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COST OPTIMIZATION OF MULTIPLE RESOURCES ALLOCATION FOR MULTI-PROJECTS

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As the construction industry grows year by year, optimization of resources is becoming essential to reduce their required number, their costs and as a consequence the total cost of the project. Project managers have to face problems regarding management of cost, time, and available resources for single projects. What is more challenging is to optimize the available resources for multiple projects, which would result in appreciable savings. Most of the companies in the construction industry; commonly; optimize the resources for single project. However, with the presence of several mega projects in many developing countries running at the same time, there is a need for a model to enhance the efficiency of available resources among multiple simultaneous projects. This paper discusses a numerical model of cost optimization and allocation of up to nine resources for up to three projects for a given company, taking into consideration the transportation of resources from one project to another and the cost of unused resources. The model was developed using a genetic algorithm, and it is used on the identified critical resources. It calculates the cost of each resource, minimizes the cost of extra resources, cost of unused resources, and generates the schedule of each project within a selected overall program.

Keywords: Construction management, Genetic algorithm, Modeling, Multiple projects.

1 INTRODUCTION

Construction industry is becoming more sophisticated every day, and there is usually deficiency in the utilization of resources. Multi-national companies face this problem more often as they might have several mega projects running at the same period of time. Therefore, such companies have to utilize available resources efficiently to cover all its projects, and minimize the cost of any extra resources needed from outside the company.

1.1 Managing Multiple Projects

In multi-national companies, projects need to be viewed as an integrated portfolio rather than separate projects. In managing multiple projects, project managers are required to maintain control over different types of construction projects, balance conflicting requirements of resources and coordinate the project portfolio to ensure the optimum outcome for the organization is achieved (Dooley *et al.* 2005).

The main challenges that have to be addressed when managing multiple are:

- Projects are overlapping with other projects and day-to-day operations, sharing common deliverables, resources, information or technology across those overlapping projects.
- Prioritization of resources on daily basis over all running projects.

- Meeting the deadlines of the projects, which contribute to the overall development objectives of the parent organization (Turner and Speiser 1992).

1.2 Resources Management

Resource management plays an important role in project management, in which the project manager tries to avoid unnecessary resources overload. There are three objective functions well established in the literature to cope with resource management (Rieck and Zimmermann 2015):

- The minimum moment has to be minimized (Harris 1973);
- The *total overload cost problem*, where costs are generated when the pool of a given resource is exceeded (Easa 1989);
- The *total adjustment cost problem*, where one is concerned with the minimization of the cumulative costs arising from increasing or decreasing the utilizations of resources (Bianco *et al.* 2016).

1.3 Previous Models

Many researches have been performed on resource levelling, with different approaches. Harris (1973) developed one of the earliest simple heuristic processes called the “Minimum Moment Algorithm” for the resource leveling problem. Later, Hiyassat (2000) modified Harris's process by taking into consideration the activities’ free float and the resources needed in the selection criteria.

In addition to the above exact formulations for the resource leveling problem, several authors proposed meta-heuristic procedures to generate near-optimal schedules. Many studies proposed a model based on genetic algorithm (GA) for resource scheduling that performs resource leveling along with resource allocation simultaneously (Aboul Fotouh and Ezeldin 2017, Jun and El-Rayes 2011). Another study proposed a GA based optimization system to minimize the weighted total deviations of resources' requirements (Leu *et al.* 2000). In 2011, a model was built for resource levelling by splitting the activities (Hariga and El-Sayegh 2011).

Recently in 2017, a multiple resources levelling and allocation model was made using genetic algorithm but not taking into consideration the cost of transportation of resources not the cost of unused resources (Aboul Fotouh 2017).

1.4 Objective

This paper generates a multi-objective genetic algorithm-based model for multiple resources levelling and allocation for multiple projects taking into consideration the following:

1- Relationships between the activities.
2- Cost of each resource within company.
3- Cost of each out-sourced resource.
4- Cost of transportation of resources.
5- Cost of unused resources.

