolio selection and scheduling problem has received significant attention. In this study, budget, investment costs and earnings are considered to be stochastic. The objectives are maximizing net present values of selected projects and minimizing variance of them. Benefiting an efficient multi-objective approach to satisfy every conflicting objective, an integer non-linear goal programming model is developed. Another contribution of this paper is to consider cost dependency between the projects, in project portfolio selection and scheduling problem. Due to the complexity of this problem, especially in large sizes, imperialist competitive algorithm and genetic algorithm are presented. The effectiveness of the model and proposed algorithms are demonstrated via a case study in a knowledge based company at Ferdowsi University of Mashhad. The result shows high performance of the both proposed algorithms.

Keywords: Project selection and scheduling; Cost dependency, Stochastic programming, Genetic Algorithm, Imperialist competitive algorithm.

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1. Introduction

Project portfolio selection problem is one of the most important problems in organizations. Projects are often scheduled after they have been selected. If the projects can begin at different time, i.e., some begin at zero time and some begin later, the company can make full use of capital and obtain more profits. This type of problem contains project selection and scheduling, and is more complicated than pure project selection (Huang and Zhao 2014). Rabbani et al. (2006) presented a deterministic model for R&D project portfolio selection with zero- one goal programming, in which project cash flows and budget were deterministic. Goal constraints include minimizing total cost, maximizing expected benefit and minimizing risk of selected projects. Tavana et al. (2015) proposed a comprehensive framework that integrates fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Data Envelopment

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Analysis (DEA) and Linear Integer Programming for project portfolio selection problem. Researchers used DEA for initial screening, TOPSIS for ranking projects, and integer linear programming for selecting the most suitable project portfolios in a fuzzy environment according to organizational objectives.

In real world conditions, it is not possible to determine all the project parameter as deterministic values. Therefore some effort is done on project portfolio selection under uncertainty. Coffin and Taylor (1996) presented a model that includes fuzzy logic in a beam search approach to both select and scheduling R&D projects. Sefair and Medaglia (2005) provided a mixed-integer programming model for the project selection and sequencing decisions, in which project investment cost was certain and project income had been forecasted. Risk is measured by computing variance of net present value. Therefore, a Monte simulation experiment was conducted to estimate the average of net present value of each project, its variance and covariance. Huang and Zhao (2014) presented a mean-chance model for portfolio selection based on uncertain measure. Chance of portfolio return failing is used to reach the threshold. Thus, it can help investors to determine their favorite tolerance toward risk. Golmohammadi & Pajoutan (2011) proposed a new model for project portfolio selection problem, which considers cost relation and stochastic revenue for the projects. It should be noted that project cost was deterministic and risk of income deficiency of a specified value was considered as a constraint. He and Qu (2014) proposed a two-stage stochastic mixed-integer programming for project selection problem that minimize the risk of project portfolio.

As it can be seen there are different works on simultaneous project selection and scheduling problem under uncertainty and different risk measures are applied. Some works consider project earnings as uncertain value but most of them considered project cost and financial budget as deterministic value. Therefore the risk of cost overrun in each period is not considered. So this paper considers stochastic cash flow for all the projects and financial budgets. Risk is defined as probability of cost overrun of available financial budget in each period. This stochastic financial resource allocation could be efficient for dealing with uncertain cost and budget. Annual earnings are stochastic and would be another source of risk. Hence, minimizing variance of the present value of earnings is defined as an objective function.

On the other hand there is a few works that employ cost dependency between projects in project portfolio selection problem (Golmohammadi and Pajoutan, 2011). To the best of our knowledge, there is no effort on considering cost dependency in simultaneous project selection and scheduling problem. Likewise, there is no work that discusses cost dependency in which costs are not deterministic. Therefore, one of the advantages of proposed model lies in applying cost dependency in project portfolio selection and scheduling problem in which project costs are stochastic.

Ultimately it is proposed a novel multi-objective nonlinear stochastic programming model for project portfolio selection and scheduling problem whose objectives are maximizing expected net present value and minimizing variance of present value of earnings.

Among various multi-objective approaches, goal programming is one of the most powerful and well-applied ones for modeling, analyzing and solving real-world problems (Lotfi and Ghaderi 2013). Therefore for the current study, goal programming method is used to model this multi-objective problem.

