INTERNATIONAL JOURNAL OF OPTIMIZATION IN CIVIL ENGINEERING
Int. J. Optim. Civil Eng., 2012; 2(2):235-246

GENETIC ALGORITHM BASED EQUIPMENT SELECTION METHOD FOR CONSTRUCTION PROJECT USING MATLAB TOOL

P. Valli[*, †] and C. Antony Jeyasehar
Department of Civil and Structural Engineering, Annamalai University, Annamalainagar,
Chidambaram -608002, Tamilnadu, India

ABSTRACT

Equipment selection is a key factor in modern construction industry. As it is a complex factor, current models offered by literatures fail to provide adequate solutions for major issues like systematic evaluation of soft factors and weighting of soft benefits in comparison with costs. This paper aims at making a comparative study between GA and AHP by utilising MATLAB as a tool. It is a convenient tool offering an orderly methodical thinking. It guides them in making consistent decisions and provides a facility for all necessary computation.

Received: 12 January 2012; Accepted: 25 March 2012

KEY WORDS: methodical thinking; soft factors; equipment selection

1. INTRODUCTION

Construction equipment planning aims in identifying the construction equipment to carry out project tasks, assessing equipment performance capability, forecasting datawise requirements of numbers and types of equipment. Finally one has to think about a particular method for selecting equipment which will be more productive and less expensive and more profiTable There are several methods pertaining to this topic are available in MATLAB tool box out of which genetic algorithm is considered in this paper.

---

[*] Corresponding author: P. Valli, Department of Civil and Structural Engineering, Annamalai University, Annamalainagar, Chidambaram -608002, Tamilnadu, India

[†] E-mail address: valli_au@yahoo.in (P. Valli)

2. REVIEW OF LITERATURE

Shapira and Goldenberg [1] presented a selection model based on analytic hierarchy process a multi attribute decision analysis method, with a view of providing solutions for two issues. The model has the capability to handle a great number of different criteria in a way that truly reflects the complex reality to incorporate the context and unique conditions of the project and allow for manifestation of user experience and subjective perception. The model was implemented in an in-house developed system that was improved and validated through testing by senior professionals. The main academic contribution of the study is the modification of AHP to corresponded with the nature of equipment selection and in its utilisation as an effective means for the formalization of knowledge by competent experienced practioners. On the side the proposed model offers an efficient convenient tool and that forces the users into orderly methodical thinking, guides them in making logical, consistent decision and provides a facility for all necessary computations. This study aims at providing an equipment selection that will both overcome the limitations of the existing models and provide solutions for the prevalent issues as identified in current practices.

Bascetin [2] directed a research of an optimal loading-hauling system in an open pit mine. There are many factors affecting equipment selection in this process. There are both quantitative and qualitative according to the structure of the selection. This paper deals with analytic hierarchy process for equipment selection in open pit mining. For this study involves with the selection of an optimal loading-hauling system from mine to the power station to be established in an open pit coal mine. The optimum alternative has been found as shovel-in-pit crusher belt conveyor.

Haidar et al. [3] described the feasibility of applying artificial intelligence methodologies to the optimization of excavating and haulage operations and the utilization of equipment in open cast mining. The decision to select equipment is often based on past experience, location, and different organisational pressures as well as complex numerical computations. Therefore this study developed a open cast mine equipment (XSOME) which was designed using a hybrid knowledge based system and genetic algorithms. The knowledge based with in XSOME is a decision making task utilizing a decision that represents several nested production rules. The knowledge base mainly relates to the selection of equipment is broad categories. XSOME also applies advanced genetic algorithms search techniques to find the input variables that can achieve the optimal cost. Four case studies are analysed.

Goldenberg and Shapira [4] described about the awareness of soft consideration in equipment selection for construction projects. It aims at increasing awareness to the nature, variety and richness of soft factors, to their significant role and potential impact and outcome of decision making and to the inherent difficulty of evaluating and integrating them with in a comprehensive selection process. This paper explains about two considerations hard and soft factors. The first one is tangible quantitative formal considerations etc. This class includes typical factors like technical specification of the equipment, physical dimensions of site and constructed facility and cost calculations they are termed as hard factors. The second one is soft factors. This includes other factors like intangible, qualitative and informal in nature. Random examples include safety considerations, company policies recording purchase/rental, market fluctuations and environmental constrains.

Alkass et al [5] described the ingredients of an integrated computer system environment concerting operations. The ingredients include a description of the integration process between expert system and other management software such as base and spread sheet; an operational; definition making program an equipment selection may be presented, the factors that need to be considered representations of construction expertisers.

