International Journal of
Science and Engineering Investigations vol. 6, issue 71, December 2017

ISSN: 2251-8843

The Investigation of Practical Application of Minimizing the Completion Time of Projects Using Optimization Algorithm Method

Kambiz Shokohi
Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran
(Shokouhi.k@gmail.com)

Abstract- Scheduling of a project is defined as determining time sequence in order to do a series of correlated activities that form a project. Minimizing is the completion time of project so that resource and priority constrains were satisfied. The main goal of research is to investigate the practical application of minimizing the completion time of project using optimization algorithm. For solving this problem a new algorithm of anarchic society optimization (ASO) has been designed. ASO just like other Meta-heuristic algorithms gives better results than methods based on priority rules. It is because of the nature of Meta-heuristic algorithms and these algorithms usually use the information related achieved responses in order to produce later responses, while the methods based on priority rules create any response independently. It should be emphasized that using a Meta-heuristic method alone, doesn't guarantee reaching optimal response. In this study, we use Taguchi methods for setting up the parameters of algorithm and implementing this algorithm on basis shows its efficiency in comparison to other existing algorithms.

Keywords- *ASO, Scheduling Project, Optimization Algorithm, Minimizing.*

I. INTRODUCTION

Emerging project management as a science have begun since first Worlds War so that in 1917, Gannt created the famous Gannt Chart. After 1950, other well-known project management techniques like critical pass method and so on developed. The science of project management has been one of the most important and applicable issues particularly in past decades. By advancing science and complicating defined project structures in different parts of science, project management is an inseparable part of general project. In today's world, by increasing competition, on time delivering goods or service or quality considering different limitations such as work force, capital, etc. look really important (Demeulmeester, 2002). According to savings from project management in time, resources and cost, the interest to this field is increasing all over the world. Among different elements of project management, project scheduling has a special position in macro management of different project planning for its important and considerable role. From practice aspect, by improving project scheduling which is a part of project management, the profit of company increases particularly companies which produce and sell simultaneously (Hindi, 2002). Of practical applications of project scheduling, software developing, planning in transportation organizations and constructions and many other fields can be mentioned. Project scheduling is important not only from practical aspect but also research and theory aspect and in recent years many researches have been done in this field. As many famous optimization problems are a special kind of problem of project scheduling, this area is an attractive field for study for people interested in.

The history of project management regardless to knowledge of project is at least 4500 years, the builders of Egypt pyramids and Maya temples in Central America are often known as the first project managers in the world. Project scheduling as the main issue of this project takes place in planning process group. Project scheduling is defined as determining time sequence in order to do a series of correlated activities that form the project. Correlated activity means priority relationships in doing them so that conducting an activity may relate to one or several other activities which can be said that project has priority constraints. Determining this scheduling plan can be under a single or several special goals. In addition to priority constraints existed in all projects among activities, there is another kind of constraint called resource constraints in projects. Project scheduling with only priority constraints are called project scheduling problems without resource constraints and if there are resource constraints, it will be called resource constrained project scheduling problem (RCPSP). Since late 1960, project scheduling models were developed in which both resource and priority constraints were considered simultaneously. It was difficult to solve these kinds of problems so that the mentioned methods for solving this kind of problems were not efficient, in new problems the time of solution increased by increasing activities exponentially and finally in big problems (more than 100 activities) using detailed methods wasn't time-efficient because these kinds of problems are considered as NP-hard optimization problems because of big aspects (Valls, 2005). Resource constrained project scheduling problem in classic form (RCPSP) is the simplest kind of resource constrained project scheduling problem which there is no exact method in big aspects (more than 100 activities). Blazevicz proved that PCPSP as a generalization of JSSP is a NP-hard problem so that needed time for finding answer by the best exact methods is very high for the networks consisting more than 30 activities (Blazewicz). Finally, the researchers tend to Heuristic and Meta heuristic methods in solving RCPSP in big aspects because these methods don't need to pass all search space and can reach the near-optimal response in reasonable time.

