International Conference on Architecture and Civil Engineering 2018

ISBN	978-81-933584-5-0
Website	www.coreconferences.com
Received	15 – January – 2018
Article ID	CoreConferences010

VOL	01
eMail	mail@coreconferences.com
Accepted	05 - February – 2018
eAID	CoreConferences.2018.010

Resource Leveling Considering Float Consumption Impact

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Abstract- *Resource levelling minimizes resource fluctuations by postpone the earliest start time (EST) of non-critical activities with corresponding floats. Float consumption for resource leveling may reduces the project completion probability. This paper presents a method to minimize the resource fluctuations with minimum impact of float consumption. A case study is presented to verify the validity and usability of the method.*

I. Introduction

The purpose of the resource leveling in a construction project is to reduce the project completion time (PCT) and the project completion cost (PPC) by reducing the hire, release and re-hire of resources (i.e., labor, equipment). Existing resource leveling studies have adopted a method of minimizing resource fluctuations by synchronizing the resource accumulation graph with the resource requirements (Essa, 1989; Senouci & Eldin 2004) and by making it closer to the bell-shape (Mattila and Abraham 1998; Yeniocak 2013).

Previous studies have achieved resource leveling by delaying the start time of activity within the float range (Keane and Caletka 2015). This resource leveling method does not affect the project completion time because it uses the float that exists in non-critical activities. However, the consumption of float due to the start time delay of activity increases the criticality index of the non-critical activities. The increase in the criticality index reduces the probability of project success due to the uncertainties of the construction project and unexpected risks. Therefore, scheduling for a successful project should ensure flexibility and sustainability of the employment status to cope with uncertainty.

In this study, we propose a resource leveling method that identifies the activities with little effect on the probability of project success, uses them for resource leveling, and identifes the start time combination of each activity considering the ratio of critical activities.

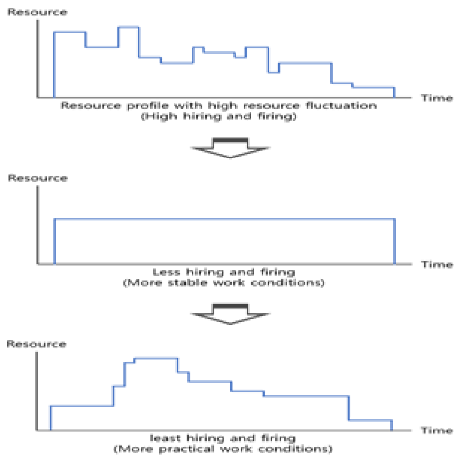

Figure 1. Resource accumulation graph

II. Methodology

The methodology minimizes the impact of float consumption and explores the activity start time combination to identify the optimal resource leveling plan. This system consists of the following four modules. (1) invoke schedule information in conjunction with the MS project, (2) implement a fitness function to achieve resource leveling considering the criticality index ratio, (3) to find the optimal activity start time combination, and (4) implemented as software integrated into MATLAB (ver. 2015b)
The detailed calculation steps are described as follows:

Step 1. Call up schedule data (activity ID, predecessor list, successor list, number of resources per day, activity duration, cost) from MS project.
Step 2. perform CPM operation.
Step 3. Store early start time, early finish time, late start time, and late finish time for each activity in the matrix.
Step 4. Calculate the project completion time (PCT).
Step 5. Identify non-critical activities.
Step 6. Define GA parameters [population size, crossing rate, mutation rate].
Step 7. Set GA end rule.
Step 8. Define the objective function [Release and Re-Hire index (RRH), weight (w1, w2)].
Step 9. Storage the critical activity.
Step 10. Sets the limit of the criticality index (CI).
Step 11. Identify critical activities.
Step 12. Replace the fitness function with the modified function.
Step 13. Define the limits of the main activity ratios.
Step 14. Create an initial population.
Step 15. Perform selection / intersection / mutation operations and compute chromosomal fitness values.
Step 16. Presents the calculation result.

