24th International Symposium on Automation & Robotics in Construction (ISARC 2007)
Construction Automation Group, I.I.T. Madras

OPTIMIZATION OF CONTRACTOR' S S-CURVE

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ABSTRACT

While striving to satisfy owners' needs, to minimize construction cost and pursue the maximum profits under a fixed contract amount and duration is always one of the most important objectives of contractors. Only a sound work plan, which includes optimal working sequences and perfect timing for executing each individual activity, can enhance the work efficiency and enable contractors to fulfill the contract at the lowest cost. This research develops a contractors' optimal S-curve model, which can optimize the allocation of resources along the project schedule, under major assumptions that for a specific task, there is a trade-off relationship in terms of work productivity between two different types of resources and there are costs for resource mobilization and demobilization. The S-curve established can be used as a baseline to measure the extra cost caused by changes and disruptions in the course of construction and the overall project performance at the completion of the project.

KEYWORDS

S-Curve, Optimization, Resource Allocation, Genetic Algorithms

1. INTRODUCTION

Conventionally, S-curve has long been adopted as an important baseline in project control system to monitor the project performance. Most owners take it as part of contractual documents to control the contractor's progress, while contractors use it to manage progress and cash flow. Projects often encounter changes and disruptions in the course of construction. If the disruptions and changes occur on the critical path, contractors can easily claim for the time delay and ask for an equitable adjustment for the damage arising thereof. However, if the disruptions and changes are not on the critical path and will not cause project delay, it would be difficult for contractors to claim for price adjustment due to the lack of a baseline for identifying the damages. Traditional network scheduling techniques such as CPM and PERT have introduced two S-curves; one is the early start S-curve and the other late start S-curve, but neither can be considered as a baseline due to their natural limitations. Many previous studies have attempted to find solutions. However, not a single model, which has been established and broadly recognized, is capable of identifying an optimal S-curve from the contractors' perspective. This paper aims to fill this gap.

2. LITERATURE REVIEW

Numerous studies have been made on the construction schedule. Plentiful results are found on areas of; (1) resource allocation, (2) resource leveling, and (3) time-cost trade-off by using various technical, such as linear programming, dynamic programming, expert systems, neural networks, and genetic algorithms.[6], [7], [9], [12], [13], [15]. And some researches used historical data and statistical method to fit or forecast the S-curves, [1-5], [8], [10], [11], [14].

However, the concept of minimizing construction cost, while considering the costs for resources mobilization and demobilization and the trade-off relationship between different resources, has drown little attention of previous researchers.

3. RESEARCH DESIGN

By using genetic algorithms technique, this research aims to build a model, which can be used to calculate and identify early start, late start, and the contractors' optimal S-curve.

3.1 Assumptions

This research is designed under the following assumptions:

1. Projects are contracted under a fixed duration, which is considered as an optimal duration for executing the project. The issue of Time-cost trade-off is not included in this research.
2. Projects are performed in optimal working sequences based on a fixed duration. The optimization process doesn't change the relationship between activities.
3. There is an ideal resource arrangement for each activity before the optimization process. The workload in each activity will not change during the optimization process.
4. For a specific task, there is a trade-off relationship in terms of work productivity between any two different types of resources.
5. There are unlimited resources available for the projects and the costs of the resources mobilization and demobilization shall be charged to the contractors.

3.2 Genetic Algorithms

Genetic algorithms mimic Darwinian principles of natural selection by creating an environment where hundreds of possible solutions to a problem can compete with one another and only the "fittest" survive. Just as in biological evolution, each solution can pass along its good "genes" through "offspring" solutions so that the entire population of solutions will continue to evolve better solutions.

3.3 Objective Function

Each activity (activity k, k = 1---n) contains several types of tasks (task I, I = 1---n), each tasks need several types of resources (Rj, j = 1---n), each resource consists of several gene cells, and the cell value is designed between 0 and 1. The chromosome for each activity is as shown in figure 1.

	Activity A									……	Total Float
	Task1				Type2				……		
Resource type →	R1	R2	R3	…..	R1	R2	R3	…..	……	……	
Gene value →	r11	r12	r13	…..	r21	r22	r23	…..	……		tf

Figure 1 Chormosome

In the model, R_j resource is the best suitable for the task i when i=j, but it can be replaced by other resources. The initial gene value rij is 1 when i=j, and rij is 0 when i≠j. While resource trade-off occurs, the gene value will be used to identify the replaceable resource quantity; for example, if R1 is replaced by R2 in the type1 task, resource quantity R2 can be express as below formula (1);

$$R2 = \frac{r12}{r11 + r12 + r13} \times R1_0 \times \frac{1}{PL} \quad \cdots\cdots\cdots (1)$$

$R1_0$ is the original resource quantity of R1 in the task1, and PL is meant for Productivity loss rate.

The objective function is as equation (2):

$$Min\{TC_g / TC_0\} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots.. (2)$$

While TC_0 is the total cost according to the early schedule plan, TC_g is the total cost after G.A. Optimization.