2. GENETIC ALGORITHM PROCESS

Genetic Algorithm process is a recently developed method. It is an artificial intelligence technique inspired by the theory of evolution and biogenesis. It is aimed at imitating the abilities of living organism of being consummate problem solvers through apparantly undirected mechanism of evolution and natural selection. They combine an artificial survival of the fittest approach with the genetic operators abstracted from nature to form a mechanism that is suited for a rarity of search problems.

Genetic algorithm optimization begins with an initial generation. The first generation produces a random population for the model number and the number of equipment related to the model. For each generation the cost is calculated and each activity is assigned a fitness based on it ability to meet constraints for the problem and achieve the minimum cost. The fittest activity is more likely to be next generation. There are three genes to the next generation. There are three main operators for the success of the process i.e., crossover, mutation and adaption.

Before planning about the equipment selection it is necessary that we have to take into account the various site conditions i.e., nature, size, floor conditions, haul distance, depth, soil conditions, ground pressure, material size, swell factor, job conditions, management conditions and weather conditions and also types of equipment. The most important point to be borne in mind is, make of equipment, model of equipment, number of equipment and operating life of equipment.

Here algorithms techniques is used for equipment selection. The use of algorithms techniques to define the make of equipment, number of equipment and operating life of the equipment that would produce the minimum total cost of the operation is shown in Figure 1.

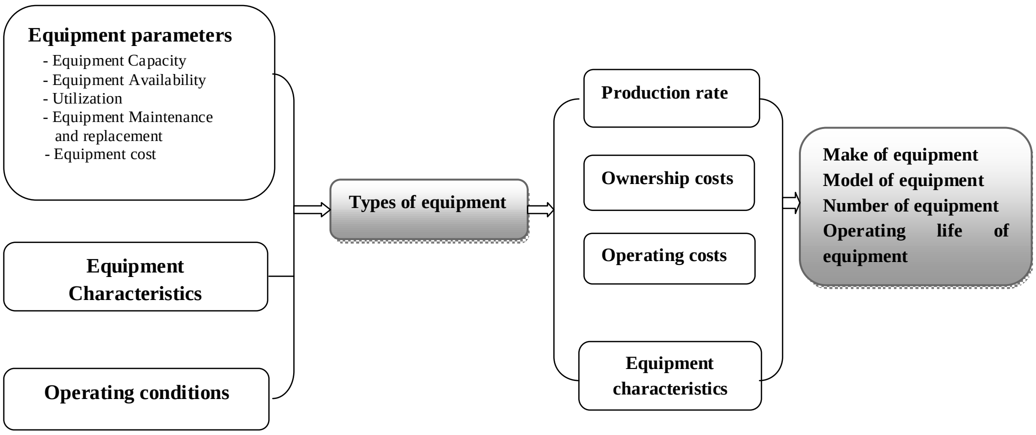


Figure 1. Genetic algorithms method of equipment selection

2.1 Output

Genetic algorithms methods help the construction industries to select the equipment that produces the minimum cost. This tool procedures cover quickly on optimal solutions and make increased output when compared to other tools. The use of this method has shown benefits in many construction areas and provides a well structured method in solving the problem. It also forces the user to take into consideration different aspects of the problem that can be overlooked. This method also provides a foundation for further development i.e., a way of examining different problems and tackling them.

3. MATLAB FEATURES

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, one can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN.

MATLAB can be used for wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modelling and analysis, and computational biology. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas.

4. GENETIC ALGORITHM TOOL BOX

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. Genetic algorithms are a part of Evolutionary computing, a rapidly growing area of artificial intelligence (AI). GAs are inspired by Darwin's theory about Evolution - Survival of the Fittest. GAs represent an intelligent exploitation of a random search used to solve optimization problems. GAs, although randomized, exploit historical information to direct the search into the region of better performance within the search space. In nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones.

4.1. Advantage of genetic algorithms

It is better than conventional AI ; It is more robust, unlike older AI systems, the GAs do not break easily even if the inputs changed slightly, or in the presence of reasonable noise. While performing search in large state-space, or multi-modal state-space, or n-dimensional surface, genetic algorithms offer significant benefits over many other typical search optimization techniques like - linear programming, heuristic, depth-first, breath-first.

Genetic Algorithms are good at taking large, potentially huge search spaces and navigating them, looking for optimal combinations of things, the solutions one might not otherwise find in a lifetime [6].

4.2 Flow chart for genetic programming

The flow chart showing the various steps of genetic programming is shown in Figure 2.

