TẠP CHÍ KHOA HỌC & CÔNG NGHỆ ĐẠI HỌC DUY TÂN
DTU Journal of Science and Technology 02(39) (2020) 24-29

Metaheuristic based resource leveling using CPM project scheduling software program developed in .NET framework

Điều hòa tài nguyên dựa trên thuật toán tìm kiếm sử dụng phần mềm CPM Project Scheduling phát triển trên nền tảng .NET

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(Ngày nhận bài: 26/12/2019, ngày phản biện xong: 00/01/2020, ngày chấp nhận đăng: 4/5/2020)

Abstract

To establish and manage a project schedule, the Critical Path Method (CPM) coupled with bar charts is a widely used approach. Nevertheless, the schedule computed by the CPM method often needs to be adjusted to smooth out the daily resource utilization. This task is known as resource leveling. This article aims at developing an open tool for performing CPM based project scheduling and visualization as well as resource leveling. The success-history based parameter adaptation for Differential Evolution with linear population size reduction, denoted as LSHADE, is used for optimizing project schedules with the focus on minimizing resource fluctuations. The newly developed tool has been established in .NET framework 4.6.2. Experimental result with a demonstrative project points out that the proposed software program can be a useful tool to assist project managers as well as lecturers in teaching project management courses.

Keywords: Project schedule management; critical path method; resource leveling; differential evolution; .NET framework.

Tóm tắt

Để thiết lập và quản lý tiến độ dự án, phương pháp đường găng (CPM) kết hợp với biểu đồ ngang là một phương pháp được sử dụng rộng rãi. Tuy nhiên, tiến độ được tính toán bằng phương pháp CPM thường cần được điều chỉnh để làm giảm sự biến động của nhu cầu tài nguyên. Nhiệm vụ này được gọi là điều hòa tài nguyên. Bài viết này nhằm mục đích phát triển một công cụ để thực hiện lập kế hoạch và hiển thị tiến độ dự án dựa trên phương pháp CPM cũng như việc điều hòa tài nguyên. Thuật toán tiến hóa LSHADE được sử dụng để tối ưu hóa tiến độ dự án với trọng tâm là giảm thiểu biến động tài nguyên. Công cụ mới đã được phát triển trong nền tảng .NET framework 4.6.2. Kết quả tính toán với công tác lập tiến độ cho 1 dự án chỉ ra rằng chương trình phần mềm được đề xuất có thể là một công cụ hữu ích để hỗ trợ các nhà quản lý dự án cũng như các giảng viên trong quá trình giảng dạy các môn học liên quan đến quản lý dự án.

Từ khóa: Quản lý tiến độ dự án; phương pháp đường găng; điều hòa tài nguyên; thuật toán tiến hóa, nền tảng .NET.

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1. Introduction

In an increasingly competitive market condition, the success of construction contractors heavily depends on their effectiveness of planning and managing resources. Poor project planning and ineffective resource utilization cause additional operational cost and ultimately lead to business failure [1, 2]. Intensive fluctuations and high resource demand at certain time may lead to project delay and higher overhead/direct costs. It is because hiring and laying off workers on a short-term basis to meet the fluctuations in the resource profile is very costly. Moreover, if the resources cannot be managed effectively, they may exceed the supply capability [3, 4]. Accordingly, a contractor has to maintain a number of idle workers and other resources during the project execution; this fact obviously causes certain profit reduction.

Since the standard CPM method does not consider the bad effects of extensive resource fluctuations, additional procedures are required to adjust the CPM based schedule to achieve a smoother resource utilization profile [5-7]. The process of smoothing out resources is known as the resource leveling [3]. The objective herein is to minimize the peak demand as well as fluctuations of the resource usage [8]. This goal can be achieved by shifting noncritical activities within their available floats [4]. In recent years, the applications of metaheuristic algorithms for resource leveling have increasingly gained more attentions of the research community [9]. Metaheuristic based methods have been successfully used to optimize project schedule with respect to resource utilization. However, open tools for optimizing project resource utilization are hardly found. Such tools can be essentially useful for practical use and educational purposes. Therefore, this study develops a software program for CPM based project scheduling and visualization as well as resource leveling. The LSHADE metaheuristic is used for optimizing resource utilization schedule. The newly constructed tool has been developed in .NET framework 4.6.2 and verified via two demonstrative projects.

2. Problem formulation

The goal of the resource leveling problem is to diminish the peak resource demand as well as fluctuations in day-to-day resource utilization. This task can be formulated as an optimization problem having the following objective function [3, 4, 7]:

$$f = \sum_{i=1}^{T} (y_i - y_u)^2 \qquad (1)$$

where T is the project duration; y_i denotes the total resource demand of the activities performed at time unit i; and $y_u = \frac{\sum_{i=1}^{T} y_i}{T}$ is a uniform resource level.