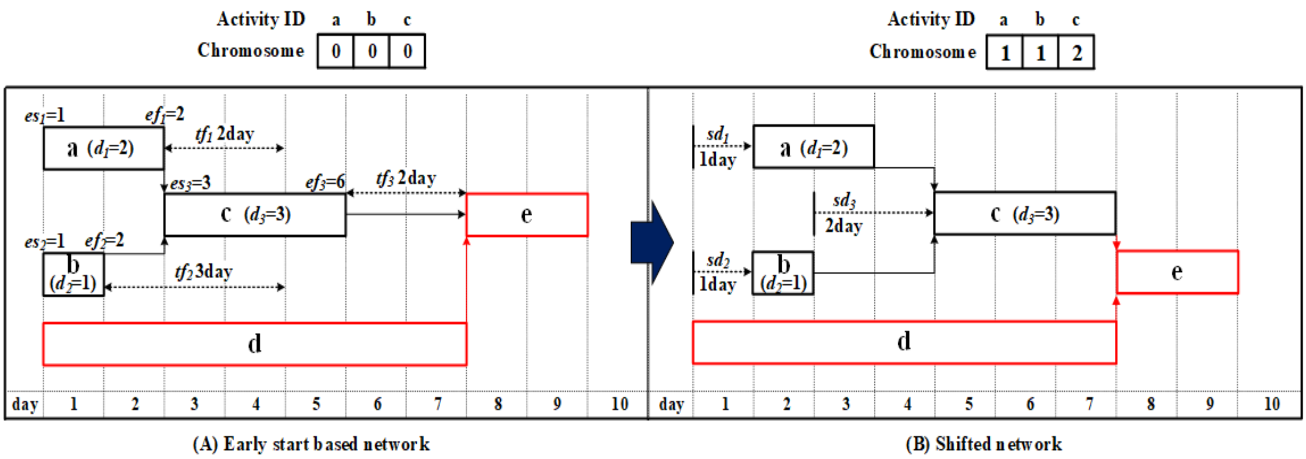

Figure 2. Chromosome & Example

Resource leveling is achieved by adjusting the start time of non-critical activities. The start time of the critical activities, maintains the original start time determined by the CPM operation. The chromosomes input for the GA operation are a set of days deliberately delayed from the originally scheduled earliest start time (es) of non-critical activities. Fig. 2 illustrates a network that is varied by gene expression and input gene values. The gene phenotype (e.g. [0, 0, 0]) in Fig.1 (A) means that the earliest start time of the non-critical activities (e.g. a, b, c) is equal to the originally scheduled time. On the other hand, the gene phenotype (e.g. [1, 1, 2]) in Fig.1 (B) shows that the earliest start time of non-critical activities (e.g. a, b, c) indicates deliberately delayed by 1, 1, and 2 days.

As the initial population is initialized with the near optimal solution, the GA search time is shortened and the reliability is improved. The genes of the early-age group are the set of shifted dates (sd), and these shifted dates are chosen considering the criticality index (CI), which is the probability of becoming the main process. Critical activities can change, because activity duration is volatile. Therefore, if a stochastic CPM calculation is performed to identify the main activity for each simulation run, a CI (e.g. a value between 0 and 100) is calculated. CI close to 100 is likely to be the main activity, and consuming float for these activities will reduce the project completion probability. Conversely, if the CI is close to 0, the probability of becoming a non-critical activity increases, and consuming the float of these activities has a relatively small impact on the project completion probability. Therefore, in order to reduce the effect of float consumption when performing resource leveling, the start time of activities with a high CI move to low probability, while the start time of activities with a low CI move to high probability. For example, if the float and CI of the activities are shown in Table 1, the activities with 0 (e.g. A, C, F, J, P and S) float are on the critical path, while the non-critical activities with some float (e.g. B, D, E, G, H, I, K, L, M, N, O, Q, R and T) are not on the critical path. Only the start time shifts of these non-critical activities are considered for resource leveling. The CI of D, G, H, and R of the non-critical activities are less than 10%, and they have less impact on the project completion probability than the other non-critical activities (e.g. B, E, K, L, M, N, O, Q, T). Thus, this methodology creates a population by preferentially adjusting the start times of D, G, H, and R activities.

Table 1. Criticality index and float

Activity ID	Total float (day)	Criticality index (%)
A	0	86.63
B	6	10.31
C	0	53.74
D	7	9.60
E	3	44.17
F	0	53.00
G	7	9.60
H	7	1.20
I	7	6.00
J	0	50.94
K	3	17.08
L	4	34.60
M	3	22.23
N	4	10.77
O	4	28.68
P	0	76.83
Q	4	26.20
R	6	2.97
S	0	78.57
T	4	26.20

III. Case Study

Using the network of Hegazy et al. (1999) (Fig. 3), verified the performance and effectiveness of this methodology. The project completion time (PCT) of this network is 32 days, and the critical path is A → C → F → J → P → S. The critical activities are B, D, E, G, H, I, K, L, M, N, O, Q, R and T and their float are [6, 7, 7, 3, 4, 3, 4, 4, 4, 6, 4]. Their start time is used to achieve resource leveling by moving within the allowable time range.