Due to complexity of this problem, especially for large size, exact methods are not suitable to solve it. For example Zhu et al. (2011) presented Practical Swarm Optimization (PSO) Algorithm to solve a non-linear constrained portfolio optimization problem with multi-objective functions and noted that traditional approaches are not efficient for this problem. Another effort in solving a nonlinear multi-objective portfolio selection and scheduling problem has been done by carezo et al. (2010); they have indicated that as the number of projects and objectives increase, the problem becomes more complex. Thus, a metaheuristic procedure based on Scatter

Search was proposed to solve it. Nahvi and Mohagheghian (2011) indicated that PSO has a good efficiency in solving mixed-variable nonlinear problem. Tseng and Liu (2011) used Genetic Algorithm (GA) for selecting and scheduling a balanced project portfolio problem and their results demonstrated the efficiency of this approach. Naderi (2013) developed a mixed integer linear programming model for project portfolio selection and scheduling problem and used Imperialist Competitive Algorithm (ICA), Simulated Annealing (SA) and GA to solve it. The results showed that ICA has a better performance than SA and GA. Nikkhahnasab and Najafi (2013) have compared the performance of GA and SA for solving this problem and the results have shown that GA is more efficient than SA. Pourkazemi et al. (2013) solved project portfolio optimization by considering interaction between projects using ICA and the results showed efficiency of this algorithm.
As mentioned, because of nonlinear nature and complexity of proposed model, solving by exact methods requires a substantial amount of time even for small size problems. As a consequence, it is suggested to use metaheuristic algorithms. In this study GA and ICA are presented.
The rest of the paper is structured as follows. In Section 2, mathematical model is developed. ICA and GA are presented for this problem, in Section 3. In Section 4, a goal programming model is developed for a case study of knowledge based company in Ferdowsi University of Mashhad, including 12 candidate projects. Finally, in the last section, conclusions and future directions about the work are provided.

2. Mathematical Model

In this section a mathematical model for project portfolio selection and scheduling problem is developed. The following assumptions are made to describe the model:

- Investment costs of the projects are stochastic and interrelated.
- Annual earnings of a project are stochastic and independent of each other and annual earnings of other projects.
- Available budgets at each period are not considered to have an exact value, but they are defined as stochastic and independent variable.

Let us assume an organization with N project proposals from which we have to decide which projects to invest and when to invest, according to a set of objectives and some constraints.

2.1. Decision Variable

$$x_{it} = \begin{cases} 1 & \text{if project i is selected and completes at time t} \\ 0 & \text{otherwise} \end{cases} \qquad y_i = \begin{cases} 1 & \text{if project i is selected} \\ 0 & \text{otherwise} \end{cases}$$

2.2. Parameters and Indices

Indices are as follow:
i, j: project's indices i = 1,. . . ,N; j= 1,. . . ,N
k: period's indices k=1,…,D_i
t: time's indices t=1,…,T
Parameters are as follow:
D_i: lifespan of project *i*
ir: interest rate
T: planning horizon
N: number of candidate projects
S: Set of precedence relations between projects; that is, if project *i* precedes project *j*, then (i,j)ϵ S.
U: set of different renewable resources

g_{ij}: the number of periods of separation or overlap between *ith* and *jth* projects.
τ_{ij}: cost dependency between projects i and j
F_{ik}: normal random variable for earnings for project *i* in period *k* (k ϵ {0,1,…,Di})
$E(F_{ik})$: Expected value of earnings for project *i* in period *k* (k ϵ {0,1,…,Di})
C_i: normal random variable for investment cost for project *i*
$E(C_i)$:Expected value of investment cost for project *i*
R_t: normal random variable for budget in time *t*.
α: maximum acceptable risk for expenditure more than R_t