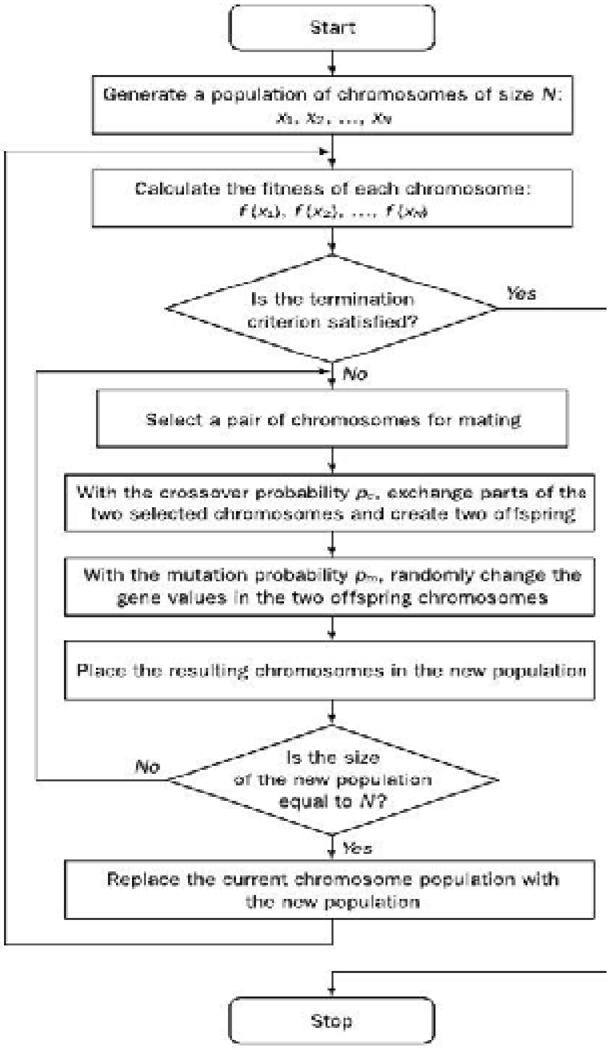


Figure 2. Flowchart for genetic algorithm

5. INPUT DATA FORMAT FOR GENETIC ALGORITHM

5.1. Required information

The following data available for each of the machinery used in the project is considered.

i. 15 Month Machine data of Availability.
ii. 15 Month Machine data of Working Hours.
iii. 15 Month Machine data of Diesel Consumption.

The above data collected for the project under consideration is given in Table 1.

5.2. Format of input

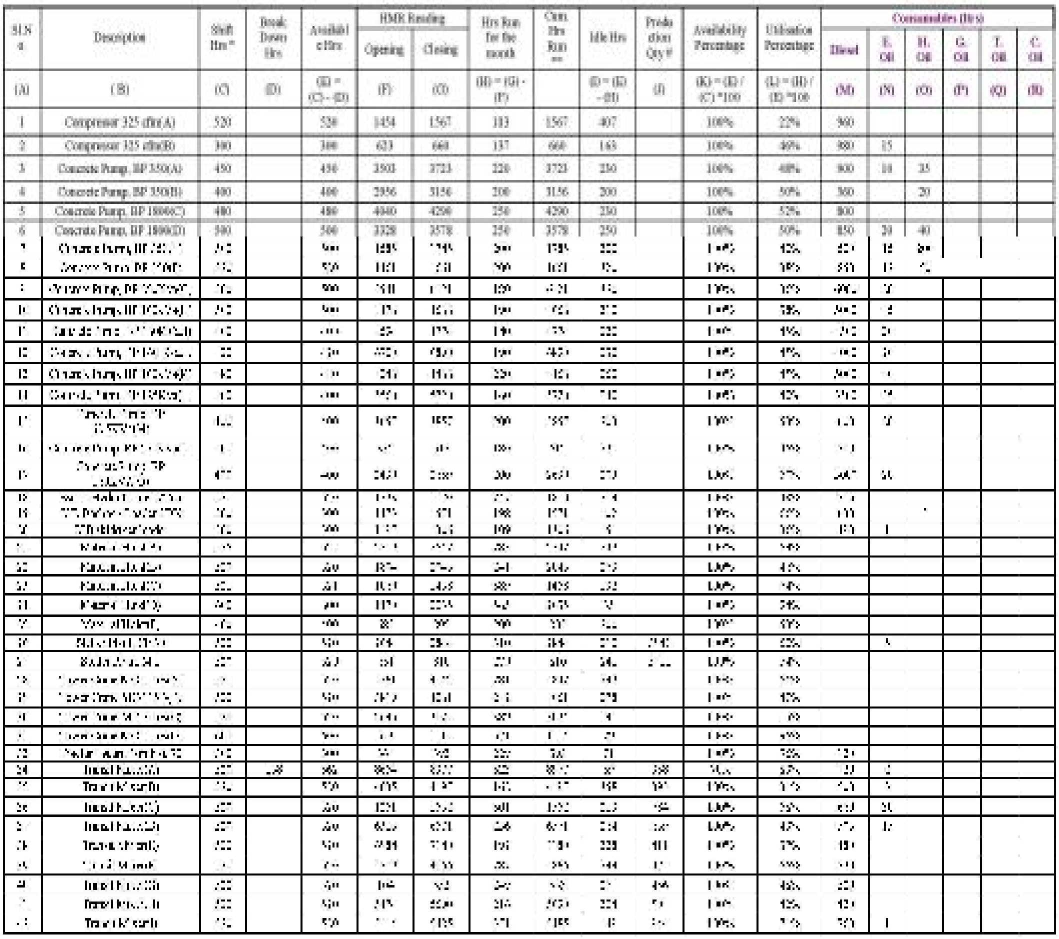
The input data has been prepared in Microsoft Excel format for ten machines, the sample of which is shown below:

<Machine _1> <Avail_ Hr s/ Month> <Working_Hrs/Month> <Idle_Hrs/Month><Diesel_Consmp/Month>
<Machine _2> <Avail_ Hr s/ Month> <Working_Hrs/Month> <Idle_Hrs/Month><Diesel_Consmp/Month>
<Machine _3> <Avail_ Hr s/ Month> <Working_Hrs/Month> <Idle_Hrs/Month><Diesel_Consmp/Month>
<Machine _n> <Avail_ Hr s/ Month> <Working_Hrs/Month> <Idle_Hrs/Month><Diesel_Consmp/Month>

Fifteen month data is taken for consideration. But here one month consumption is given as a random.

The performance data provide information about the actual productivity of each equipment for a period of 15 months. It shows the equipment's particulars, nature of work done, with detailed information about shift hours, available hours, running hours along with availability percentage, utility percentage and diesel consumption. The equipment productivity at the end of every month is shown in monthwise plant and equipment performance data are given in Table 1.

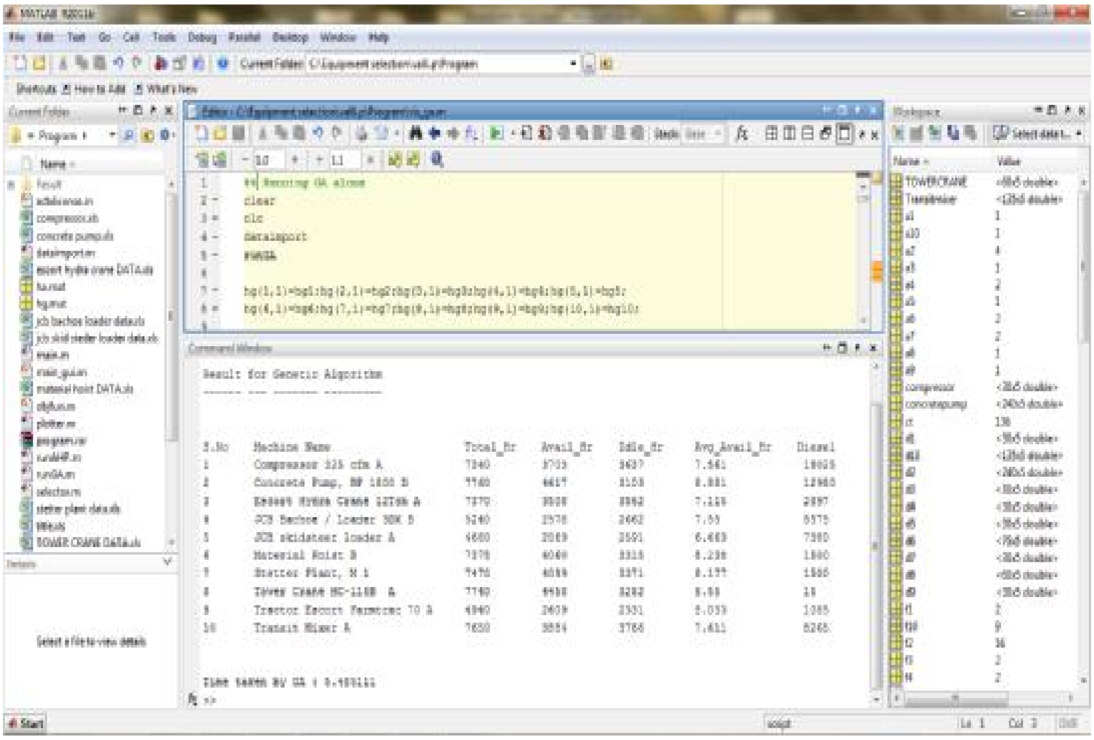
Table 1. Monthly plant & equipment performance data