Therefore, it attempts in this paper, to use new Meta heuristic algorithm of anarchic society optimization (ASO) in order to study the practical application of completion time by resource constrained in classic form and compare the results with the best algorithms applied before.

II. METHODOLOGY

Analyzing scheduling problems. In RCPSP model, it is assumed that for each activity there is only on performance, the case we study is a project with an actual activity and 2 virtual activity which there is only priority relation FSmin = 0 among activities and each activity needs only renewable resources. The length of jth activity performance is equal to dj and a certain amount in this paper. The rate of jth activity in each time period to k∈R resource is equal to rjk. It is assumed that from renewable k∈R in each time period, ARk is available. In this problem the amount of ARk and rjk are constant, positive and integer. The objective function of RCPSP is funding a schedule that is reasonable from both priority and resource point of view and has the least length of scheduling.

A. Presenting RCPSP concept model

RCPSP concept model is as below:

Minimize Sn+1 (1)

St:

S0 =0 (2)

Sj ≥ Si + di (3)

∀(i,j)∈ E

$\sum_{i\in S(t)} r\text{ik} \leq \text{ARk}$ (4)

t ≥ 0

i = 0, 1,… , n + 1 ; k = 1, 2, … , m

In the formula above the first and n+1 activity is virtual and the rest is actual. The variables of Si shows the time of activity beginnings. In formula 3, E set shows the priority relationships among activities. Di shows the length of ith activity. In formula 4, the S(t) shows the activities developing during t time. The variable rik shows the need of ith activity to kth resource in any time period that is certain. ARk shows the renewable resource in any time period. Equation 1, shows the objective function of minimizing the time of beginning the last virtual activity. Equation 2 shows that first virtual activity begins in Zero time. Equation 3, shows the priority relationships among activities that is only FSmin = 0. Equation 4 shows that at the moment of doing project, each activity can make its selection. Mathematical concept model cannot be solved directly because there is no way for translating S(t) in formula 4. So, there was a need for mathematical model which is capable of solving in 1960s that Pritsker model (1969), Kaplan (1988), Alvarz-Valdez model (1993), Mingozzi model (1998), Klein model (2000) can be mentioned (Ahmadi-Javid, 2012).

B. General explanation of algorithm,

The structure of Meta heuristic algorithm based on population depends on characteristics of society members. Therefore, selection of society with suitable principle is very important in designing these algorithms. The fact is that, the human society is a motivation to create meta heuristics algorithm based on population because of its unique characteristics and it is assumed that instead of population based on birds or ants or insects, a human society with abnormal behavior is used (Nonobe, 2005). In fact, anarchic society optimization algorithm is a new optimization method coming from human society that its members behave in order to improve the conditions abnormally. In this algorithm it is assumed that the members of this human society behave irrationally and adventurously so that the members may move toward worse conditions and situations. Meta heuristic Anarchic Society optimization algorithm gives us this possibility to search all the space and ignore the local optimal traps. The main idea beyond Meta heuristic PSO algorithm is that any bird is known as a particle which is searching for optimal response in optimization space. Each particle identifies the speed rate based on the personal experience and information obtained from relation and interaction with population. The structure of PSO has been introduced at the beginning of optimization problems without constrains. In a continuous search space, any aspect of place border of bird is related to a decision variable of considered problem. In the other words, the location each particle is a potential response for considered problem and suitability of this particle can be calculated by placing amounts of each particle in a pre-identified objective function. When suitability function for location of a particle is more than desire, the place is identified as better place. Now, the mathematical schematic of Meta heuristic PSO algorithm is expressed as follow: we assume that a set of particles is searching for overall optimal response in d-dimensional space. Two d-dimensional borders for any ith particle in kth level should be identified that the first is d-dimensional Xi(k) border that shows the location of ith particle in kth level. The second border is Vi(k) border that shows ith speed in kth level. Other two important d-dimensional border in PSO algorithm are Pi(k) and G(k) borders that is defined in PSO algorithm similar to definition of ASO algorithm.

