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GENETIC ALGORITHM OPTIMIZATION OF MULTIPLE RESOURCES FOR MULTI-PROJECTS

SARAH FOTOUH and A. SAMER EZELDIN

Construction Engineering Dept, The American University in Cairo, Cairo, Egypt

Optimization of resources is very important in all construction projects. Project managers have to face problems regarding management of cost, time and available resources for single projects. This is more challenging when managing multiple projects. Most of the recent studies focused on optimization of resources for a single project, or a single resource. This paper presents a numerical model of multiple resources optimization for multiple projects using Genetic Algorithm. Most of the companies in the construction industry optimize the resources for single projects only. However, with the presence of several mega projects in several developing countries running at the same time, there is a need for a model to enhance the efficiency of available resources, and decreases the fluctuation as much as possible and try to maximize the use of the available pool of resources. The proposed model is user friendly, and it can optimize up to nine resources in three different projects running at the same time. The model is used on the identified critical resources. It calculates the cost of each resource, minimize the cost of extra resources as much as possible and generate the schedule of each project within a selected overall program.

Keywords: Construction management, Resource leveling, Cost optimization, Modeling.

1 INTRODUCTION

Project management is mainly concerned with coordination and integration between activities using the available pool of resources. Managing multiple projects (MP) is usually more challenging, as the projects manager has greater responsibilities and have to maximize the efficiency of resources (Belay *et al*. 2016).

Resources management is one of the most challenging problems that face any project manager. In the literature, there have been many studies that tried to solve this problem using heuristic methods and meta-heuristic methods (Leu *et al.* 1999, Zhao *et al.* 2006, Alsayegh *et al.* 2012). Most of them were focused on decreasing the fluctuation of using the resources, without considering the different costs of each resource into the equation.

All of the studies addressed resource leveling compared their results of GA models with Heuristics models and all of them proved that GA was more flexible and gave better results for single project (Doulabi *et al*. 2010, Ponz-Tienda *et al*. 2013). Most of GA studies focused on three aspects in resource leveling: (1) levelling of a single resource in a single project, (2) levelling of multiple resources for a single project, (3) levelling of single resource for multiple projects. Few of the studies addressed focused on how to level multiple resources within a company's entire profile, not only within a specific project using fuzzy logic (Iyer *et al.* 2015, Tran *et al.* 2016). This paper utilizes a GA based model because the literature has indicated that it provides better results in single projects. The proposed model will study resource leveling of multiple resources for a multi-project management, taking into consideration maximum pool of resources available and time constraints. The maximum total number of resources to be levelled in the model is 9 resources.

The resources are divided into three categories; namely (i) Human resources: HR1, HR2, HR3, (ii) Equipment resources: ER1, ER2, ER3 and (iii) Material resources: MR1, MR2, MR3. Each category has three different resources. The resources to be included in the model should be the resources that have the highest effect on the total cost of the project. The model is tested on three different projects running simultaneously, and they share the nine resources to be levelled.

2 METHODOLOGY

2.1 Model's Genetic Algorithm

The model in this study is Genetic Algorithm. It consists basically of an initial population that evolves through a number of iterations. The outcome solution is called *Chromosome* and is represented by set of integer values called *Genes.*

The initial population is generated randomly, then the fitness is calculated for all possible solutions and the following operators are performed (1) Reproduction operator, (2) Crossover operator, (3) Mutation Operator.

This model's population is the number of days to be shifted for each non-critical activity. Of course, the critical path may change after each iteration, but the total duration of the project remains the same.

The quality of individuals (feasible solutions) is evaluated and ranked using a fitness function to minimize the total cost of resources.

2.2 Model's Input

The user has to input the following data for the model to be executed:

(i) The predecessors of each activity.

(ii) The start date of each project.

(iii) The resources needed for each activity.

(iv) The duration of each activity.

(v) Pool available for each resource.

(vi) Cost of resources within the pool.

(vii) Cost of resources that is above the pool limit.

2.3 Model's Constraints

The model has two types of constraints: (a) hard, (b) soft. The hard constraint, it cannot be broken, while the soft constraint can be broken with a certain penalty.

In this model, the hard constraints are the deadlines for each project while the soft constraint is the pool of available resources. If the model cannot reach an optimum solution that all the resources needed are within the pool limit, then an additional cost will be added depending on which resources is exceeding the pool limit and its associated cost. The model will automatically select the resource with the least additional cost instead of the resource with the higher cost to minimize the cost as much as possible.