SLNo	Description	Shift Hrs*	Break Down Hrs	Available Hrs	HMR Reading		Hrs Run for the month	Cum. Hrs Run **	Idle Hrs	Production Qty #	Availability Percentage	Utilisation Percentage	Consumables (ltrs)					
					Opening	Closing							Diesel	E. Oil	H. Oil	G. Oil	T. Oil	C. Oil
(A)	(B)	(C)	(D)	(E) = (C) - (D)	(F)	(G)	(H) = (G) - (F)		(I) = (E) - (H)	(J)	(K) = (E) / (C) *100	(L) = (H) / (E) *100	(M)	(N)	(O)	(P)	(Q)	(R)
1	Compressor 325 cfm(A)	520		520	1454	1567	113	1567	407		100%	22%	360					
2	Compressor 325 cfm(B)	300		300	623	660	137	660	163		100%	46%	980	15				
3	Concrete Pump, BP 350(A)	450		450	3503	3723	220	3723	230		100%	49%	900	10	35			
4	Concrete Pump, BP 350(B)	400		400	2956	3156	200	3156	200		100%	50%	360		20			
5	Concrete Pump, BP 1800(C)	480		480	4040	4290	250	4290	230		100%	52%	800					
6	Concrete Pump, BP 1800(D)	500		500	3328	3578	250	3578	250		100%	50%	850	20	40			

6. RESULTS FOR GENETIC ALGORITHM

The input data like availability, working hours, diesel consumption available in the excel files are accessed and processed by the genetic algorithm tool box and the result are presented. The equipment taken into consideration are compressor, concrete pump, escort hydra crane, JCB bachoe loader, JCB skidsteer loader, material hoist, stetter plant, tower crane, tractor escort farmtrack, transit mixer. The sample output is shown in Figure 3.



```
%% Running GA alone
clear
clc
dataimport
runGA

hg(1,1)=hg1;hg(2,1)=hg2;hg(3,1)=hg3;hg(4,1)=hg4;hg(5,1)=hg5;
hg(6,1)=hg6;hg(7,1)=hg7;hg(8,1)=hg8;hg(9,1)=hg9;hg(10,1)=hg10;
```

```
Result for Genetic Algorithm
------ --- ------- ---------


S.No   Machine Name                   Total_Hr   Avail_Hr   Idle_Hr   Avg_Avail_Hr   Diesel
1      Compressor 325 cfm A           7340       3703       3637      7.561          18025
2      Concrete Pump, BP 1800 B       9780       4617       5153      8.881          12960
3      Escort Hydra Crane 12T5M A     7370       3508       3862      7.116          2897
4      JCB Bachoe / Loader 3DX B      5240       2578       2662      7.55           5575
5      JCB skidsteer loader A         4680       2089       2591      6.483          7380
6      Material Hoist B               7378       4060       3318      8.238          1800
7      Stetter Plant, M 1             7470       4099       3371      8.177          1500
8      Tower Crane MC-115B  A         7740       4458       3282      8.55           15
9      Tractor Escort Farmtrac 70 A   4940       2609       2331      5.033          1065
10     Transit Mixer A                7650       3884       3766      7.611          8265


Time taken by GA : 0.485111
>>
```

Figure 3. Matlab equipment selection result for genetic algorithm in command window

7. GRAPHICAL RESULTS OBTAINED FROM MATLAB

For test case, 10 different kinds of machines with different category, (hoist, crane, tractor escort, hydra crane, compressor, concrete pump, etc.) are considered. Various brands of machines and their performance is taken into account for every catagory. The sample is taken as the best machine from the availability of the machines, Woking hour, Idle Hour, Percentage of the availability and Diesel consumption of the machine.

In the graph, ***continuous line*** indicates the selected machine among various other brands based on their performance and ***dotted line*** indicates the other machines which are unselected and their performance index in percentage.

