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Selection and optimization of working groups Machines on Earthworks projects by Using Genetic Algorithm and Comparison of the results of a project carried out

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Abstract

One of the most important factors in successful projects and large construction projects, as well as how to choose the machines and their management is. In addition, projects that are large soil operations, Machinery is the most important part of the project. In this paper we use a mathematical model to examine the question of machinery Earthworks. Due to the high volume parameters and calculations, the program was written using genetic algorithms, which have the ability to resolve the above issue. Then with The comparison of a construction project that has already been implemented and all the data that was available, with the results of this study, the results of the project was to optimize the cost and time.
Keywords: Machines, Earthworks, Optimization, Genetic Algorithm.

1. INTRODUCTION

In a soil operation, the main goal of the project, the project with the least overall cost of operations. It includes operational data volumes and data, during the time period during which the project must be completed and the number and characteristics of all machinery that could be used for this project, are. Against, Unknown parameters, including production and the corresponding cost for each machine Allocation of suitable machinery for each project activity and the detailed planning of operations. Indeed determine the volume of soil, where it ought to be moved by what machinery.

In recent years considerable progress has been made in this regard However, all these methods have limitations in terms of volume of work or machinery under cover, respectively.

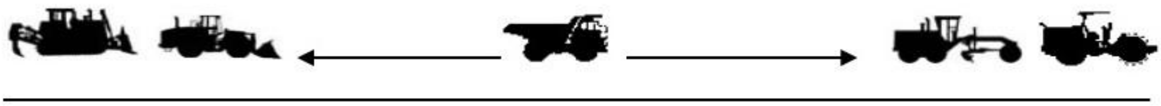
In this study, we tried to make use of a mathematical model is comprehensive selection of machinery Earthworks examined. To solve the problem, a model to optimize fleet of machines for the production of certain proposed that it can be used without any limitation on the number, type and model of machine select the best car. The mathematical model also accounted for optimal fleet of amphibious operations, provided that the appropriate allocation of fleet operations to optimize the unit cost of production. By combining these two mathematical models and solve them in a row, it selects the best machinery in order to optimize the overall cost of dirt as matter can be resolved. Due to the high volume parameters and the model calculations in a project Earthworks individually and manually is very time consuming and difficult calculations. Therefore, the computation is inevitable. That's why the program was written using genetic algorithms, which have the ability to resolve the above issue is. In this program after importing a project (such as the time and the total volume of operations, the amount of excavation and embankment, soil type, location and loan deposits depot, the transportation routes, number, type and specifications of machines available for use in projects and cases other) The system calculates the rate of production machinery and machine costs and Fleet optimization based on the production rate set by the user And at the end The fleet will be assigned to the project, the project during his time with the least possible cost to the finish.

2. CREATE A MATHEMATICAL MODEL TO OPTIMIZE FLEET OPERATIONS SOIL MACHINES

In this section, a mathematical model in order to select the optimal fleet of machines of all machines available, provided That it can be used Regardless of any restrictions on the number, type and model of machine In each of the five working groups (including excavation, loading, carrying, leveling and compaction), the best machines in each group selected for inclusion in the fleet.

Machine cycle operation of a fleet of amphibious operations generally consists of five steps in each of these stages, a special machine is used. This process is continuous and chains like earthy content material generated at each step of the computation is the next step. Among the machines, bulldozers and loaders, Operate in the excavation area. This way, the loaders lade the product obtained from the operation of bulldozers in to the Trucks. Trucks transporting soil from the excavation of the embankment area. In the earthen embankment grader who had been brought by trucks to leveling up and then the roller soil will compact.

As is clear, Volume for each machine operation depends on the previous operation is done by machines, it may not be possible to produce a machine, more than any other car in mind. In Figure 1, the operation of the earthen embankment and excavation area is shown.



Fixed fleet (the excavation) Fleet Mobile (Portable) Fixed fleet (the embankment)

Figure 1. The operation of the earthen embankment and excavation area

On the other hand, it is clear that the ability to produce all the machines only function is dependent on the local. Thus it can be assumed constant value of their. This group of cars, are called fixed fleet. If you are not on the truck and the distance between the excavation and embankment, as a major factor, the number of trucks needed to transport the soil influences. Thus, the dependence of trucks to distance carrying, called them to the mobile fleet. Given the focus of this paper is to prove fixed fleet. Because the truck has done extensive research and convincing results obtained.