The optimization process starts from the early schedule and shifts the non-critical activities within the time span of total float.

4. APPLICATION

A project, which includes twenty activities, is used for the study. The durations and workloads of each activity, the unit price of each resource, and working sequences are as shown in Table 1.

The commercial software MS excel and MS project are adopted to analyze the project data and plot s curve. Genetic algorithms software Palisade Evolver is used to perform the optimization process.

4.1 Resource Trade-off

Based on the general chromosome model as describes in figure 1, each activity consists of three tasks and each task needs three types of resources. Therefore, in addition to the gene cell of the total float, each activity requires 10 genes to form the chromosome.

Table 1 Project Data

Activity	Duration (days)	Precedence	Total Float (days)	Workload		
				source require to finish the activ		
				R1	R2	R3
A	6		0	60	30	18
B	2		9	26	42	18
C	4	1	0	32	64	64
D	6	3	13	180	144	108
E	8	2	9	128	240	96
F	10	3	0	120	60	90
G	3	4	13	15	6	18
H	2	5	9	20	20	16
I	2	8	9	12	8	16
J	7	6	0	105	210	147
K	1	9	9	10	10	15
L	2	7	13	24	16	16
M	5	11	9	35	35	35
N	2	12	13	14	16	16
O	3	13	9	45	45	36
P	5	10	0	75	50	75
Q	6	15	9	180	240	252
R	2	14	13	20	12	12
S	6	16	0	72	144	216
T	2	17,19,18	0	4	24	8
Total Resource required				1177	1416	1272
PS:Unit price of resources R1=1000,R2=1200/day,R3=1300/day						

The unit prices of resources R1, R2, R3 are 1000, 1200, and 1300 respectively. Different types of resources are assumed replaceable with productivity loss as table2; for example, if R1 is replaced by R2, the productivity will be reduced to 90%. And, the mobilization and demobilization costs are assumed 20% of the resource's unit price. When mobilization and demobilization costs are higher than the resources trade-off costs, the resources trade-off occurs.

4.2 Optimization Process

Since this model is set to focus on the optimization of cost without considering resource leveling, in consideration of the costs of resources and their mobilization and demobilization, the total cost calculated based on the early start schedule and late start schedule are 4,667,280 and 4,688,060 respectively. A near optimal cost, 4,640,540 is further obtained through imputing the total float and the trade off relation between resources. Three S curves, which are plotted based on the early start schedule, the late start schedule, and the optimal schedule, are shown in figure 2. That the optimal S curve positions between the early start S curve and late start S curve means the optimal schedule is reasonably ahead of the late schedule and behind the early schedule at a specific time. Furthermore, according to the comparison of resource utilization between the early start schedule and the optimal schedule in figure 3, the allocation of resources in the optimal schedule is much smoother than that in the early start schedule. It indicates that the cost minimization process simultaneously improve the allocation of resource.

Table 2 Productivity Loss Rate

	R1	R2	R3
R1	1.00	0.90	0.95
R2	0.80	1.00	0.90
R3	0.75	0.85	1.00

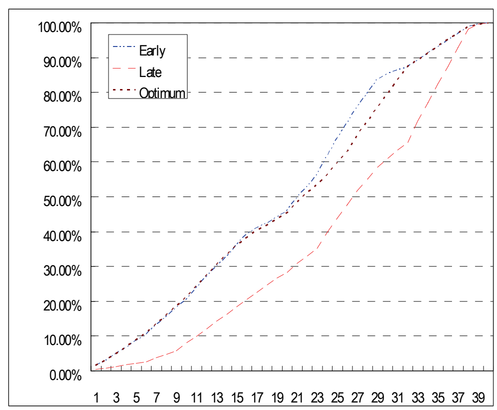

Figure 2 The Optimal S-Curve

5. CONCLUSIONS

Under the reasonable assumptions of the trade off relationships between different types of resources and the resources mobilization and demobilization costs, this research successfully proposes a contractors' S curve model, which can be used to obtain the lowest overall construction cost and identify the near optimal schedule including the optimal quantities for each resources and the timing of performing each activity. Furthermore, this model suggests that any disruptions of works in the course of construction will cause extra costs to contractors and contractors are entitled to claim for an equitable adjustment when the disruptions are not caused by the contractors.

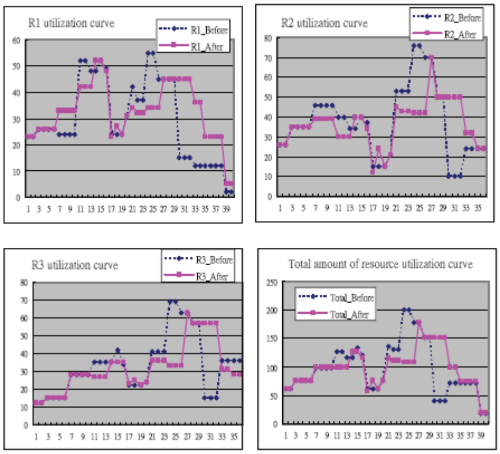

Figure 3 The Resource Leveling

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