2.4 Fitness Function

The fitness function or the objective function is to minimize the total extra cost of resources required greater than the available pool and is represented by the following Eq. (1):

$$\sum_{i=1}^{3} EHRi * ECHRi + EERi * ECERi + EMRi * ECMRi \tag{1}$$

where:

EHR: Extra Human Resources

ECHR: Extra Cost of Human Resources

EER: Extra Equipment Resources

ECER: Extra Cost of Equipment Resources

EMR: Extra Material Resources

ECMR: Extra Cost of Material Resources

3 MODEL’S OUTPUT RESULTS

3.1 Updated Schedule of Each Project

For each project in the portfolio, a base schedule will be generated as in Figure 1 and updated schedule will be generated after optimizing the cost of the resources as in Figure 2.

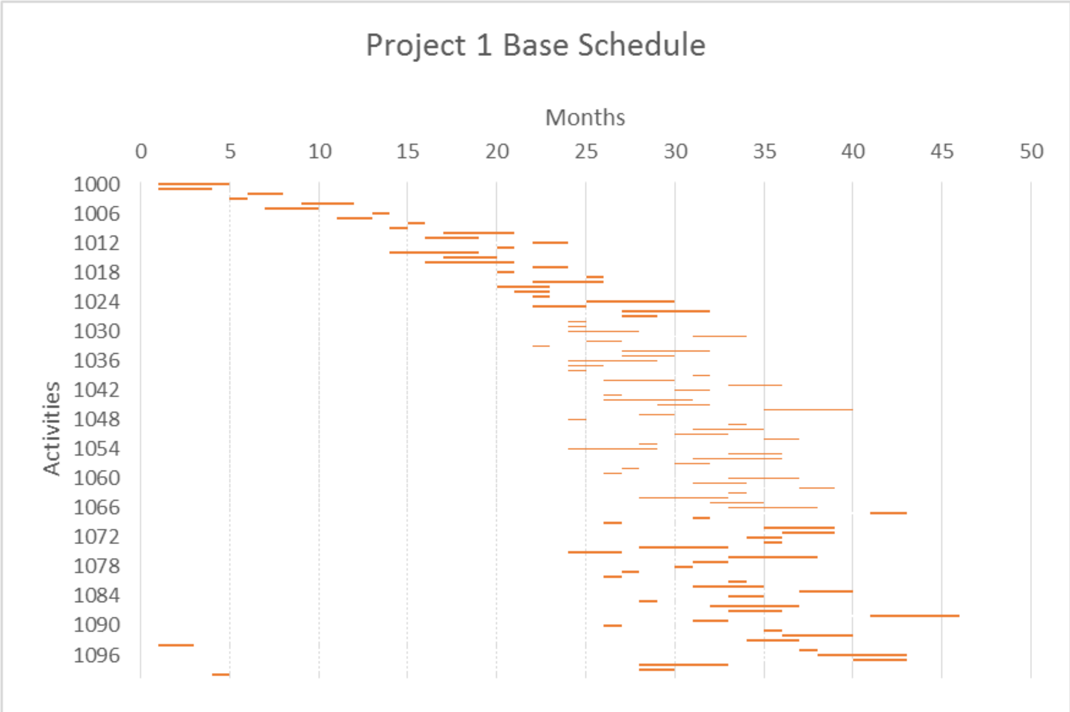

Figure 1. Sample of base schedule for Project 1.