The new speed of each particle in PSO Meta heuristic algorithm is calculated as follows:

Vi (K + 1) = ωVi(k) + ʎ1r1(k) [G(K) – Xi(k)] + ʎ2r2(k) [Pi(k) – Xi(k)] (5)

In the formula above, ʎ1 and ʎ2 are positive constant amounts that are considered as acceleration coefficient.

In formula above, ω is a positive constant named inertia factor. Also, in above formula, (k)1r and (k)2r are the amounts which initialize by a probability distribution in (0,1) range randomly in kth level.

Here, we would like to show that PSO Meta heuristic algorithm is a special kind of ASO Meta heuristic algorithm. For this first we introduce the below borders:

Vicurrent(k) = ω Visum(k)

Visociety(k) = ʎ1r1(k) [G(k)–Xi(k)] (6)

Vipast(k) = ʎ2r2(k) [Pi(k) – Xi(k)]

Where the general formula is given:

Visum(k) = Vicurrent (k –1) +

Visociety(k –1) + Vipast(k –1) (7)

Movement policies and combination law are defined as follow:

Movement policy of MPicurrent(k) is considered as the movement of ith particle in kth level with Vicurrent(k) speed in single unit time distance. Movement policy of MPisociety(k) is considered as the movement of ith particle in kth level with Visociety(k) speed in single unit time distance. Movement policy of MPipast(k) is considered as the movement of ith particle in kth level with Vipast(k) speed in single unit time distance. Combination law is considered as a following of three mentioned movement policies. The new local of ith member after applying above mentioned policies is similar to this manner that the particle moves with the speed below in k+1 level for a unit time:

Visum(k + 1) = Vicurrent (k) + Visociety(k) + Vipast(k) (8)

Therefore, by explanation mentioned in ASO Meta heuristic algorithm we have:

Xi(k + 1) = Xi(k) + Vi (k+1) (9)

So we can conclude that PSO Meta heuristic is a special form of new ASO Meta heuristic algorithm, so we can benefit the ASO algorithm structure for all problems solved by PSO Meta heuristic algorithm, particularly for problems using PSO Meta heuristic algorithm for continuous problems (Pan, 2008).

III. Results and Discussion

A. *Encoding and responses*

In order to use Meta heuristic algorithms, we need to encode each response of problem in a simple and applicable form in coding. The method of coding has considerable impact on precision and speed of each Meta heuristic algorithm; encoding responses should be based on these conditions.

1- A spanning and one to one relationship should be between each response of problem and the way of showing responses. It means each response of problem is exactly demonstrates with one structure and each structure corresponds only to one response.

2- Every response should be saved in a small memory space.

3- Demonstration of each response should be selected in a way that using operators and neighborhood needed in Meta heuristic algorithm become easy.

B. *Setting parameters*

Five parameters are considered for designed ASO algorithm that identifies the characteristics and parameters of suggested ASO algorithm. These parameters are: size of population, F parameter in movement based on current location, E_1 and E_2 parameters in movement based on location of other members of human society and P parameter in movement based on personal history of every member.

Operators and parameters that their suitable amount should be selected are given in table 1 as some factors.

TABLE I. THE FACTORS AND THEIR LEVEL FOR SETTING PARAMETERS OF ASO ALGORITHM

Factor	Levels				No
	1	2	3	4	
population size	15	30	45	60	4
F parameter in movement based on current location	0.02	0.05	0.1	02	4
E_1 parameters in movement based on location of other members of human society	0.02	0.05	0.1	0.2	4
E_2 parameters in movement based on location of other members of human society	0.02	0.05	0.1	0.2	4
P parameter in movement based on personal history of every member	0.001	0.005	0.01	0.05	4

Table 2 shows 16 needed exam for L16 design.

TABLE II. TAGUCHI L16 DESIGN FOR ASO ALGORITHM.