The purpose of this section, we present a mathematical model of linear programming models designed to optimize fixed fleet. In this model, the power generation fleet is considered as a fixed amount and the goal is to minimize the cost of the fleet. Table 1 shows the parameters used in the objective function is to minimize the cost of the final hour written fleet shows.

(1) $$\text{MinZ} = \sum_i C_{B(i)} y_{B(i)} + \sum_j C_{L(j)} y_{L(j)} + \sum_k C_{G(k)} y_{G(k)} + \sum_d C_{C(d)} y_{C(d)}$$

Where $C_{B(i)}$، $C_{L(j)}$، $C_{G(k)}$ ،$C_{C(d)}$ is assumed constant. Also $y_{B(i)}$ ، $y_{L(j)}$، $y_{G(k)}$، $y_{C(d)}$ are decision variables and model can only be integers greater than or equal to zero.

Table 1. Parameters used in the objective function

$P_{B(i)}$ = Bulldozers production of type i	$C_{B(i)}$ = Hourly cost of bulldozer-type i	$y_{B(i)}$ =Bulldozers number of type i
$P_{L(j)}$ = Loaders production of type j	$C_{L(j)}$ = Hourly cost of Loader-type j	$y_{L(j)}$ = Loaders number of type j
$P_{G(k)}$ = Graders production of type k	$C_{G(k)}$ =Hourly cost of Grader-type k	$y_{G(k)}$ = Graders number of type k
$P_{C(d)}$ = Rollers production of type d	$C_{C(d)}$ = Hourly cost of Roller-type d	$y_{C(d)}$ =Rollers number of type d

The first type of constraints: The minimum production capacity in each of the working groups

Shackles related to the bulldozers: $\sum_i P_{B(i)} y_{B(i)} \geq Q$

Shackles related to the Loaders: $\sum_j P_{L(j)} y_{L(j)} \geq Q$

Shackles related to the Graders: $\sum_k P_{G(k)} y_{G(k)} \geq Q$

Shackles related to the Rollers: $\sum_d P_{C(d)} y_{C(d)} \geq Q$

Q = Minimum production requirements fleet that must be provided.
The above constraints $P_{B(i)}$ ، $P_{L(j)}$، $P_{G(k)}$ ، $P_{C(d)}$ and Q is assumed to be constant and the component data model.

The second type of constraint: Limits the maximum number of machines in each of the working groups

Shackles related to the bulldozers: $\sum_i \ y_{B(i)} \leq B$

Shackles related to the Loaders: $\sum_j \ y_{L(j)} \leq L$

Shackles related to the Graders: $\sum_k \ y_{G(k)} \leq G$

Shackles related to the Rollers: $\sum_d \ y_{C(d)} \leq C$

These constraints are applied only in cases that the working conditions in excavation or embankment limitations exist in terms of the number of machines.، B, L, G and C are constants and represents the maximum number of machines are used in each of the working groups.

3. PROVIDE A MODEL FOR OPTIMAL ALLOCATION FLEET OF SOIL OPERATIONS AND OPTIMIZE THEM FOR THE FINAL COST OF THE PROJECT

In this section, a mathematical model for optimal allocation of fleet (results of the previous model) is proposed projects Earthworks. This model can assign the fleet to activities while detailed planning and scheduling of project activities, possible to provide an estimated time and optimize the operation of the unit cost of production.

Here, as in the model fleet optimization, linear programming is used. Objective linear programming techniques to optimize the operation of terrestrial systems are minimizing costs or maximizing profits it is also involved in the overall project duration. Careful selection of machinery, mining finance and distribution depot and correct material is clearly needed in this process. In addition, factors such as inflation and contraction coefficients of the soil, allowing the use of mines and loan depot, and existing different layers of soil excavation areas must be considered.

Like all linear models, this model has a decision variables, objective function and constraints. Decision variables in the model, the soil volume between the two segments i and j replaced by a fleet of machines (n) which are X (i, j, n) are expressed.

In this model, the objective function is to minimize the total cost of the project as the sum of multiplying the volume of displaced soil excavation and embankment between the costs of these shifts. Both of these parameters to the fleet that will make the transfer, soil layers in sections embankment and excavation and embankment sections are dependent on the Consolidation.