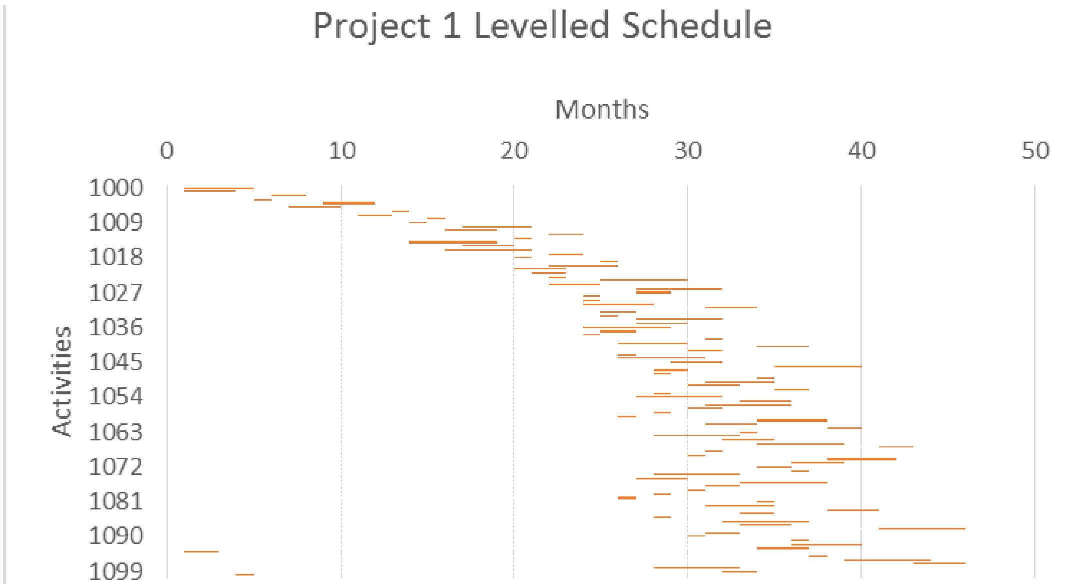

Figure 2. Sample of updated schedule for Project 1.

3.2 Resources Histogram

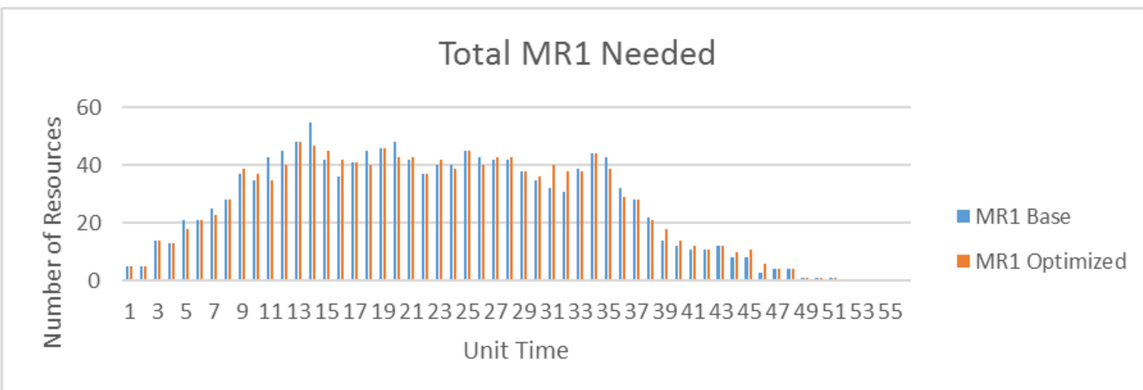

Figure 3. Sample of resources needed histogram.

As seen in Figure 3, MR1 maximum required per unit time is reduces to meet the pool level, which was in this example 10% less.

3.3 Extra Increase in Resources Cost

Decreasing the pool of resources by the following percentage of the maximum resources needed created a sensitivity analysis: (i) 10%, (ii) 15%, (iii) 20%, (iv) 25%. As mentioned before, each resource has two different cost: (1) Cost within the pool limit, (2) Cost when exceeding the pool limit. In the sensitivity analysis, we increased the cost of the resources exceeding the pool limit by the following percentages from the original cost within the pool limit; (i) 10%, (ii) 15%, (iii) 20%, (iv) 25%, (v) 30%. There was a significant decrease in the cost of the extra resources. Table 1 shows the extra cost needed before optimization, while Table 2 shows the extra cost needed after optimization.

Table 1. Base schedule extra cost of resources needed.

Base Extra Cost of Resources					
Pool	Extra Resources Increase in Price				
	B10%	B15%	B20%	B25%	B30%
-10%	7,430	8,905	14,860	18,575	22,290
-15%	18,451	27,676	36,902	46,127	55,352
-20%	37,924	56,886	75,848	94,810	113,772
-25%	77,426	116,139	154,853	193,566	232,279

Table 2. Optimized schedule extra cost of resources needed.

Optimized Extra Cost of Resources					
Pool	Extra Resources Increase in Price				
	O10%	O15%	O20%	O25%	O30%
-10%	70	105	140	175	210
-15%	105	18,368	24,490	30,613	36,735
-20%	140	34,436	45,914	57,393	68,871
-25%	175	115,389	153,853	192,316	230,779

Figure 4 shows the graph of Tables 1 and 2; where "B" indicates Base Schedule and "O" indicates Optimized Schedule.