The Eq. (1) can be expressed further as follows:

$$f = \sum_{i=1}^{T} y_i^2 - 2y_u \sum_{i=1}^{T} y_i + y_u^2 \qquad (2)$$

Since duration of activities and rate of resource for each activity are unchanged, y_u and $\sum_{i=1}^{T} y_i$ are constant. Hence, the objective function can be rewritten as follows:

$$f = \sum_{i=1}^{T} y_i^2 \qquad (3)$$

3. The history-based adaptive differential evolution with Linear Population Size Reduction (LSHADE)

The Differential evolution (DE) [10] is a powerful metaheuristic method for solving global optimization problem. The DE is based on the employment of a novel crossover-mutation operator using a linear combination of three different individuals and one subject-to-replacement parent (or target vector) [11-13]. This operator yields a trial vector (or child vector) which will compete with its parent in a greedy selection operator. Tanabe and Fukunaga [14] further improve the standard DE algorithm by proposing the LSHADE with several enhancements:

(i) The mutation scale factor (*F*) and the crossover probability (*CR*) are adapted during the optimization process instead of being constants.

(ii) A mutation strategy called DE/current-to-pbest/1 is implemented to better explore the search space [15]:

$$v_{i,g+1} = x_{i,g} + F_i(x_{r1,g} - x_{r2,g}) + F_i(x_{pbest,g} - x_{i,g}) \quad (4)$$

where $v_{i,g+1}$ is a trial vector; $x_{i,g}$ is a target vector; $x_{r1,g}$, $x_{r2,g}$ are two randomly selected members; $x_{pbest,g}$ is the current best solution.

(iii) A population size shrinking strategy is employed to both enhance convergence rate and reduce computational expense.

The crossover operation aims at combining the information of the newly created candidate and its parent according [16]:

$$u_{j,i,g+1} = \begin{cases} v_{j,i,g+1}, & if \;\; rand_j \le Cr \;\; or \;\; j = rnb(i) \\ x_{j,i,g}, & if \;\; rand_j > Cr \;\; and \;\; j \ne rnb(i) \end{cases} \quad (5)$$

The selection process compares the fitness of the trial and the target. Under a greedy manner, if the trial vector has a lower objective function value than its target vector, the trial vector supersedes the target vector. Moreover, the L-SHADE employs two archives of MF and MCR which are vectors of a fixed length *H*; MF and MCR store the mean values of the mutation scale and the crossover probability. In addition, the two sets of SF and SCR contain information of all *CR* and *F* values that deliver trial vectors better than their parents [17].

4. Software program application

The user needs to provide the project information containing the project name, activity names, activity durations, and activity predecessors. The project schedule is then computed automatically using the CPM method. After the CPM based schedule is computed, the LSHADE is used to perform the resource leveling process; this metaheuristic method attempts to shift noncritical activities within their float values to seek for an optimal project schedule. The demonstrative project contains 14 activities. The project information is provided in **Table 1**. The project schedule calculation based on the CPM method is shown in **Fig. 1** with the project duration is 30 days and the maximum worker demand is 30 for both early and late start schedules. The resource leveling outcome is illustrated in **Fig. 2** with the maximum worker demand being reduced to 25. The project duration remains to be 30 days.

Table 2 Information of the experimental project

Activity	Activity Name	Duration	Worker Demand Per Day	Predecessors		
1	Site Preparation	2	5	0	0	0
2	Fence Construction	2	5	1	0	0
3	Site Electrical System	6	10	1	0	0
4	Site Water System	4	5	1	0	0
5	Temporary House	3	15	2	3	4
6	Site Excavation	3	10	5	0	0
7	Soil Improvement	5	20	6	0	0
8	Scaffolding Setup	1	10	6	7	0
9	Foundation Formwork	3	15	6	7	0
10	Foundation Rebar	2	5	6	7	0
11	Foundation Concrete	2	20	8	9	10
12	Concrete Curing	2	5	11	0	0
13	Formwork Removal	2	10	12	0	0
14	Finishing Tasks	2	5	12	13	0