Restrictions are applied to the model. These constraints are three different types of constraints related to the equilibrium volume, and time constraints associated with non-negative constraints can be divided. Constraints on balance volume, the limited amount of soil removal and excavation of the loan, and the limited amount of dumping soil embankment and depot are included. Constraints on time, ensure completion of the project within the time set for it. Non-negative constraints, constraints are evident and should be introduced in order to complete the model. In this section, symbols and variables used in the model described above.

i = Number parts of the excavation.
j = Number pieces in which the embankment is done.
p = Number of loan mines in operation.
k = Number of depot mines in operation.
b = Number of The cost of preparing loan mines in operation.
d = Number of Mines depot preparation cost of operations.
s = Number of layers in each piece of excavation.
n = Number fleet between the work pieces.

$X_{(i,j,s,n)}$ = The volume of soil from layer(s) to the excavation Part(i) by Part embankment(j) fleet(n) is transferred. (Decision variables)
$X_{D(i,k,s,n)}$ = The volume of soil from layer(s) to the excavation Part(i) by Depot (k) fleet(n) is transferred. (Decision variables).
$X_{B(p,j,n)}$ = The volume of soil from Borrow Mine(p) to Part embankment(j) fleet(n) is transferred. (Decision variables).
$X_{SD(i,d,s,n)}$ = The volume of soil from layer(s) to the excavation Part(i) by Depot (d) (with the cost of preparation) fleet(n) is transferred. (Decision variables).
$X_{SB(b,j,n)}$ = The volume of soil from Borrow Mine(b) (with the cost of preparation)to Part embankment(j) fleet(n) is transferred. (Decision variables).
$C_{(i,j,s,n)}$ = The cost of cubic meters of soil removed from the excavation(i) layer(s) segment to by fleet(n) segment embankment(j).
$C_{D(i,k,s,n)}$ = The cost of cubic meters of soil removed from the excavation(i) layer(s) segment to by fleet(n) segment depot(k).
$C_{B(p,j,n)}$ = The cost of cubic meters of soil removed from the Borrow Mine(p) segment to by fleet(n) segment embankment(j).
$C_{SD(i,d,s,n)}$ = The cost of cubic meters of soil removed from the excavation(i) layer(s) segment to by fleet(n) segment depot (d). (With the cost of preparation)
$C_{SB(b,j,n)}$ = The cost of cubic meters of soil removed from the Borrow Mine(b) segment to by fleet(n) segment embankment(j). (With the cost of preparation)
$P_{(i,j,s,n)}$ = Production rate of (n) fleet for Soil displacement of layer(s) excavation to Embankment segment(j).
$P_{D(i,k,s,n)}$ = Production rate of (n) fleet for Soil displacement of layer(s) excavation to depot segment(k).
$P_{B(p,j,n)}$ = Production rate of (n) fleet for Soil displacement of Borrow Mine(p) to Embankment segment(j).
$P_{SD(i,d,s,n)}$ = Production rate of (n) fleet for Soil displacement of layer(s) excavation to depot segment(d). (With the cost of preparation)
$P_{SB(b,j,n)}$ = Production rate of (n) fleet for Soil displacement of Borrow Mine(b) to Embankment segment(j). (With the cost of preparation)
$K_{SD(d)}$ = The cost of preparing depot d
$K_{SB(b)}$ = The cost of preparing Borrow Mine b
$Y_{SD(d)}$ = Variable zero and one for depot d (Decision variables)
$Y_{SB(b)}$ = Variable zero and one for Borrow Mine b (Decision variables)

The objective function: Minimize the total cost of Earthworks

As mentioned, in this model, the objective function is to minimize the total cost of the project and can be expressed as follows:

$$MinZ = \Sigma_i \Sigma_j \Sigma_s \Sigma_n C_{(i,j,s,n)} . X_{(i,j,s,n)} + \Sigma_i \Sigma_k \Sigma_s \Sigma_n C_{D(i,k,s,n)} . X_{D(i,k,s,n)} + \Sigma_p \Sigma_j \Sigma_n C_{B(p,j,n)} . X_{B(p,j,n)}$$
$$+ \Sigma_d K_{SD(d)} Y_{SD(d)} + \Sigma_i \Sigma_d \Sigma_s \Sigma_n C_{SD(i,d,s,n)} . X_{SD(i,d,s,n)} + \Sigma_b K_{SB(b)} Y_{SB(b)} + \Sigma_b \Sigma_j \Sigma_n C_{SB(b,j,n)} . X_{SB(b,j,n)}$$