Psize	F	E1	E2	P	Res
15	0.02	0.02	0.02	0.001	5208
15	0.05	0.05	0.05	0.005	5346
15	0.1	0.1	0.1	0.01	5323
15	0.2	0.2	0.2	0.05	5267
30	0.02	0.05	0.1	0.05	5443
30	0.05	0.02	0.2	0.01	5250
30	0.1	0.2	0.02	0.005	5346
30	0.2	0.1	0.05	0.001	5233
45	0.02	0.1	0.2	0.005	5227
45	0.05	0.2	0.1	0.001	5319
45	0.1	0.02	0.05	0.05	5299
45	0.2	0.05	0.02	0.01	5435
60	0.02	0.2	0.05	0.01	5240
60	0.05	0.1	0.02	0.05	5393
60	0.1	0.05	0.2	0.001	5208
60	0.2	0.02	0.1	0.005	5279

After achieving the results of Taguchi test, the ratio of S/N was calculated using Minitab software. Figure 1 demonstrates the average of S/N for each level and each factor.

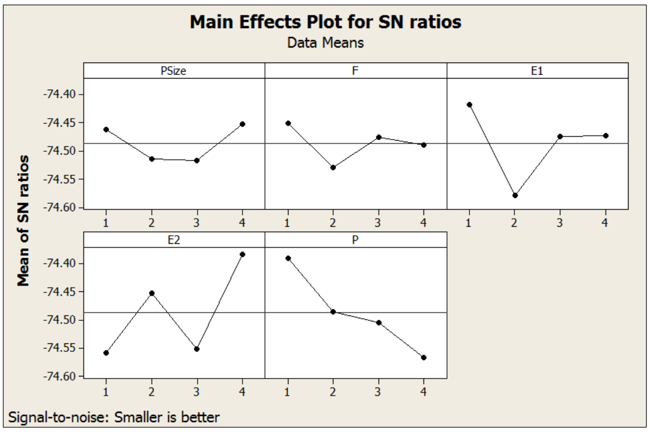

Figure 1. The diagram of S/N ratio for each level, factor

Using figure 1 the optimal amounts for factors to table 3 are:

TABLE III. OBTAINED OPTIMAL LEVELS

Factor	Optimal level
Population size	60
F parameter in movement based on current location	0.02
E_1 parameters in movement based on location of other members of human society	0.02
E_2 parameters in movement based on location of other members of human society	0.2
P parameter in movement based on personal history of every member	0.001

The diagram of sum of objective functions of tested problems for different levels of factors are given in figure 2. As it can be seen this diagram confirms the selected levels in table 4.

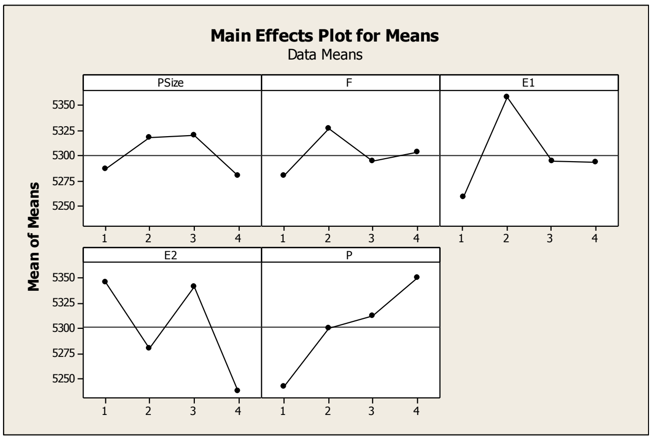

Figure 2. The diagram of sum of objective functions of tested problems

C. The results of research

In this section, the operation of ASO algorithm has been compared with other designed Meta heuristic algorithm for RCPSP. Colish and Hartmann (2006) has collected the last presented algorithms and their operations (Hartmann, 2006). The assessment criterion for each series of sample are:

- For 30 activity series, the optimal response of problems are obtained using detailed methods and algorithms for each 480 projects.
- For 60 activity series, 431 problems of 480 problems are solved optimally. Critical pass method was used for the rest of lower bound problems that the deviation of this amount is our assessment criteria.