The result obtained from the different brands of **COMPRESSOR**, *"Compressor cfm 325 (A)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4 [a])

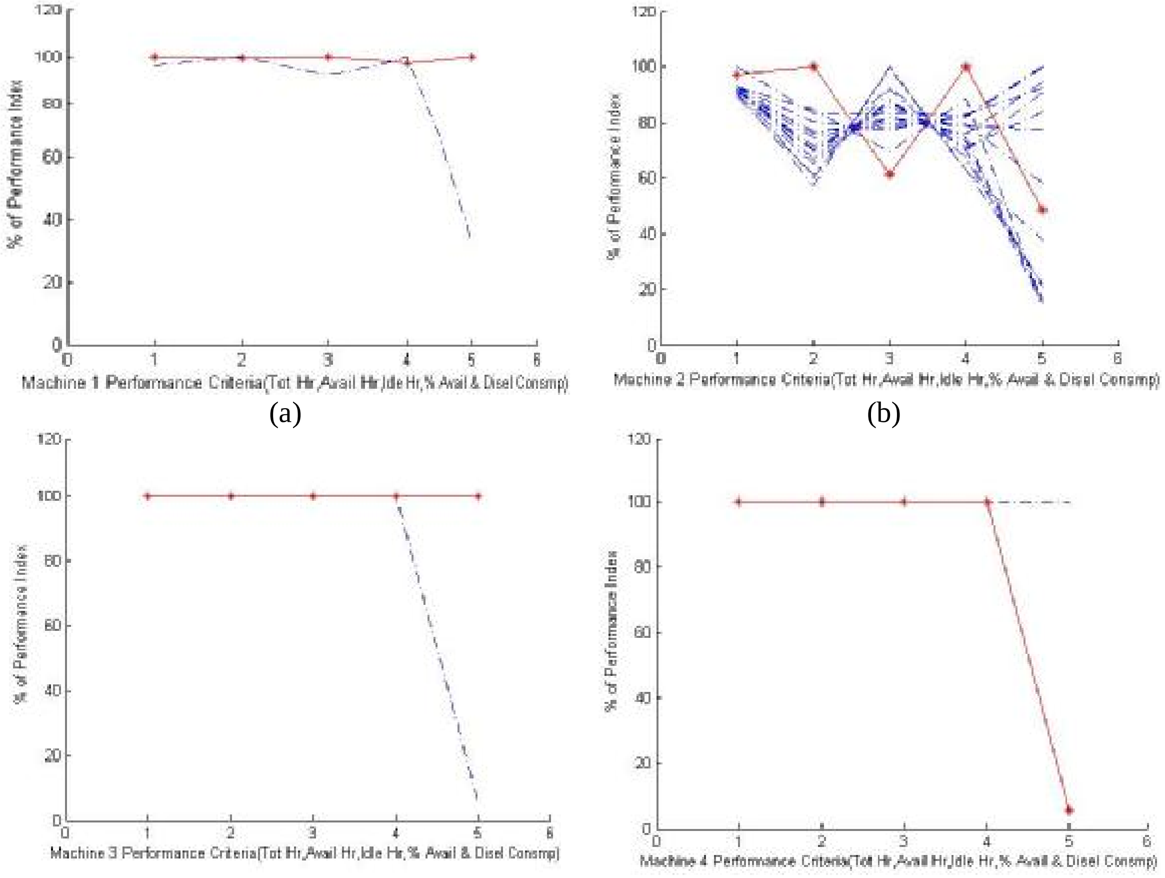
The result obtained from different brands of **CONCRETE PUMP**, *"Concrete pump BP 1800 (D)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4 [b])

The result obtained from different brands of **HYDRA CRANE**, *"Escort Hydra Crane 12Ton (A)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4[c]).

The result obtained from different brands of **JCB BOCHE LOADER**, *"JCB Boche / Loader 3DX (B)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4[d])