2.3. Formulation

$$\max Z_1 = \sum_{i=1}^{N}\sum_{t=1}^{T}\sum_{k=1}^{D_i}\frac{E(F_{ik}).x_{i(t+D_i-k)}}{(1+ir)^t} - \sum_{i=1}^{N}\sum_{t=1}^{T}\frac{E(c_i).x_{it}}{(1+ir)^{t-D_i}}\times\prod_{j=1}^{n}(1-\tau_{ij}\times y_j) \quad (1)$$

$$\min Z_2 = \mathrm{var}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\sum_{k=1}^{D_i}\frac{F_{ik}x_{i(t+D_i-k)}}{(1+ir)^t}\right) \quad (2)$$

$$p\left(\sum_{i=1}^{N}c_i.x_{i(t+D_i)}\prod_{j=1}^{n}(1-\tau_{ij}\times y_j)\geq R_t\right)\leq\alpha \qquad \forall t=0,1,2,\ldots,T \quad (3)$$

$$\sum_{t=1}^{T}x_{it}=y_i \qquad \forall i=1,2,..,N \quad (4)$$

$$\sum_{t=1}^{T}(t-D_i).x_{it}\geq 0 \qquad \forall i=1,2,..,N \quad (5)$$

$$\sum_{t=1}^{T}x_{jt}.\left(\sum_{t=1}^{T}(t+g_{ij}).x_{it}\right)\leq\sum_{t=1}^{T}(t-D_j).x_{jt}; \qquad \forall(i,j)\in S(i,j) \quad (6)$$

$$\sum_{t=1}^{T}x_{it}\geq\sum_{t=1}^{T}x_{jt} \qquad \forall(i,j)\in S(i,j) \quad (7)$$

$$x_{ij}\in\{0,1\};\quad y_i\in\{0,1\}; \qquad \forall i,j,t \quad (8)$$

The two objective functions are shown in Equations (1) and (2).The first term of equation 1, indicates the expected net present value of sum of the project's earnings and the second term is expected net present value of sum of each project's cost considering other projects. The second objective is minimizing variance of the present value of earnings. Set of constraints (3) indicate that probability of expenditure overrun from available budget must be lower than α. Constraint (4) indicates that if a project is selected, it would be completed within a given planning horizon (T). In other words, it guarantees that each project will only finish once during the planning horizon. Constraint (5) indicates that if a project is selected, the finish time must be at least greater than or equal to its duration. In other words, it explicitly forbids starting projects when it is not possible for them to be carried out. Constraints (6) and (7) show how the precedence relations are modeled. The last constraint is established for decision variables. As it can be seen, the proposed model is a stochastic programming. Therefore chance-constrained programming would be used to determine deterministic form of constraint (3), as equation (9), where σ_i^2 denotes to variance of investment cost of project *i*.

$$\sum_{i=1}^{N} E(c_i).x_{i(t+D_i)} \prod_{j=1}^{n}(1-\tau_{ij}\times y_j) \le E(R_t) - k_\alpha \sqrt{\sum_{i=1}^{N}\sigma_i^2 x_{i(t+D_i)}^2 \prod_{j=1}^{N}(1-\tau_{ij}y_j)^2 + var(R_t)} \quad \forall t = 0,1,2,...,T; \tag{9}$$

2.4. Goal Programming

Goal programming (GP) has been a popular theoretical method to deal with multiple objective decision making problems (Orumie and Ebong 2014). Lotfi and Ghaderi (2013) believe that it is one of the most powerful approaches for modeling, analyzing and solving real-world problems. In general, the idea of goal programming is to convert original multiple objectives into a single goal (Orumie and Ebong 2014). Therefore, in this research goal programming technique is used in optimization of multiple objective goals by minimizing deviation for each of the objectives from the desired target.

The first goal constraint maximizes total net present value of chosen projects as shown in Equation (10), where G^*_1 is the amount that we wishes our profit to be at least as much as G^*_1. Therefore, d_1^- and d_1^+ are negative deviation and positive deviation from the first goal, respectively. Since the first objective is kind of maximizing, the positive deviation is zero and negative deviation is minimized.

$$\sum_{i=1}^{N}\sum_{t=EF_i}^{LF_i}\sum_{k=1}^{D_i}\frac{E(F_{ik}).x_{i(t+D_i-k)}}{(1+r)^t} - \sum_{i=1}^{N}\sum_{t=EF_i}^{LF_i}\frac{E(c_i).x_{it}}{(1+r)^{t-D_i}}\times\prod_{j=1}^{n}(1-\tau_{ij}\times y_j) + d_1^- - d_1^+ = G_1^* \tag{10}$$

If G_2^* be the ideal value of the second objective and be the lower bound for it, then the second goal constraint is minimizing total variance of selected project as below:

$$var\left(\sum_{i=1}^{N}\sum_{t=EF_i}^{LF_i}\sum_{k=1}^{D_i}\frac{F_{ik}x_{i(t+D_i-k)}}{(1+r)^t}\right) - d_2^+ = G_2^* \tag{11}$$

In equation (11), d_2^+ is positive deviation from the second goal.