1) Problems with 30 activity

In PSBLIB standard library, 480 sample problems are given for projects for 30 activities. All these problems are solved optimally. Designed ASO algorithm could obtain to optimal response of 412 problems of 480 problems with 30 activities. The mean of deviation from optimal response is 0.36% for solving 480 problems that among the best algorithm, Anarchic Society Optimization has reached to almost good response.

TABLE IV. THE COMPARISON OF DESIGNED ASO ALGORITHM WITH OTHER ALGORITHMS FOR 30-ACTIVITY PROBLEMS.

Algorithm	SGS	Resource	Error percentage
GA – self-adapting	both	Hartmann	0.08
GA – activity list	serial	Hartmann	0.08
sampling – LFT, FBI	both	Tormos, Lova	0.09
TS – activity list	serial	Klein	0.17
sampling – random, FBI	serial	Valls et al.	0.11
SA – activity list	serial	Bouleimen, Lecocq	0.23
GA – late join	serial	Coelho, Tavares	0.16
sampling – adaptive	both	Schirmer	0.44
TS – schedule scheme	related	Baar et al.	0.44
sampling – adaptive	both	Kolisch, Drexl	0.52
GA – random key	serial	Hartmann	0.23
sampling – LFT	serial	Kolisch	0.27
sampling – global	serial	Coelho, Tavares	0.28
sampling – random	serial	Kolisch	0.51
GA – priority rule	serial	Hartmann	0.88
sampling – WCS	parallel	Kolisch	1.28
sampling – LFT	parallel	Kolisch	1.13
sampling – random	parallel	Kolisch	1.22
GA – problem space	mod. Par.	Leon, Ramamoorthy	1.59
ASO	serial	Our Research	0.36

2) Problems with 60 activities

Designed ASO algorithm in this paper has been performed for all 480 projects in PSBLIB site. The designed algorithm has gained the optimal response for 323 cases of 431 with proved optimal response. The Error percentage for each response can be obtained from $\frac{ASO\text{ response} - \text{lower bound}}{lower\ bound} \times 100$ and by their mean, in average every response differs 1.88% from lower bound.

TABLE V. THE PERCENTAGE OF MEAN OF DEVIATION FROM OBTAINED LOWER BOUND FOR –ACTIVITY SERIES BY 2006

Algorithm	SGS	Resource	Error percentage
Scatter Search – FBI	serial	Debels et al.	10.71
GA – hybrid, FBI	serial	Valls et al.	10.73
GA, TS – path relinking	both	Kochetov, Stolyar	10.74
GA – FBI	serial	Valls et al.	10.74
GA – forw.-backw., FBI	both	Alcaraz et al.	10.84
GA – self-adapting	both	Hartmann	11.21
GA – activity list	serial	Hartmann	11.23
sampling – LFT, FBI	both	Tormos, Lova	11.36
sampling – LFT, FBI	both	Tormos, Lova	11.47
GA – forw.-backward	serial	Alcaraz, Maroto	11.86
sampling – LFT, FBI	both	Tormos, Lova	11.54
SA – activity list	serial	Bouleimen, Lecocq	11.9
TS – activity list	serial	Klein	12.03
TS – activity list	serial	Nonobe, Ibaraki	11.58
sampling – random, FBI	serial	Valls et al.	11.94
sampling – adaptive	both	Schirmer	12.58
GA – late join	serial	Coelho, Tavares	11.94
GA – random key	serial	Hartmann	12.25
GA – priority rule	serial	Hartmann	12.26
sampling – adaptive	both	Kolisch, Drexl	13.06
sampling – WCS	parallel	Kolisch	13.21
sampling – global	serial	Coelho, Tavares	12.83
sampling – LFT	parallel	Kolisch	12.85
TS – schedule scheme	related	Baar et al.	13.48
GA – problem space	mod. Par.	Leon, Ramamoorthy	13.49
sampling – LFT	serial	Kolisch	12.97
sampling – random	parallel	Kolisch	13.66
sampling – random	serial	Kolisch	14.22
ASO	serial	Our research	.88

IV. CONCLUSION

The main focus on designing this algorithm is to use various policies and neighborhood for algorithm in order to increase the efficiency. The designed algorithm was tested on 4 series of sample problems tested by progeny software and the general results were achieved based on output of algorithm.