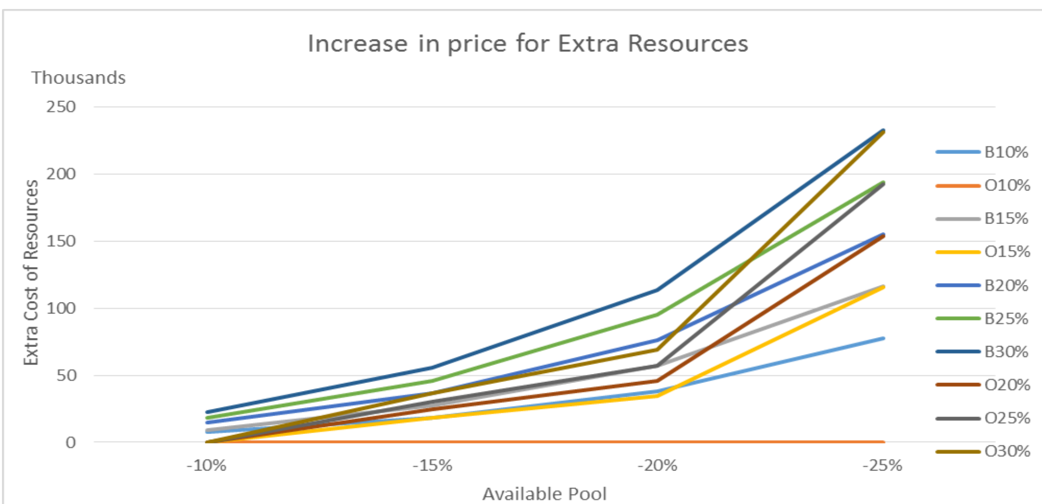

Figure 4. Increase in price of extra resources needed in Base Schedule and Optimized Schedule with different increase in the cost of the resources.

4 CONCLUSIONS

In the literature, most of the studies were on levelling multiple resources for a single project or leveling single resource for multiple projects without taking into consideration the cost. This study was on levelling multiple resources for multiple projects and minimizing the cost of the resources was the target. The model generates base schedule and an updated schedule for every project in the portfolio program. Also, it shows the resources needed in each period of time, and how much associated extra cost for each resource. The results showed that the cost of extra resources needed has decreased after optimization. This model would benefit the multiple-projects manager on how to utilize the available resources efficiently on the different projects and to minimize additional cost.

References

Alsayegh, H., and Moncer, H., Hybrid Meta-Heuristic Methods for the Multi-Resource Leveling Problem with Activity Splitting, *Automation in Construction*, 27, 89-98. 2012.

Belay, A. M., Torp, O., and Thodesen, C., Managing Concurrent Construction Projects Using Knowledge Management and Set-based Thinking, *Procedia Engineering,* 164, 235-42, 2016.

Doulabi, H. H., Seifi, S.,and Shariat, A., S. Y. (2010). Efficient Hybrid Genetic Algorithm for Resource Leveling via Activity Splitting, *Journal of Construction Engineering and Management,* 137(2), 137-146, 2010.

Iyer, P., Yuxin, L., Farnaz, S., and Brennan, R. W., A Fuzzy-Logic Based Resource Levelling Optimisation Tool, *IFAC-PapersOnLine* 48.3, 1942-947, 2015.

Leu, S. S., Yang, C. H., and Huang, J. C., Resource Leveling in Construction by Genetic Algorithm-based Optimization and Its Decision Support System Application, *Automation in Construction,* 10.1, 27-41, 2000.

Ponz-Tienda, J. L., Yepes, V., Pellicer, E., and Moreno-Flores, J., The Resource Leveling Problem with Multiple Resources using an Adaptive Genetic Algorithm, *Automation in Construction,* 29, 161-72, 2013.

Tran, D. H., Cheng, M. Y., and Pham, A. D., Using Fuzzy Clustering Chaotic-based Differential Evolution to Solve Multiple Resources Leveling in the Multiple Projects Scheduling Problem, *Alexandria Engineering Journal*, 55.2, 1541-552, 2016.

Zhao, S. L., Liu, Y., Zhao, H. M., and Zhou, R. L., GA-Based Resource Leveling Optimization for Construction Project, *2006 International Conference on Machine Learning and Cybernetics*, n. pag., 2006.