In this section, a new multi-objective project portfolio selection and scheduling model was presented. The proposed model can help the investors to select and schedule a balanced project portfolio, under uncertainty of available budget, cost and earnings of project. It is also provided stochastic budget constraints that control the risk of dealing with budget shortage in a specified level. Another important issue in this model is considering cost dependency between projects, which is more conforming to real world conditions.

3. Proposed Algorithm

An integer non-linear goal programming model is developed in pervious section. Due to complexity of this problem, especially for large size, exact methods are not suitable to solve the proposed model. As a consequence, in this section metaheuristic algorithms of ICA and GA are presented.

3.1. ICA

The imperialist competitive algorithm is a novel population based evolutionary algorithm that is developed by Atashpaz-Gargari and Lucas (2007). In past researches, high performance of the ICA in project selection problem (Pourkazemi et al. 2013), and project selection and scheduling problem (Naderi 2013) is demonstrated. Therefore, it is used to solve the proposed model. In this algorithm each country represents a possible solution for the problem and it is defined as a cell which contains two rows. The first row is a string of random zero-one number which denotes

whether a candidate project *i* is selected or not, and the second row is a random permutation of *N* candidate projects that specify project order. Then, this is used to generate a feasible start and finish date for each chosen project considering other constraints and objective functions.
Atashpaz-Gargari and Lucas (2007) introduced the steps of ICA, as follows:

1. Select some random points on the function and initialize the empires.
2. Move the colonies toward their relevant imperialist.
3. If there is a colony in an empire which has lower cost than that of imperialist, exchange the positions of that colony and the imperialist.
4. Compute the total cost of all empires.
5. Pick the weakest colony (colonies) from the weakest empire and give it (them) to the empire that has the most likelihood to possess it (Imperialistic competition).
6. Eliminate the powerless empires.
7. If there is just one empire, stop, if not go to 2.

3.2. Genetic Algorithm

As it was mentioned in the literature, GA has a good performance in solving project portfolio selection and scheduling problem (Tseng and Liu 2011, Nikkhahnasab and Najafi 2013). Likewise, Golmohammadi and Pajuatan'swork (2011) also represented that GA has better performance in comparison with Electromagnetism-like (EM- like) algorithm in solving a nonlinear project portfolio selection problem. Therefore, in this section GA is provided to solve the proposed model. In this research, definition of each chromosome is the same as a country in the ICA. Due to select the parents, the roulette wheel selection is used. Therefore, two parents are chosen and then used randomly as one of the single point crossover, double point crossover or uniform crossover. Also, mutation operator applied only on the first row of chromosomes. According to mutation rate, some chromosome's genes are selected and their value (x) is changed to 1-x.
The steps of GA are as follows (Nikkhahnasab and Najafi 2013):

1. Begin the algorithm.
2. Initialize a population of solutions randomly.
3. Repeat the following steps for generation number times.
4. Compute the objective value for each chromosome.
5. Select chromosomes of the new population by using the roulette wheel method.
6. Repeat the following steps as many times as the population size.
7. Generate a random number between 0 and 1 (r_1).
8. If $r_1 <$ crossover probability,
9. Select parents (using roulette wheel method).
10. Randomly choose one of the following: single point, double point or uniform crossover.
11. Do crossover.
12. End if crossover.
13. Generate a random number between 0 and 1 (r_2),
14. If $r_2 <$ mutation probability,
15. Randomly choose a segment to mutation.
16. Do the mutation.
17. End if mutation.
18. Copy the chromosome in the new generation.
19. End repeat.
20. Store the best solution from the population as the final solution.
21. End the algorithm.