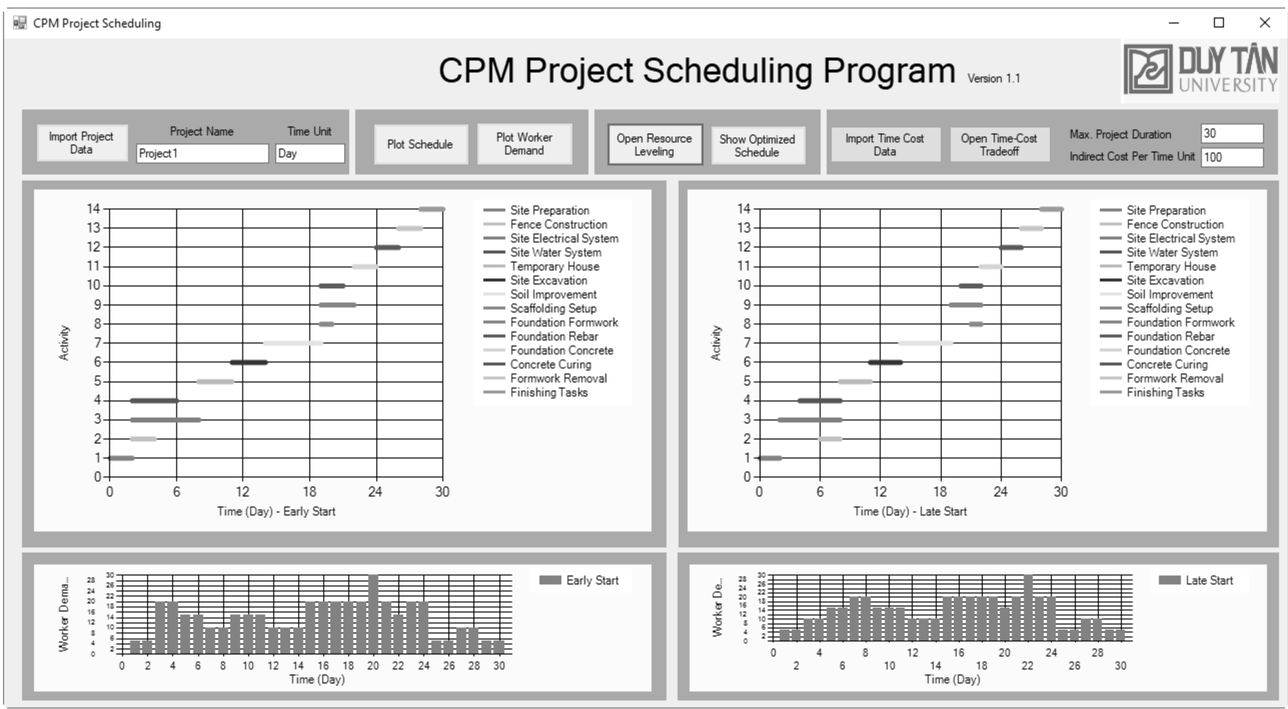

Fig. 1 The project schedule calculation based on the CPM method

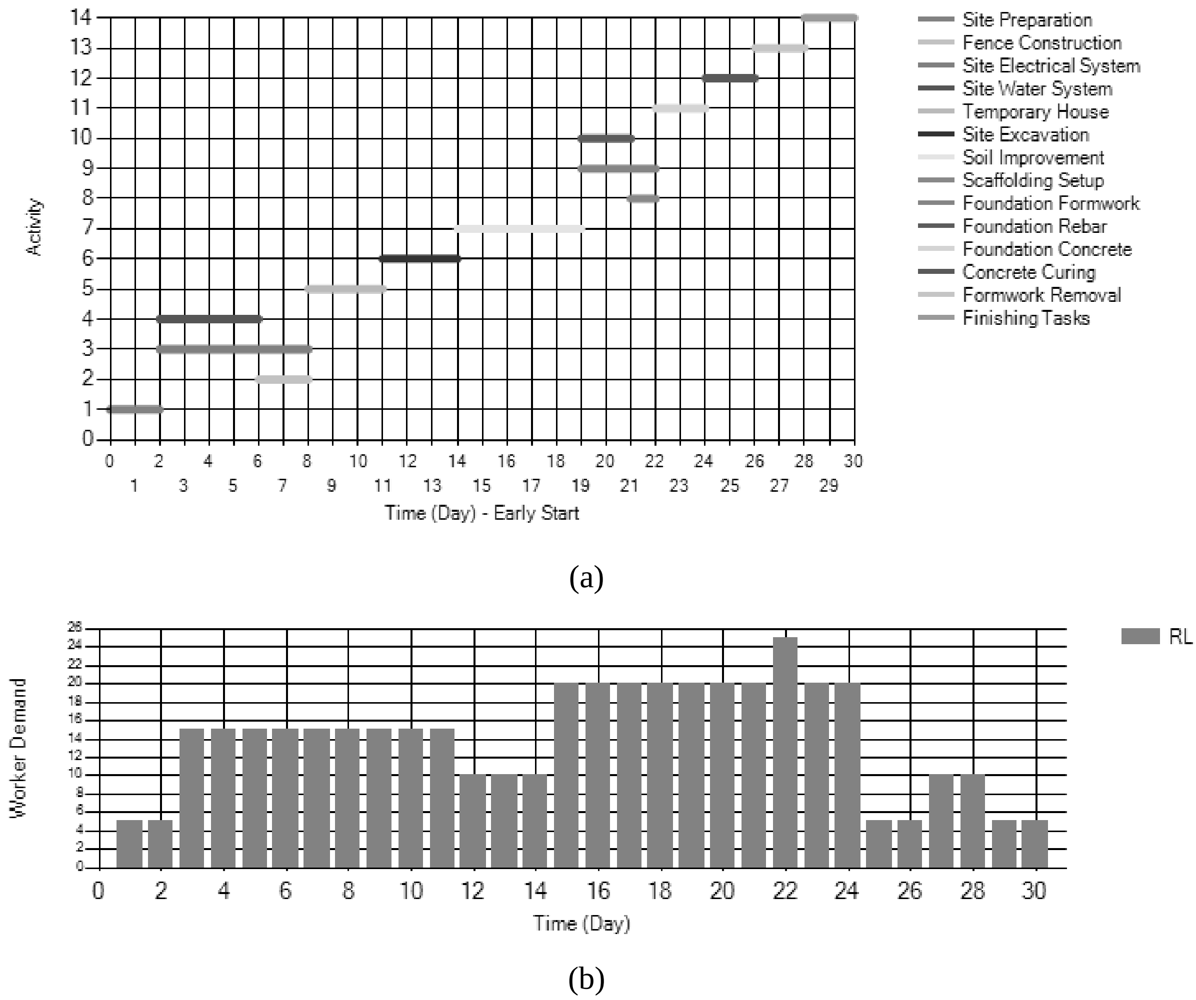

Fig. 2 The resource leveling result: (a) Schedule bar chart and (b) Resource profile

5. Conclusion

This study develops an open tool, named as CPM project scheduling, for project scheduling and solving resource leveling problem. The LSHADE metaheuristic is employed to perform project resource leveling. The project schedule and resource demand are conveniently visualized using the charts provided in the software program. The program applicability is demonstrated via a project containing 14 activities. Experimental result shows that the newly developed tool is promising to assist project managers in coping with the resource leveling problem.

Supplementary material

The Excel solver can be downloaded at: https://github.com/NhatDucHoang/CPM_ProjectSchedulingV1.1.

References

[1] H. A. El-khalek, R. F. Aziz, and E. S. Morgan, "Identification of construction subcontractor prequalification evaluation criteria and their impact on project success," *Alexandria Engineering Journal*, vol. 58, pp. 217-223, 2019/03/01/ 2019.

[2] M. Bilal, L. O. Oyedele, H. O. Kusimo, H. A. Owolabi, L. A. Akanbi, A. O. Ajayi, *et al.*, "Investigating profitability performance of construction projects using big data: A project analytics approach," *Journal of Building Engineering*, vol. 26, p. 100850, 2019/11/01/ 2019.