The system searched for the combination of the start time shift of non-critical activities as [6,7,3,0,2,2,3,0,3,0,0,2,0,0]. Cumulative resource graphs before resource leveling are shown by solid lines in Fig. 4, and it can be seen that hire, release, and re-hire are frequent occurrences. The cumulative resource graph of the resource leveling result of the methodology is shown in the dotted line in Fig. 4. This confirmed that optimum resource leveling options with a criticality index of 60% in the bell-shape can be determined.

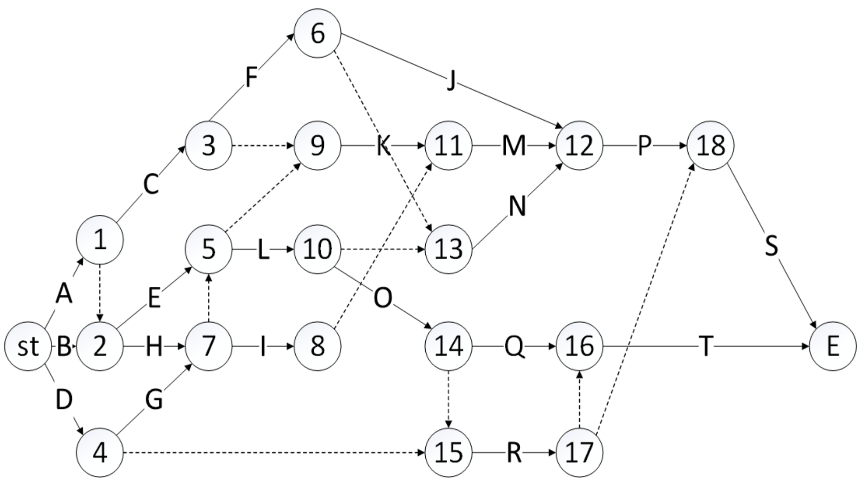

Figure 3. Case project network information

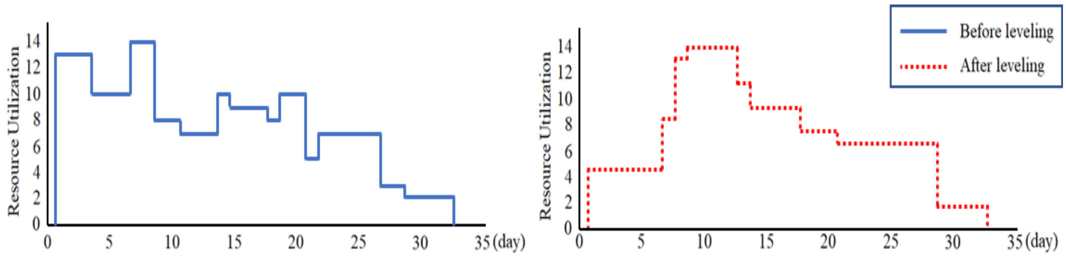

Figure 4. Resource profiles obtained before/after leveling

Table 2. Criticality index and float

Activity ID	Total float (day)	Shifting date	Remaining float (day)	CP & close-CP
A	0	0	0	*
B	6	**6**	0	*
C	0	0	0	*
D	7	**7**	0	*
E	3	**3**	0	*
F	0	0	0	*
G	7	**0**	7	
H	7	**2**	5	
I	7	**2**	5	
J	0	0	0	*
K	3	**3**	0	*
L	4	**0**	4	
M	3	**3**	0	*
N	4	**0**	4	
O	4	**0**	4	
P	0	0	0	*
Q	4	**2**	2	*
R	6	**0**	6	
S	0	0	0	*
T	4	**0**	4	

IV. Conclusion

This study presents the implemented a methodology that considers the ratio of critical activity index, and verified the effectiveness by case study. This methodology identifies activities that have little impact on project success probability and regard as a priority of resource leveling, and regard as a priority of resource leveling, and confirmed practicality through resource leveling case study.

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (NRF-2016R1D1A1B03933080).

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