4. Case Study

In this section, a case study of knowledge based company is employed to evaluate the model and proposed algorithms. In the year of 2008, the company of Paya Fannavaran Ferdowsi is established in Ferdowsi University of Mashhad.Various products in the field of electronic and mechanical has been prototyped and commercialized in this company. This company has 12 candidate projects with 9 planning horizons with the data shown in Table1.The last column is shown precedence relation between projects. The most common precedence relationship is when one activity cannot start until another activity has finished. This relation is known as Finish- to- Start (FS) relationship. In Table 1, normal distribution is specified with its mean and standard deviation. Annual budget is N (900, 90) and interest rate is 10%. Since the proposed model is a multi-objective problem, in the next section goal programming method is presented. Cost dependency is also shown in Table 2. It should be noted that a substantial amount of expense of R&D project includes manpower and technical knowledge costs. As a consequence these projects have a lot of joint cost. For example τ_{52} is equal to 0.8 which means that if we select project 2, 80 percent decrement in investment cost of project 5 would be obtained. In other words project 2 and 5 have some joint investment cost, 80 percent of investment cost of project 5 would be spend by implementation of the project 2. It should be mentioned that the symbol of "-"in jth column of row i, means that there is no cost dependency between projects of i and j.

Table 1: Project's data

Row	Project name	Annual earning ($\times 10^6$ million rial)	Investment Cost ($\times 10^6$ million rial)	Project's lifespan (year)	Precedence relation
1	Satellite tracking on the internet	N(500, 50)	N(500,50)	5	---
2	Satellite tracking on the mobile	N(650,65)	N(500,50)	5	$FS_{12}(-4)$
3	Personal tracker	N(70,7)	N(200,40)	5	$FS_{13}(-4)$
4	Satellite tracking + Alarm on the internet	N(1500,150)	N(600,60)	5	$FS_{14}(-3)$
5	Satellite tracking + Alarm on the mobile	N(1800,180)	N(700,70)	5	$FS_{15}(-2)$
6	foot scanner machine	N(1000,100)	N(2000,200)	5	---
7	shoe's insole making machine	N(500,50)	N(500,50)	5	$FS_{67}(-4)$
8	foot scanner machine(research project)	N(700,70)	N(2000, 200)	5	$FS_{68}(-3)$
9	Equipping Foot scanner centers	N(900,90)	N(600,60)	5	$FS_{69}(-3)$
10	three- mode load Sensor of automobile's	N(200,20)	N(100,10)	5	---
11	exact load sensor of automobile	N(600,60)	N(200,20)	5	$FS_{10\,11}(-4)$
12	System of liquid level measurement	N(750,75)	N(500,50)	5	---

Table 2: Cost dependency of projects

Project	1	2	3	4	5	6	7	8	9	10	11	12
1	-	-	-	-	-	-	-	-	-	-	-	-
2	0.6	-	-	-	-	-	-	-	-	-	-	-
3	0.8	-	-	-	-	-	-	-	-	-	-	-
4	0.7	-	-	-	-	-	-	-	-	-	-	-
5	0.8	0.8	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	0.1	-	-	-	-	-	-
8	-	-	-	-	-	0.9	-	-	-	-	-	-
9	-	-	-	-	-	0.6	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	0.5	-	-
12	-	-	-	-	-	-	-	-	-	-	0.5	-

To determine the goals of each objective, genetic algorithm is used. Table 3 shows relative GA parameter's value. Generation number is equal to 100. GA parameters are derived from Golmohammadi and Pajoutan's study (2011) that solves a similar problem in project portfolio selection problem.

Table3:GA parameters

GA parameters	Population size	Crossover probability	Mutation probability
Corresponding value	30	0. 9	0.1

As can be seen in Table 4, it is obvious that for the second objective, the ideal value is zero. For the first objective, if resource constraints have been removed and the precedence constraints are considered only, the result would be 26296.3, that is obtained by selecting all of projects in their earliest start time that is reasonable because all of the projects are economic. Consequently, considering resource constraint it seems that 19529.9489 for $G_1^*$is a reasonable value.