The first constraint: Constraints on balance volumes

Constraint 1: Size limit for each layer (s) of excavation at each point (i)
If $Q_{C(i,s)}$ is the amount of excavation required in layer s, We have:

$$\Sigma_j \Sigma_n X_{(i,j,s,n)} + \Sigma_k \Sigma_n X_{D(i,k,s,n)} + \Sigma_d \Sigma_n X_{SD(i,d,s,n)} = Q_{c(i,s)}$$

Constraint 2: Size limits for embankment sections (j)
If $Q_{F(j)}$ is the volume of the embankment to the (j) point , We have:

$$\Sigma_i \Sigma_s \Sigma_n X_{(i,j,s,n)} + \Sigma_p \Sigma_n X_{B(p,j,n)} + \Sigma_b \Sigma_n X_{SB(b,j,n)} = Q_{F(j)}$$

Constraint 3: Limited amount of loan taken in (p)
If $Q_{B(p)}$ excavation capacity may be the source of the (p) loan, We have:

$$\Sigma_j \Sigma_n X_{(p,j,n)} \leq Q_{B(p)}$$

Constraint 4: The limited amount of resources depot (k)
If $Q_{D(k)}$ embankment capacity may be the source depot (k) , We have:

$$\Sigma_i \Sigma_s \Sigma_n X_{D(i,k,s,n)} \leq Q_{D(k)}$$

Constraint 5: Limited amount of extractable Borrow (b) (With the cost of preparation)
If $Q_{SB(b)}$ embankment capacity may be the source Borrow (b) , We have:

$$\Sigma_j \Sigma_n X_{(b,j,n)} - Q_{SB(b)}.Y_{SB(b)} \leq 0$$

Constraint 6: The limited amount of resources depot (d) (With the cost of preparation)
If $Q_{SD(d)}$ embankment capacity may be the source depot (d) , We have:

$$\Sigma_i \Sigma_s \Sigma_n X_{SD(i,d,s,n)} - Q_{D(d)}.Y_{SD(d)} \leq 0$$

Constraint 7: The amount of usable

$$\Sigma_k \Sigma_n X_{D(i,k,s,n)} + \Sigma_d \Sigma_n X_{SD(i,d,s,n)} \geq \frac{(100-\alpha).Q_{c(i,s)}}{100}$$

Two types of constraints: constraints on time

Constraint 7: Time limits for the each fleet of machines
If D is the duration of the project, for each fleet n, we have:

$$\Sigma_i \Sigma_j \Sigma_s \left[\frac{X_{(i,j,s,n)}}{P_{(i,j,s,n)}}\right] + \Sigma_p \Sigma_j \left[\frac{X_{B(p,j,n)}}{P_{B(p,j,n)}}\right] + \Sigma_i \Sigma_k \Sigma_s \left[\frac{X_{D(i,k,s,n)}}{P_{D(i,k,s,n)}}\right]$$

$$+ \Sigma_b \Sigma_j \left[\frac{X_{SB(b,j,n)}}{P_{SB(b,j,n)}}\right] + \Sigma_i \Sigma_d \Sigma_s \left[\frac{X_{SD(i,d,s,n)}}{P_{SD(i,d,s,n)}}\right] \leq D$$

Constraint 7: Time limits for work performed between any two pieces given
The soil displacement between any two pieces given j, i, we have:

$$\Sigma_s \Sigma_n \left[\frac{X_{(i,j,s,n)}}{P_{(i,j,s,n)}}\right] \leq D$$

The soil displacement between each segment i and k depot, we have:

$$\Sigma_s \Sigma_n \left[\frac{X_{D(i,k,s,n)}}{P_{D(i,k,s,n)}}\right] \leq D$$

The soil displacement between loan barrow (p) and each source segment (j), we have:

$$\Sigma_n \left[\frac{X_{B(p,j,n)}}{P_{B(p,j,n)}}\right] \leq D$$

The soil displacement between each segment (i) and depot (d) (With the cost of preparation), we have:

$$\Sigma_s \Sigma_n \left[\frac{X_{SD(i,d,s,n)}}{P_{SD(i,d,s,n)}} \right] \le D$$