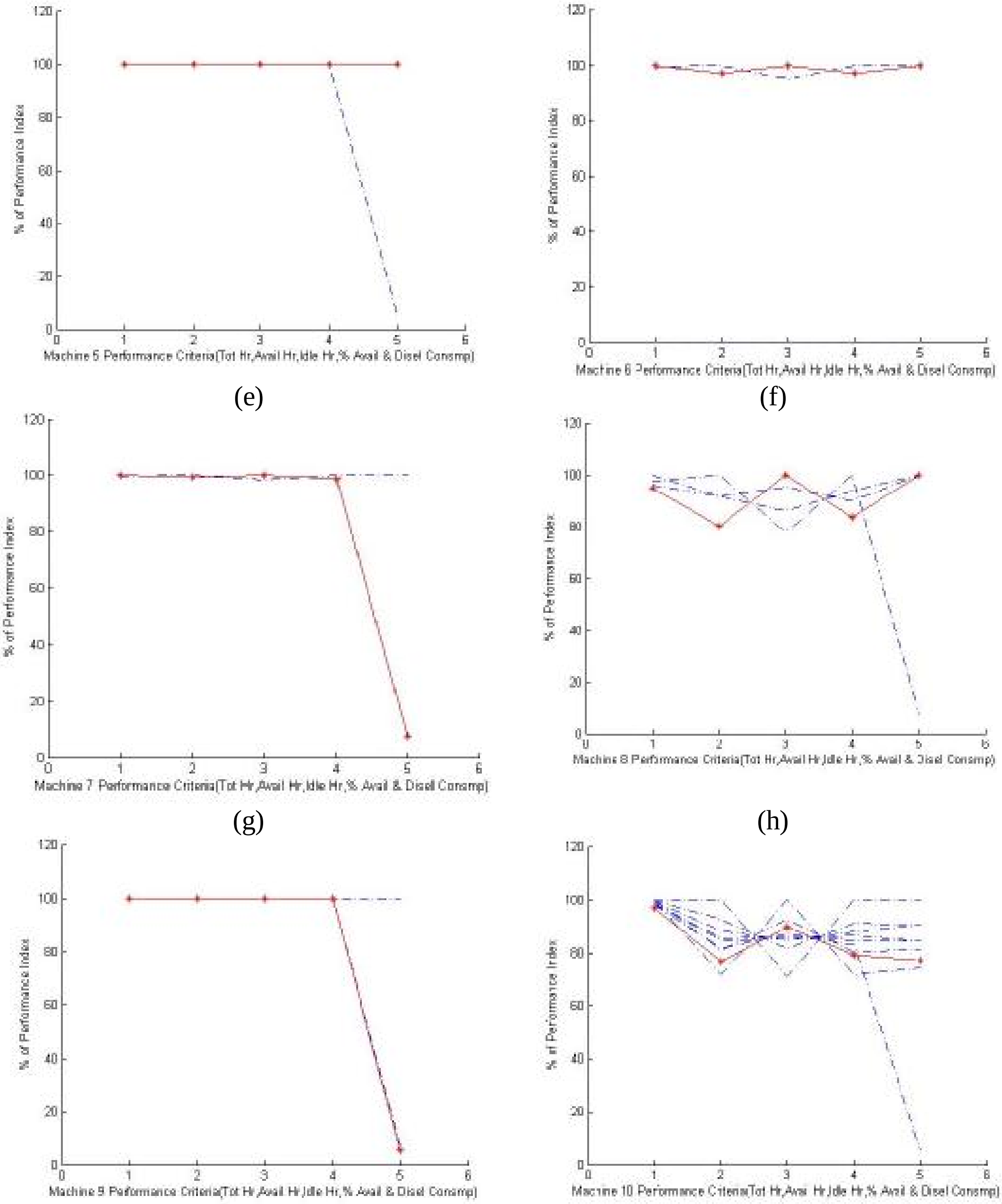
The result obtained from different brands of **JCB SKID LOADER**, *"JCB skidsteer loader (A)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4[e])

The result obtained from different brands of **MATERIAL HOIST**, *"Material Hoist (B)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4 [f])



(a) (b)

(c) (d)



(e) (f)

(g) (h)

(i) (j)

Figure 4. Graphical results obtained from Matlab

The result obtained from different brands of **STETTER PLANT**, *"Stetter plant M1"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4[g])

The result obtained from different brands of **TOWER CRANE**, *"Tower crane MC-115 (A)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4 [h])

The result obtained from different brands of **TRACTOR**, *"Tractor Escort Farmtrac 70 (A)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4 [i])

The result obtained from different brands of **TRANSIT MIXER**, *"Transit Mixer (A)"* is selected based on availability of equipment, utilization percentage, diesel consumption etc. (Figure 4[j])

8. COMPARATIVE STUDY FOR GA AND AHP

Proper method for selecting equipment which will be more productive, less expensive and profitable There are several methods pertaining to the topic out of which genetic algorithm and analytical hierarchy process are considered in this work. Major equipment data are given in the study. The output data for the two methods are compared. From the comparison of output result for both genetic algorithm and analytical hierarchy process, the equipment's performance in total hours, available hours, idle hours and average available hours along with diesel consumption is discussed.

From Table 2, it is concluded that AHP method is best suited for equipment selection as it is less time consuming, best performance, with less cost as compared with the GA method.