Table 4: Goals'value

Goal	G^*_1	G^*_2
Goals'value without considering resource constraint	19529.9489	0
Goals' value with considering resource constraint	26296.3	0

Finally, the objective function will attempt to minimize the weighted sum of the deviations associated with the above constraints in the model. Since functions have different scales, so normalization methods are used for these objective functions. The most robust approach to transforming objective functions, regardless of their original range, is given as follows (Koski and Silvennoinen 1987,Rao and Freiheit 1991):

$$Z_i^{trans} = \frac{Z_i(X) - Z_i^o}{Z_i^{'} - Z_i^o} \quad (12)$$

Where Z_i^o and $Z_i^{'}$ are ideal and anti-ideal values, respectively. For the first objective, that is minimizing negative deviation from the G_1^*, the ideal and anti-ideal values would be zero and G_1^*, respectively.

The second objective is minimizing positive deviation from G_2^*. Therefore the ideal value would be obtained when this deviation is equal to zero. In order to access maximum positive deviation (for calculating anti- ideal value) from G_2^*, variance of earnings' present value should be maximized and it is acceptable when we select all of the projects and start in their earliest start time. Thereinafter, respective value would be equal to 203749.4174.

Next, we have to solve this problem with transformed function using Equation (13):

$$Z^{trans} = w_1\left(\frac{d_1^-}{19529.9489}\right) + w_2\left(\frac{d_2^+}{203749.417}\right) \tag{13}$$

In Equation (13), $w_1$and w_2 are the weight of first and second function and their relative value are equal to 0.6 and 0.4, respectively. It should be noted that they are determined based on expert opinions.

4.1. Numerical Results

In this section, GA and ICA are run for this problem. Due to comparing the results of these metahurestics with an exact method, Lingo solver is employed to solve this problem, too. GA parameter are the same as previously mentioned and the parameters of ICA are taken from the work of Pourkazemi et al. (2013) on project selection problem and shown in Table 5.

Table 5: ICA Parameters

Parameter	No. of country	No. of initial imperialist	No. of decade	Revolution rate	Assimilation rate
Value	200	8	25	0.3	2

Atashpaz-Gargari and Lucas (2007) introduce equation of 14 for total power of an empire. They believe that total power of an empire is mainly affected by the power of imperialist country and some percent of power of colonies of an empire.

$$TC_n = \text{Cost}\ (\text{imperialist}) + \xi\ \text{mean}\left\{\text{Cost}\ (\text{colonies of empire})\right\} \tag{14}$$

Where TC_n is the total cost of the nth empire and ξ is a positive number which is considered to be less than 1. We have used the value of 0.02 for ξ in this research.

As shown in Table 6, Lingo solver has received better solution than two other algorithms but computational time is very long in comparison to GA and ICA. In other words both genetic algorithm and imperialist competitive algorithm render the suitable results, in a reasonable time, whereas the final result isn't very different from the lingo results.

Table 6:Comparison of computational time and final results of solving problem

Method	Objective value	Computational time (second)
Lingo	0.1363783	7208
GA	0.30764	6.531275
ICA	0.30764	13.276433

Table 7 shows the result details of each algorithm. Due to the size and parameters of the model, the results of GA and ICA are identical. As it can be seen projects of 1, 2, 3, 4, 5, 10, 11 and 12are selected in both exact and metahurestic methods. But start time of selected projects in Lingo solution differs from the GA and ICA solution. It should be mentioned that sum of the net present value of chosen projects and earnings' variability are calculated from equation 1 and 2, respectively. Finally, the results validate the ability of the model to balance two conflicting goals of maximizing expected net present value and minimizing variance of earnings' present value.

Table7: Computational results

Variable/ objective	GA and ICA result	Lingo result
d^-_1	2197.806245334981	3278.925
d^+_2	122309.1425295146	18155.62
Start time (S.T) of project1	1	0
S.T of project 2	2	3
S.T of project 3	2	3
S.T of project 4	3	4
S.T of project 5	4	4
S.T of project 6	-	-
S.T of project 7	-	-
S.T of project 8	-	-
S.T of project 9	-	-
S.T of project 10	0	0
S.T of project 11	1	1
S.T of project 12	0	3
Sum of the net present value of chosen projects	17332.14265466502	16251.025
Earnings' variability	122309.1425295146	18155.62
Finish time of project portfolio	9	9

In order to compare the performance of GA and ICA algorithms, iteration, calculation time and also times of referring to the fitness function (TRF), until the first time that algorithm access to the final solution is calculated, and is shown in Table 8. Since the number of countries in ICA is more than GA population, GA is faster to access the final solution. Algorithm's results versus iteration are shown in Figure 1 and 2.

