Optimizing Construction Alternatives for Scheduling Repetitive Units

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Abstract: Efficient scheduling and resource management are the key factor to reduce construction project budget (e.g., labor cost, equipment cost, material cost, etc.). Resource-based line of balance (LOB) technique has been used to complement the limitations of existing time-driven scheduling techniques (e.g., critical-path method). Optimizing construction alternatives contributes to cost savings while honoring the project deadline. However, existing LOB scheduling is lack of identifying optimal resource combination. This study presents a method which identifies the optimal construction alternatives, hence achieving resource minimization in a repetitive construction by using genetic algorithm (GA). The method provides efficient planning tool that enhances the usability of the system.

Keywords: Repetitive units, line of balance (LOB), construction alternative, resource minimization, genetic algorithm (GA).

I. Introduction

The line of balance (hereafter, LOB) has been widely used for effective schedule management on linear and/or repetitive construction project. The LOB is a resource oriented scheduling method that facilitates the diagrammatic representation for a production planning, and controls the progress to meet the project completion time. For sure, the existing LOB establishes an optimized scheduling that minimizes the resources allocation. It determines resources allocation plan that satisfies the project deadline given the project completion time. However, in a practical perspective, the amount of resources assigned to particular activities can be reduced while meeting the project completion time and cost compared to planed time and cost. The optimum resource allocation plan can be obtained by selecting a set of construction methods (namely, construction alternatives) (i.e., low cost-long period and high cost-short period methods) which deliver activities of a project. The construction alternatives selection is an important decision process because it directly affects the project completion time and cost. This study presents a method that establishes an optimum resource scheduling which may deliver a project with a minimum cost by considering the resource productivity rate and the project deadline bounded.

II. Literature Review

Network techniques (e.g., CPM, PERT, PDM, etc) have been widely used as a project planning tool in the construction scheduling community. However, the application of network techniques to repetitive projects has been criticized for the inability to maintain work continuity and resource handling. For this reason, alternative techniques known as linear scheduling methods (e.g., LOB, LSM, RSM, etc) have been developed in the previous two decades.

Reda (1990) introduced the repetitive project model (RPM) to incorporate time–cost trade-off analysis in scheduling. Suhail and Neale (1994) proposed a mathematical model for determining the number of crew to meet the project deadline. Maravas and Pantouvakis (2011) developed the fuzzy based RSMs (F-RSM) which enables to effectively deal with uncertainties inherent in a repetitive project. Moselhi and El-Rayes (1993) introduced a dynamic programming model which minimizes a project cost. Feng et al. (1997) developed an optimal time-cost trade-off system using genetic algorithm (GA). Hegazy (1999, 2002) evolved Feng et al.'s model so that it allows schedulers to investigate construction methods needed to achieve both the project deadline and to minimize project expense. However, these methods do not provide a mean to identify construction alternatives that require minimum resources utilization. For sure, they do not provide a plan which maximizes productivity. This paper presents a genetic algorithm based method that selects optimal construction alternative and performs resource minimization for linear and/or repetitive project.

Ⅲ. Research Methodology

The new method identifies a set of optimal construction alternatives by using a genetic algorithm and minimizes the input resources for improving the productivity of the project. The chromosome is a set of construction

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alternatives of each and every activity, that is, the combination of construction alternative as shown in Figure 1.

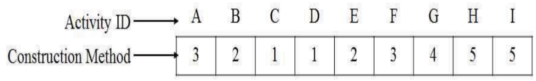

Figure 1. The chromosome of construction alternatives

The number written in the gene of the chromosome is the ID of the construction method. Each construction alternative has its own activity duration and cost. The set of construction alternatives is represented as a string. The chromosome of the network having nine activities is shown in Figure 1. The IDs of construction alternatives of each and every activity is [3,2,1,1,2,3,4,5,5]. Using the cost and duration of construction alternatives assigned to each activity, LOB calculation is performed. The method selects the construction alternative that requires the minimal cost and meets the bounded project deadline, and computes the number of crew required for each activity. It graphically illustrates the result including the relationship (preceding and succeeding) between all activities, and analyzes the resource minimization scheme. It makes sure if excessive resources are hired to each activity. The relationship between activities that can be used for minimizing the resource commitment is shown in Fig 2.

The strategy to minimize the resource commitment may be implemented only if it does not violate the precedence relationships between activities as shown in Figure 2. The activities in Figure 2(a) should have a finish-to-start relationship between activities in the first unit and the slope of the two lines that define activity B must be less than the slope of the preceding activity A and greater than the slope of the succeeding activity C; Three activities in Figure 2(b) should have a finish-to-start relationship between activities in the last unit and the slope of the lines that define activity Et must be greater than the slope of the preceding activity D and less than the slope of the succeeding activity F.