The soil displacement between each borrow segment (b) segment (j) (With the cost of preparation), we have:

$$\Sigma_n \left[\frac{X_{SB(b,j,n)}}{P_{SB(b,j,n)}} \right] \le D$$

Three types of constraints: constraints nonnegative

$$X_{(i,j,s,n)} \ge 0 \qquad X_{B(p,j,n)} \ge 0$$

$$X_{SD(i,d,s,n)} \ge 0 \qquad X_{D(i,k,s,n)} \ge 0$$

$$X_{SB(b,j,n)} \ge 0 \qquad Y_{SB(b)}, Y_{SD(d)} = \begin{cases} 0 \\ 1 \end{cases}$$

4. SOLVE THE MODEL USING GENETIC ALGORITHMS

After writing the objective functions and constraints can be seen that this model has many variables and parameters is very complex and interdependent Therefore, it requires a relatively fast and accurate solution to be felt. With the surveys conducted among existing optimization methods such as computer simulations, neural networks and genetic algorithms in this paper as an acceptable solution is used and the objective function and all constraints are fully identified by genetic algorithm And a program written in MATLAB And then we try to optimize. It should be noted that genetic algorithms are two conditions to stop and end. Crossing is one of the n-th, the amount is determined by the user and if the answer is repeated in successive which, as can be seen in Figures 2 and 3 Algorithms are called convergent solution obtained is the optimum solution. The program is written, it is able to perform a specific job in the first phase of several fleet optimization And secondly the optimal fleet management and organization so that the final cost of the project at any given time is optimized.

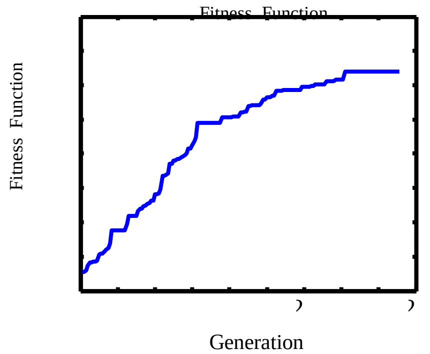


Figure3- the convergence of the algorithm for the second objective function

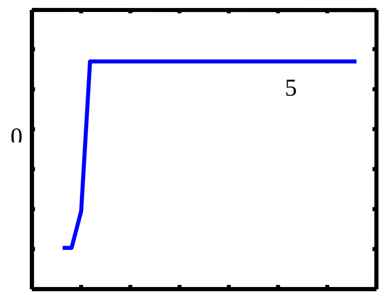
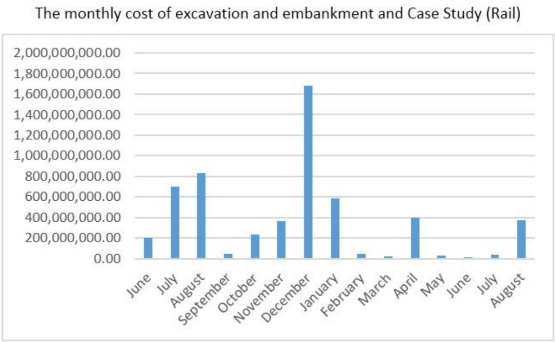
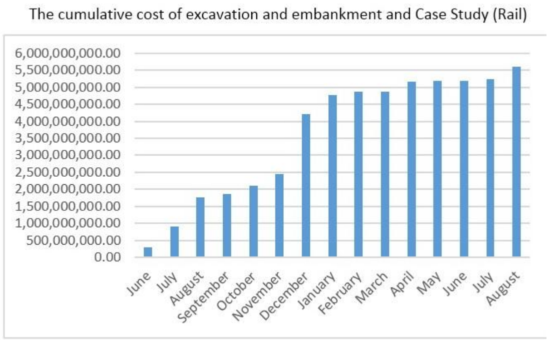


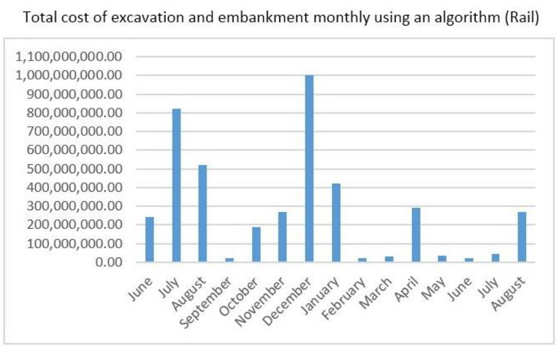
Figure2- the convergence of the algorithm for the first the objective function