This model is tested on three different over-lapping projects and nine different resources. The model can be adjusted to fit the needs of the project manager by increasing the number of projects and resources as desired.

2 METHODOLOGY

Evolutionary algorithms (EAs) are stochastic search methods that simulate the natural biological evolution and/or the social behavior of different species. Such algorithms have been developed to arrive at near-optimum solutions to large-scale optimization problems, when precision is not the highest priority and the optimal solution would be exhaustive or difficult to find (Elbeltagi *et al.* 2005).

The first evolutionary-based technique introduced in the literature was the genetic algorithms (GAs) (Elbeltagi *et al.* 2005). GAs were developed based on the Darwinian principle of the 'survival of the fittest' and the natural process of evolution through reproduction (Elbeltagi *et al.* 2005). It is a method for solving both constrained and unconstrained optimization problems by generating feasible solutions for optimization problems by natural evolution, such as mutation, selection, and crossover (Elbeltagi *et al.* 2005).

2.1 Model's Input

The user has to input some data;

- The start date of each project.
- The predecessors of each activity.
- Duration of each activity.
- The number of resources needed by each activity.
- The number available of each resource (Pool of available resources).
- The cost of each extra resources needed.
- The transportation cost of each resource.
- Cost of unused resources

2.2 Model's Development

2.2.1 The Model's objective function (fitness function) is shown in Eq. (1):

$$Min \sum_{i}^{1} ECR + TC + CUR \tag{1}$$

Where;

- "ECR" is the Extra Cost of Resources,
- "TC" is the Transportation Cost of resources,
- "CUR" is the Cost of Unused Resources
- "i" is the number of projects.

2.2.2 Model's variable

The variable cells in this model is the number of days needed to shift each activity to reach the minimum cost of extra resources needed taking into consideration the transportation cost. These variables will be added to the start date, so that the activity will be shifted by the number written in the variable cells.

2.2.3 Model's constraints

This model has two types of constraints:

Hard Constraints: These are the constraints that the model cannot break, in this model it is the deadline of each project. This means the model cannot extend the duration of any project and only able to use the available float for each activity (Eq. (2)).

$$Max.\ of\ FDP \leq DLP \tag{2}$$

Where,

- FDA is the Finish Date of Project
- DLP is the Deadline of Project

Soft Constraints: These are the constraints that the model will try to abide by it, but if it cannot, then they can ignore it but add a certain penalty. In this model the soft constraints are the maximum number of resources needed per period of time should be less than the pool of available resources. If the model cannot reach a near optimum solution that all the resources needed are within the pool limit, then an additional cost will be added depending on which resource 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 (Eq. (3)).

$$max\ NRT \leq Pool\ of\ available\ resources \tag{3}$$

Where,

- NRT is the number of resources needed per unit time.

2.3 Model's Outputs

The model generates the following outputs;

I- Updated schedule of each project.
II- Extra cost of extra resources such as in Figure 1.
III- Cost of resources' transportation from one project to another such as in Figure 1.
IV- Cost of un-used resources such as in Figure 1.
V- Histograms of resources needed per unit time before and after optimization such as in Figure 2.

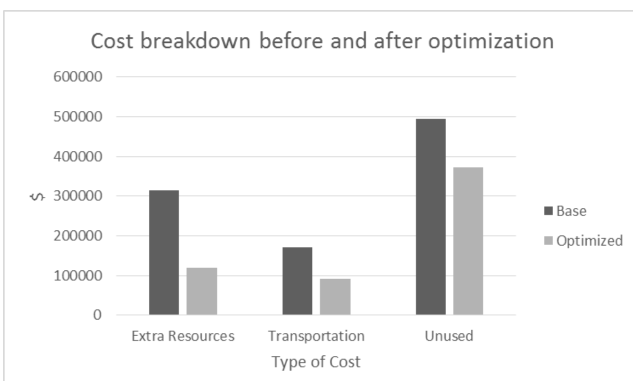

Figure 1. Cost breakdown before and after optimization.