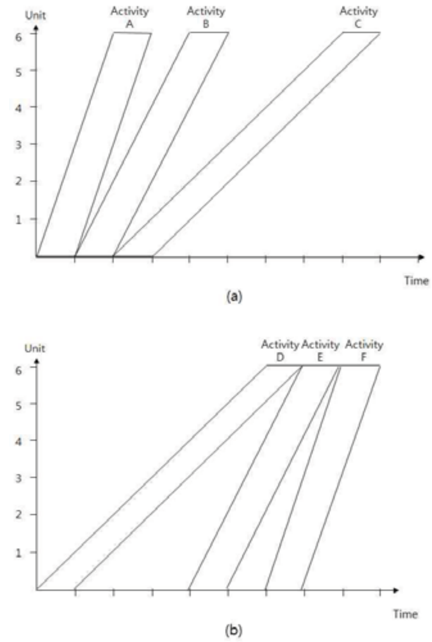

Figure 2. Relationship between activities for resource minimization

These two cases are considered as a resource minimization strategies. The activities such as activity B in Figure 2(a) and activity E in Figure 2(b) are candidates for the proposed strategy. The slope of the activity B is greater than the activity C, but less than the activity A. So, the productivity rate of activity B may be slow down as possible. This measure may not affect the total construction deadline. Therefore, the productivity rate of activity B may be adjusted to the same rate as that of the activity C in order to minimize resource input without changing the total project duration. The activity E in Figure 2(b) may be adjusted to the same rate as that of the activity D in Figure 2(a). After performing the resource minimization strategy, the total project cost is calculated using the information given in Table 1.

Table 1 . Information of the Construction Alternative

Activity	Predecessor	Cost1 ($)	Duration1 (day)	Cost2 ($)	Duration2 (day)	Cost3 ($)	Duration3 (day)	Cost4 ($)	Duration4 (day)	Cost5 ($)	Duration5 (day)
A	-	1,200	24	1,500	21	1,900	16	2,150	15	2,400	14
B	-	1,000	25	1,500	23	1,800	20	2,400	18	3,000	15
C	-	3,200	33	4,000	22	4,500	15				
D	-	30,000	20	35,000	16	45,000	12				
E	A	10,000	30	15,000	28	17,500	24	20,000	22		
F	A	18,000	24	32,000	18	40,000	14				
G	E	22,000	18	24,000	15	30,000	9				
H	F	120	24	208	21	200	16	215	15	220	14
I	F	100	25	150	23	180	20	240	18	300	15
J	B,F	320	33	400	22	450	15				
K	H	300	20	350	16	450	12				
L	E,H,I,J	1,000	30	1,500	28	1,750	24	2,000	22		
M	C	1,800	24	3,200	18	4,000	14				
N	D,J	2,200	18	2,400	15	3,000	9				
O	L	3,500	16	4,500	12						
P	M N	1,000	30	1,500	28	1,750	24	2,000	22	3,000	20
Q	K,N,O	1,800	24	3,200	18	4,000	14				
R	P,Q	2,200	18	2,400	15	3,000	9				

Ⅳ. CASE STUDY

A network adopted from Feng et al. (1997) is used to demonstrate the proposed method. The contract term is 210 days and the construction alternatives along with activity durations are presented in Table 1. Table 2 presents the number of crews required, the number of actual crew, and the actual productivity rate (slope) calculated by LOB computation. It identifies the set of construction alternatives that produce minimal resource usage.

Table 2. The result of GA-LOB Calculation

Activity	Construction Alternative	Actual Crew	Actual Rate	Cost	Duration
A	5	2	0.1429	2,400	14
B	1	3	0.1200	1,800	20
C	3	1	0.0667	4,500	15
D	2	1	0.0625	35,000	16
E	1	3	0.1000	10,000	30
F	1	3	0.1250	18,000	24
G	3	1	0.1111	30,000	9
H	1	2	0.0833	120	24
I	5	2	0.1333	300	15
J	1	4	0.1212	320	33
K	3	1	0.0833	450	12
L	3	3	0.1000	1,750	24
M	1	2	0.0833	1,800	24
N	3	1	0.1111	3,000	9
O	1	2	0.1250	3,500	16
P	2	3	0.1071	1,500	28
Q	2	2	0.1111	3,200	18
R	3	1	0.1111	3,000	9

The original construction alternative combinations, the construction alternative identified by genetic algorithm, the resource minimization strategy are shown in (a), (b), and (c) of Figure 3, respectively. When the original alternative construction is adapted, the project duration and the project cost are 225 days and $ 551,060, respectively. When the GA-LOB operation is applied, the optimal project duration and the optimal project cost are 215 days and $ 411,620, respectively. It was confirmed that the project duration and the project cost may be shortened by 10 days and may be saved by $ 139,440, respectively.

Ⅴ. CONCLUSION

This research develops the method for selecting the optimal set of construction alternative to minimize resource usage by using genetic algorithm. It contributes to reduce resources by identifying the logical dependency of the activity. In addition, it may identify the schedule to complete the project at the lowest cost possible. It may be an effective decision-making support method to manage resource for the linear construction project.

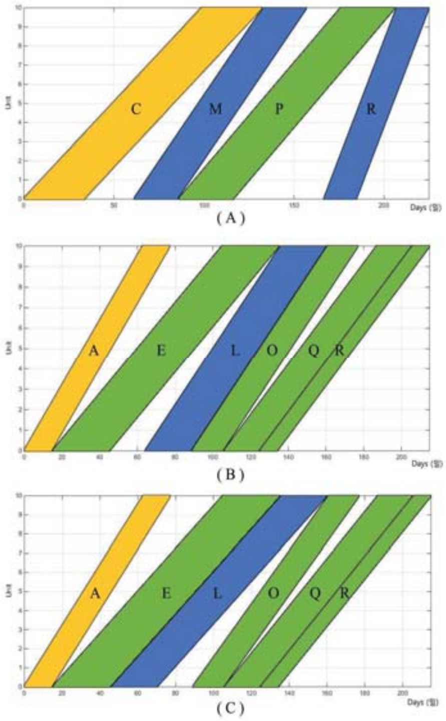

Figure 3. The LOB Schedule Step-by-Step Graph

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