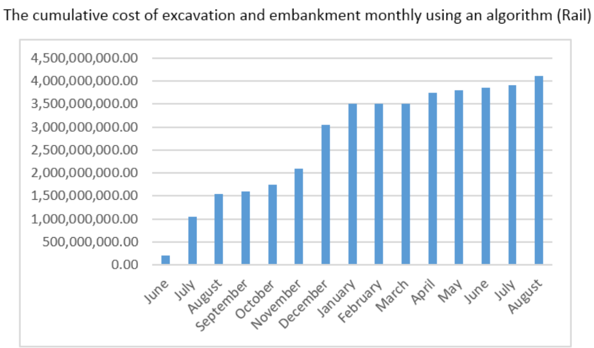
After writing the program and ensuring its proper function, the algorithm converges then, one construction project is a case that had been performed in 15 months and we examined. First, the cost of excavation and embankment of the project were outlined in the chart below.





Then, This construction project with a program that was written, we model and we examined. The following results were obtained with model answers can be found in the following tables.





The results differed significantly (about 25%) of the cost of the project show, this amount represents the ability of this program is to manage and optimize time and costs.

5. CONCLUSION

The results showed that the model has the ability to optimize the Earthworks and it can be used in construction projects. The results of this study, a significant difference in the cost of the project shows. But the significant difference in the amount of time and cost in this model becomes, to this extent, the operation will not be made in the workshop and this is because the model is a model of ideal working conditions or academic. In action several parameters in project Leads to delays and cost overruns. Especially in our country, several factors such as Weather, Failure to provide timely financial resources, Used machines and the failure of them, And the frequent change of directors, have caused the closure of operations. However, in such circumstances a small improvement in each of the stages could make one step forward and save the human and financial resources.

In addition, as we know, in our country, the machinery management (Including issues of buying, select the type of machinery, operation, maintenance, and more) is traditional and use of machinery has Low efficiency. While having such a model can be easily optimized fleet of machines dedicated to road projects and also reduced the cost of the project. Thus, managers, employees, contractors and the total of all those who are somehow linked to decision-making and management of construction projects recommended, Use of such a model in their decisions.

Perhaps one of the disadvantages or problems with this model, it is actually hard work. For example, to enter the basic information on this model and then work with it and get the correct answer, the user must be fluent in MATLAB and the harder it is familiar with genetic algorithms. It is recommended that students and those familiar with computer programming languages Applications based on this study provide That it does not need to know the specific program And all managers, engineers have the opportunity to use it.

It is hoped that this research will be a small step towards the development and advancement of our country.

6. REFERENCES

1. Burt,C. Caccetta,L. Hill,s. and Welgama,P. (1989) “*Models for mining Equipment selection”* ,ASCE,Journal of Construction Engineering and Management.

2. Jayawardane and Harris. (1990) “*Further development of integer programing in earthwork optimization”*. ASCE, Journal of Construction Engineering and Management, vol 116, No 1.

3. Said,M. Easa.(1998) “*Earthwork allocations with linear unit costs”*. ASCE, Journal of construction engineering and management, Vol 114, No 4.

4. Mattila and Myers. (2005) “*Determination of haul distance and direction in mass excavation”*, ASCE, Journal of construction engineering and management, Vol 131, No 3.

5. Marzouk and Moselhi. (2003) “*Object-oriented simulation model for earthmoving operatins”*, ASCE, Journal of construction engineering and management, Vol 129, No 2.

6. Marzouk and Moselhi. (2004) “*Multiobjective optimization of earthmoving operations”*, ASCE, Journal of construction engineering and management, Vol 130, No 1.

7. Marzouk and Moselhi. (2002) “*Selecting earthmoving equipment fleets using genetic algoritms”*, ASCE, Journal of construction engineering and management.

8. Behbahani and khaki. (2006) “*Construction equipment and procedures”*, Tehran, Elmo Sanat University.

9. Kia M. (2009) “*Genetic Algorithms in MATLAB”*, Tehran, Qian green computer publishing services.

10. Abas Pour Naderi,P and Forsat kar,A (2005) “*The choice of the optimal fleet of machines, making strategic projects Earthworks”*, First International Conference on Strategic Management of Projects,Tehran.