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Stochastic Scheduling for Repetitive Construction Projects

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Abstract: Line of Balance (LOB) method is suitable to schedule construction projects composed of repetitive activities. Since existing LOB based repetitive project scheduling methods are deterministic, they do not lend themselves to handle uncertainties involved in repetitive construction process. Indeed, existing LOB scheduling dose not handle variability of project performance indicators. In order to bridge the gap between reality and estimation, this study provides a stochastic LOB based scheduling method that allows schedulers for effectively dealing with the uncertainties of a construction project performance. The proposed method retrieves an appropriate probability distribution function (PDF) concerning project completion times, and determines favorable start times of activities. A case study is demonstrated to verify and validate the capability of the proposed method in a repetitive construction project planning.

Keywords: Repetitive units, Line of Balance (LOB), stochastic scheduling, genetic algorithm(GA)

I. INTRODUCTION

The common objectives of a project are satisfying the bounded deadline, allocating appropriate resources, and avoiding a budget overrun, etc. The relationship among these objectives may be complicated. To establishing a reliable project schedule by considering the complexity among these requirements has been a challenging issue in a construction industry.

Projects having repetitive activities or units have been increased due to the increasing complexity and hugeness of construction projects. Indeed, the application of the repetitive project scheduling technique is essential for a successful project management in recent years.

Typical scheduling methods for a project network (i.e., critical path method (CPM)) is capable of scheduling repetitive projects (Hegazy and Wassef 2001; Arditi et al. 2002); Line-of-balance (LOB) is dependent on linear scheduling method in repetitive projects demanding for the consideration of the continuity of each and every activity (Iulian Trofin, 2004). Corresponding to the requirements for the repetitive project scheduling approach, various researches have been carried out. The uncertainty relative to activity durations, as the nature of construction project, has been always existed. (Hua Ke, 2005). However, scheduling methods based on LOB are deterministic.

Natural rhythm is a main principle in LOB method. However, the repetitive project scheduling is limited in considering both “natural rhythm” principle and the concept of uncertainty involved in activity durations. To complement this issue, this study presents an advanced stochastic method which allows LOB scheduling by applying the principle of natural rhythm.

II. LITERATURE REVIEW

The application of the LOB to a project network is relatively difficult. That is why many researchers have tried to integrate CPM and LOB method (Suhail and Neale, 1994; Ammar, 2012). Damci et al. (2013) proposed a resources leveling method with GA (Genetic Algorithm) considering natural rhythm. Especially, a few researchers developed a CPM/LOB oriented scheduling method for satisfying deadline constraint as follows: SYRUS (System for Repetitive Unit Scheduling) (Arditi and Psarros, 1987), RUSS (Repetitive Unit Scheduling System) (Ariditi et al., 2002), CHRISS (Computerized High Rise Integrated Scheduling System) (Arditi et al., 2002) and ALISS (Advanced Linear Scheduling System) (Tokdemir et al., 2006). Dolabi et al. (2014) developed SHLOB (Search based Heuristic Line of balance) and compared the performances between SHLOB and RUSS. Noteworthy is that these existing LOB methods are deterministic. Maravas et al. (2010) introduced F-RSM (Fuzzy Repetitive Scheduling Method) considering the uncertainty of production rate. However, the uncertainty of production rate differs from stochastic activity duration.

III. STOCHASTIC LOB CONSIDERING NATURAL RHYTHM

The stochastic LOB method (SLOB) assumes that activity duration of a repetitive unit is a random variate of a probability distribution function (PDF). The existing LOB methods are based on a production rate. The activity duration of a unit may not be a fixed value. This study proposes an algorithm that achieves SLOB considering natural rhythm. The detailed calculation procedure for the proposed method is described as follows:

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- Step 1 - The number of crews for each activity is determined by executing GA using the chromosome shown in Table 1. The number of crews assigned to activity A is three in this case.

Table 1.
Chromosome defining the number of crews for each activity

Activity ID	A	B	C	D	E	F	G
N.Crew	3	5	6	4	2	2	4

- Step 2 – The deadline, a project completion time, is input by a user. The GA searches for minimum project completion cost (PCC) by adjusting gene within the deadline.
- Step 3.The start time of first crew at each unit is calculated as shown in Figure 1 which shows the allocation plan of crews engaged in each unit respectively. D_{ij} defines a duration required for i^{th} activity at j^{th} unit. D_{ij} varies by units. In detail, Crew 1 transfers to $j + N^{th}$ unit after finishing the activity of 1^{st} unit.