Some of these projects have very little deviation (sometimes zero) from optimal response. While in others the deviation is so much. The reason can be found in the amount of various parameters defined for each project. Kolish and Speecher mentioned that by increasing NC, the problem becomes simpler and easier to solve. Vice versa, increasing resource coefficient makes problem worse and it is completely obvious that increasing RS i.e. resource strength makes problem simple.

Based on this and according to this point that problems are created based on different combination, when problem has the lowest amount of NC and RS and the highest amount of RF, the times the algorithm has gained the optimal response was very low (sometimes, the algorithm has never gained the optimal response) and therefore, the highest deviation of optimal amount are in these problems. It is obvious that the lowest deviation is in problems with the highest amount of NC and RS and the lowest amount of RF (in this form the algorithm has reached the optimal response).

The point that should be mentioned is ASO just like other Meta heuristic algorithms have better results than methods based on priority rules. The reason is because of the nature of Meta heuristic algorithms and these algorithms usually use the information related to responses in order to create later responses, while the methods based on priority law create each response independently. Furthermore, it should be emphasized that using a Meta heuristic method alone doesn't guarantee reaching to optimal response.

Generally, there are 2 kind of methods in order to solve scheduling a project under resource constrains. Detailed and Meta heuristic methods. For small-scale problems, detailed methods always give the optimal response, but by growing the problem, this method loses its efficiency. While Meta heuristic methods in big problems can easy find the response but don't guarantee the optimality of the response.

REFERENCES

[1] Demeulmeester, E. K. & Horroelen, W. S. (2002). Project Scheduling: A research Handbook, Springer.

[2] Blazewicz, J., Lenstra, J.K., and A.H.G. Rinnooy Kan, "Scheduling Subject to Resource Constraints: Classification and Complexity", Discrete Applied Mthematics, 5(1983), PP. 11-24. Evalutionary Computation (CEC), June 5-8, New Orlens, LA, pp. 2586-2592, 2011.

[3] Bottcher, J., Drexl, A., Kolisch, R., Salewski, F. (1996). "Project Scheduling Under Partially Renewable Resource Constraints". Technicl report 398 Manuscipte aus den Instituten fur Betriebswritschaftslehre der Universitat Kiel.

[4] Talbot, F.B (1982). "Resource-Constrined Project Scheduling with Time-Resource Tradeoffs: The Nonpreemptive Case". Management Science, 38: pp. 1498-1509.

[5] Pritsker, A. B., Watters, L. J. and Wolfe, P. M., Multiproject scheduling with limited resources: A zero-one programming approach. Management Science, 1969, 16, 93-108.

[6] Demeulemeester, E. and Herroelen, W., New benchmark results for the resource-constrained project scheduling problem. Management Science, 1997, 43, 1485-1492.

[7] Brucker, P., Schoo, A. nd Thiele, O., A branch-and-bound algorithm for the resource-constrained project scheduling problem. European Journal of Operational Research, 1998, to appear.

[8] Dorndorf, U., Pesch, E., Phan-Huy, T. A branch-and-bound algorithm for the resource-constrained project scheduling problem, Mathematical Methods of Operations Research 52(2000) 413-439.

[9] Kohlmorgen, U., H. Schmeck and K. Haase (1999), Experiences with Fine-Gained Parallel Genetic Algorithms, Annals of Opertions Reseach, 90, 203-219.

[10] S. Hartmann, A competitive genetic algorithm for resource-constrained poject scheduling, Naval Research Logistics 49 (2002) 433-448.