Table 8: Comparing the algorithms

Algorithm	Iteration	TRF	Calculation time(second)
GA	6	216	0.434344
ICA	1	441	0.766171

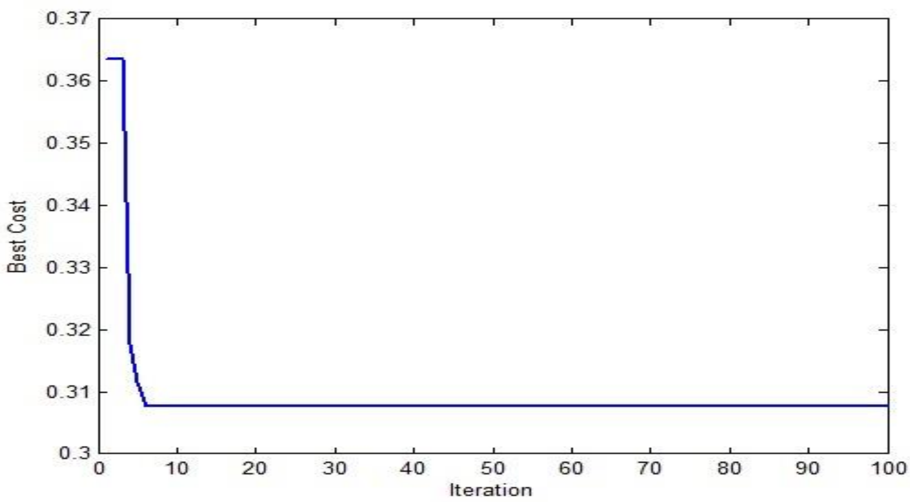

Figure 1: GA's result versus iteration

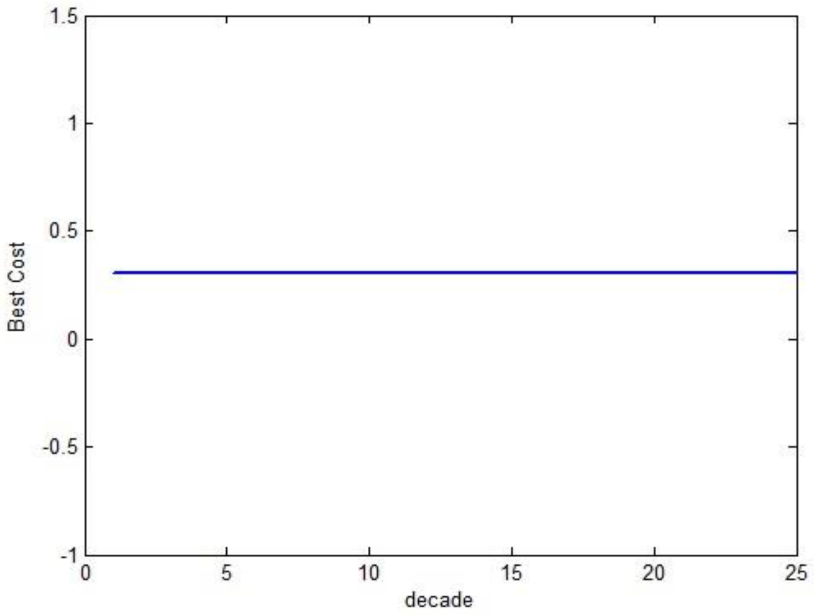

Figure 2: ICA's result versus decade

5. Conclusion

This paper presented an integer non-linear goal programming model with stochastic constraint which was transformed to deterministic form using chance constraint programming method. Investment costs were uncertain and dependent on each other. Earnings of project are also considered to be stochastic and risk is measured by earnings variability and probability of expenditure overrun from available financial budget. Then, for this problem imperialist competitive algorithm and genetic algorithm were presented. The model was validated using a case study of a knowledge-based company in Ferdowsi University of Mashhad with12 candidate projects. The results of suggested algorithms are compared to the results of Lingo solver. It was observed that exact method needs substantial time especially in large size. Therefore suggested algorithms were efficient to render the suitable results, in a reasonable time.

For the future study, another multiobjective method and also another metaheuristics could be applied for this novel proposed model.

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