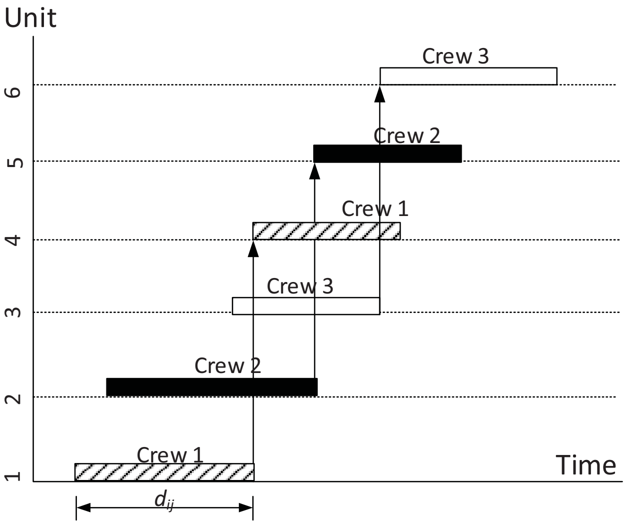

Figure 1. Crew allocation plan

- Step 4 – The start time of last crew is calculated by considering last unit one by one. As shown in Figure 1, Crew 3 commences at 6^{th} unit. In other words, the activity start time of last crew is determined by a way of reverse calculation. Unlike the way of computation of Crew 1, after determining start time at the 6^{th} unit, following start time of Crew 3 is reversely calculated at j-N^{th} unit.
- Step 5 – The start time of other crews are also calculated. Except for the Crews 1 and 3, constraints caused by the natural rhythm of Crew 2 are as follows: first, at 2^{nd} unit, start time of Crew 2 is not allow to be faster than one of Crew 1; second, at 5^{th} unit, finish time of Crew 2 is not allowed to be later than one of Crew 3. Then, start time of Crew 2 could be determined by satisfying natural rhythm.
- Step 6 – The buffers between activities are considered. After all start times of crew at each activity is obtained from previous steps, buffer times need to be calculated by considering relationship between predecessor and successor. At 1^{st} unit, the shortest delay exists between activities P and S. Buffers at rest of units are generated based on buffer time at 1^{st} unit while maintaining formation of crews as shown in Figure 2.).

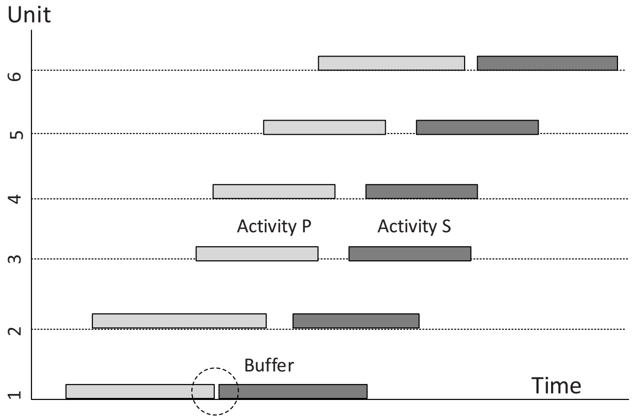

Figure 2. Buffers between predecessors and successors

- Step 7 - PCT and PCC are computed from Step 6. When PCT is longer than the deadline predefined by a user, delay cost is charged and accrued to PCC.

IV. CASE STUDY

The linear project case is demonstrated to verify the advanced LOB method. The contractual terms are as follows: the deadline is 315 days and the number of units is 12. It is assumed that durations of individual activities are dependent on triangular distributions as shown in Table 2. The number of crews available is constrained from 2 to 5. The labor costs per activities are shown in Table 2. The results of optimal project duration and cost are 314 days and $ 32,530, respectively, where the optimal number of crews was computed as [2, 4, 3, 4, 4, 3, 5]. Figure 3 presents an optimal resource allocation plan obtained by the proposed method.

Table 2. The information of case study project.

Activity ID	Min	Mode	Max	Cost ($)
A	8	10	12	20
B	28	30	32	50
C	22	24	26	60
D	30	32	34	50
E	33	36	38	40
F	25	28	30	50
G	38	40	42	20

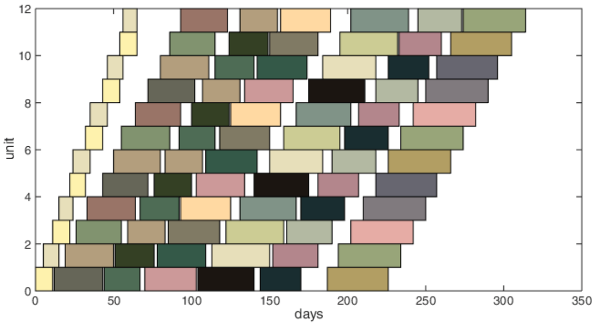

Figure 3. The LOB graph of case study project

V. CONCLUSION

This study proposes the stochastic method that determines the optimal number of crews at each activity and maintains natural rhythm by using GA while handling the uncertainty of activity durations. The proposed method facilitates retrieving practical resource allocation plan by taking into account project completion time and project completion cost.

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