[11] J. Alcaraz, C. Maroto, A robust genetic algorithm for resource allocation in poject scheduling, Annals of Operations Research 102 (2001) 83-109.

[12] S. Hartmann, A self-adapting genetic algorithm for project scheduling under resource constraints, Naval Research Logistics 49 (2002) 433-448.

[13] Y.C. Toklu, Appliction of genetic algorithm to construction scheduling with o without resouce constraints, Candian Journal of Civil Engineeing 29 (2002) 421-429.

[14] K.S. Hindi, H. Yang, K. Fleszar, An evolutionary algorithm for resource-constrained project scheduling, IEEE Transaction on Evolutionary Computation 6 (2002) 512-518.

[15] J. Coelho, L. Tavares, Comparative analysis of metaheuicstics for the resource constrained project scheduling problem, Technical, report, Depertmant of Civil Engineering, Instituto Superior Tecnico, Portugal.

[16] J. Gonclves, J. Mendes, A random key based genetic algorithm for the resource-constained poject scheduling problem. Technical report, Depatamento de Engenharia Universidade do Porto, 2003.

[17] Goncalves JF, Beirao NC. Um algoritmo genetic baseado em chaves aleatorias para sequenciamento de operacoes. Revista Associacao Portuguesa Investigacao Opeacional 1999;19:123-37 (in Portuguese).

[18] Mendes. J.J.M, Goncalves. J.F, Resende. M.G.C. A random key based genetic algorithm for the resource constrained project scheduling problem. Computers and Operations Research 36 (2009) 92-109.

[19] K. Nonobe, T. Ibaraki, Formulation and tabu search algorithm for the resource constrained project scheduling problem, in: C.C. Ribeiro, P. Hansen (Eds.), Essays and Surveys in Metaheuristics, Kluwer Academic Publishers, 2002, pp. 557-588.

[20] N. Pan, P. Wen Hsaio, K. Chen, A study of project scheduling optimization using Tabu Search algorithm, Engineering Applications of Artificial Intelligence 21 (2008) 1101-1112.

[21] V. Valls, M.S. Quintailla, F. Ballestin, Resource-constrained project scheduling: A critical reordering heuristic, European Journal of Operational Research 149 (2003) 282-301.

[22] V. Valls, F. Ballestin, M.S. Quintanilla, Justification and RCPSP: A technique that pays, European Journal of Operational Research 165 (2005) 375-386.

[23] H. Zhang, X. Li, H. Li, F. Huang,"Particle swarm optimization-based schemes for resource-constrained project scheduling ", Automation in construction 14 (2005) 393-404.

[24] R.M. Chen, C,L, Wu, C.M. Wang, Sh.T. Lo, "Using novel particle swarn optimization scheme to solve resource-constrained scheduling problem in PSPLIB ", Expert Systems with Applications, Volume 37. Issue 3, 15 March, 2010, pp. 1899-1910.

[25] A. Ahmadi-Javid, P. Hooshangi-Tabrizi, An Anarchic Society Optimization Algorithm for a Flow-Shop Scheduling Problem with Multiple Transporters between Successive Machines, Proceedings of the 2012 International Conference Industrial Engineering and Operations Management Istanbul, Turkey, July 3-6, 2012.

[26] J.Kennedy and R. Eberhart, "Particle swarn optimization", Proceedings of the IEEE International Conference on Neural Networks (Perth, Australia) 1942-1948, 1995.

[27] Kolisch, R. and A. Sprecher (1996), PSPLIB - A project scheduling library, European Journal of Operational Research,Vol. 96, pp. 205--216.

[28] Taguchi, G., 1986. Introduction to quality engineering. White Plains: Asian Productivity Organization/UNIPUB.

[29] R. Kolisch und S. Hartmann (2006): Experimental Investigation of Heuristics for Resource-Constrained Project Scheduling: An Update, European Journal of Operational Research 174, 23-37, 2006.