Table 2. Result for genetic algorithm

S.No	Machine name	Total_Hr	Avail_Hr	Idle_Hr	Avg_Avail_Hr	Diesel
1	Compressor 325 cfm A	7340 *(+1820)*	3703 (-168)	3637(+198)	7.561 (-1.52)	18025*(+1086)*
2	Concrete Pump, BP 1800 D	7620	3142	4478	6.285	31820
3	Escort Hydra Crane12TonA	7370	3508	3862	7.115	2897
4	JCB Bachoe / Loader 3DXB	5240	2578	2662	7.55	8575
5	JCB skidsteer loader A	4660	2069	2591	6.663	7380
6	Material Hoist B	7375 (+400)	4060(-850)	3315(+124)	8.238 (-1.69)	1500
7	Stetter Plant, M 1	7470 (+210)	4099(-217)	3371(+427)	8.177 (-0.9)	1500 (+4500)
8	Tower Crane MC-115B A	7740 (+1365)	4458(-2828)	3282(+413)	8.55(-6.53)	15000
9	Tractor Escort Farmtrac70A	4940	2609	2331	8.033	1085
10	Transit Mixer A	7760 (-770)	3287(-4844)	4433(+434)	6.319 (-8.34)	7285(-10788)

Note: In table –ve sign indicates how much value lower that the Equipment selected by another technique via +ve sign indicates how much value higher than that the Equipment selected by another technique. Red colour identification indicates un desired and green indicates desired.

Same variables are taken for consideration in both genetic algorithm and analytical hierarchy process method of selection. The data derived from the study shown in Table 2 indicates that the best selection method is analytical hierarchy process, as it is less time consuming, profit oriented, solves all complex problems, guides them making logical and consistent decisions and provide all facilities for necessary computations. It offers an effective means for the formalization of knowledge by competent and experienced persons.

9. CONCLUSIONS

i) This selection model offers a comprehensive solution for a systematic evaluation of qualitative decision factors. It will guide the construction industries to handle different complex criteria without losing its practicality. It also incorporates the context and unique conditions of the project, allowing manifestation of user experience and subjective perception. It gives a framework for a structural process and assuring solution consistency.
ii) This study will be very helpful for the construction industry as it gives better guidelines for the method of equipment selection. Unlike the genetic algorithm, the analytic hierarchy process method is found to be the best as it gives a wide spectrum of planning and personal judgement to take apt decision.
iii) As it gives guideline about the entire site plant and thereby allows the engineer's to make the evaluation of any equipment option.
iv) The systematic consideration of soft and hard factors of this project will make the project engineer's to accommodate owned and rented equipment duly considering cost evaluation. It gives the users in making sound and logical decisions and will guide them to train novice engineers. It gives guideline to solve complex and challenging problem that the modern construction industry spaces.
v) Above all the study will be of great importantce for the future construction industry as it aims at advance decision making in equipment organisation and equipment location covering all phases of equipment use on the project.
vi) The study gives a detailed account about actual assimilation in construction companies and its long term application in construction projects.
vii) This study offers an efficient and convenient tool that makes the users into methodical thinking, guides them in making logical, consistent decisions and provides a facility for all necessary computation.
viii) As this selected tool gives a detailed account about availability hours, working hours, idle hours allowing construction industry to decide about the wastage hours. It enables them to decide the apt equipment and gives ideas about reducing the idle equipment and thereby minimizing cost and maximising profit.

REFERENCES

1. Shapira A, Goldenberg M. AHP - Based Equipment Selection Model for Construction Projects, *J Constr Eng Manag, ASCE*, 2005; **131**(12): 1263-73.

2. Basctin A. A Decision Support system for optimal equipment selection in open pit mining: analytical Hierarchy process, Report of Mining Engineering Department, 2003; **16**(2): 1-11.
3. Haider A, Naoum S, Howes R, Tah J. Genetic Algorithms Application and Testing for Equipment Selection, *J Constr Eng Manag, ASCE*, 1999; **125**(1): 32-8.
4. Goldenberg M, and Shapira A. Soft Considerations in Equipment for Building Construction Project, *J Constr Eng Manag, ASCE*, 2007; **133**(10): 749-60.
5. Alkass S, Alhussein M, Moselhi O. Computerized Crane Selection for Construction Projects, J Constr Eng Manage, Association of Researchers in Construction Management, 1997; **2**: 427-36.
6. Mangano Sal. *Computer Design*, 2nd Edition, Springer, 1995, pp. 153-160.