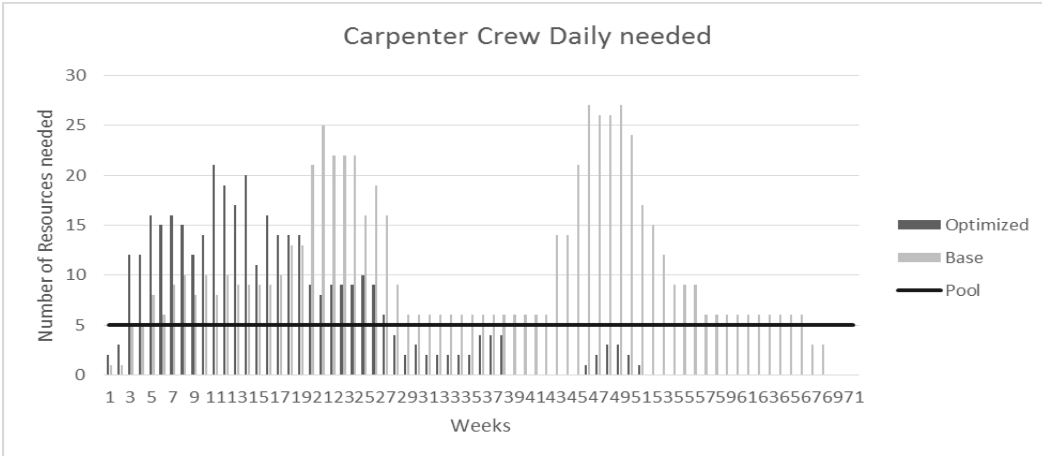

Figure 2. Sample of resources needed per unit time before and after optimization.

3 RESULTS AND DISCUSSION

The model is able to reduce the cost of extra resources, transportation of resources and the cost unused resources for all three projects and nine resources. In these specific data the cost of extra resources needed was reduced the most in comparison with cost of un-used resources and transportation cost as shown in Figure 1.

Figure 2 shows a sample of one resource's (Carpenter) bar chart before and after optimization that is in the model. Figure 2 shows that the extra resources needed at the end of the projects were shifted to the beginning of the projects.

Figure 3 shows that the total cost of resources decreased by almost 40% for all three projects together using nine resources.

The results obtained shows how the model succeeded to decrease the cost of projects and eventually increase the company's mark-up. This model is best to use in the scheduling process and resource allocation, but it can also be used after the start-up of the projects to be able to utilize efficiently the use of available resources and maintaining the deadlines of the projects.

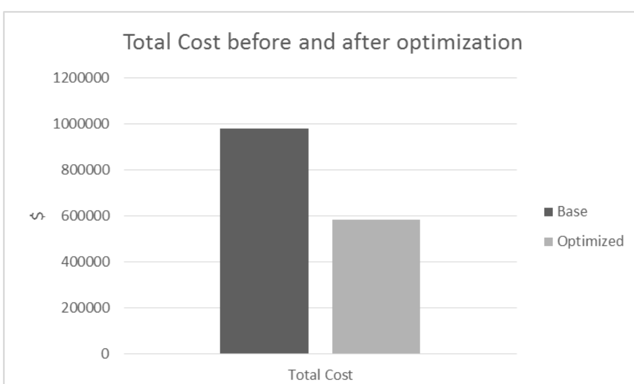

Figure 3. Total Cost of Resources before and after optimization.

4 CONCLUSION

This paper discusses the allocation of resources for multiple projects and multiple resources, taking into consideration the cost of extra resources needed, the cost of unused resources, and the transportation of resources from one project to another. A genetic algorithm-based model was built, and it was able to reduce all three types of costs, which at the end can save the company a large percentage of the total cost of resources. The results generated by the model indicate a good validation of the model.

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