[3] H.-H. Tran and N.-D. Hoang, "A Novel Resource-Leveling Approach for Construction Project Based on Differential Evolution," *Journal of Construction Engineering*, vol. 2014, p. 7, 2014.

[4] M.-Y. Cheng, D.-H. Tran, and N.-D. Hoang, "Fuzzy clustering chaotic-based differential evolution for resource leveling in construction projects," *Journal of Civil Engineering and Management*, vol. 23, pp. 113-124, 2017/01/02 2017.

[5] K. El-Rayes and D. H. Jun, "Optimizing Resource Leveling in Construction Projects," *Journal of Construction Engineering and Management*, vol. 135, pp. 1172-1180, 2009.

[6] H. Li and X. Dong, "Multi-mode resource leveling in projects with mode-dependent generalized precedence relations," *Expert Systems with Applications*, vol. 97, pp. 193-204, 2018/05/01/ 2018.

[7] T. Atan and E. Eren, "Optimal project duration for resource leveling," *European Journal of Operational Research*, vol. 266, pp. 508-520, 2018/04/16/ 2018.

[8] J. L. Ponz-Tienda, V. Yepes, E. Pellicer, and J. Moreno-Flores, "The Resource Leveling Problem with multiple resources using an adaptive genetic algorithm," *Automation in Construction*, vol. 29, pp. 161-172, 2013/01/01/ 2013.

[9] H. Alsayegh and M. Hariga, "Hybrid meta-heuristic methods for the multi-resource leveling problem with activity splitting," *Automation in Construction*, vol. 27, pp. 89-98, 2012/11/01/ 2012.

[10] R. Storn and K. Price, "Differential Evolution – A Simple and Efficient Heuristic for global Optimization over Continuous Spaces," *Journal of Global Optimization*, vol. 11, pp. 341-359, December 01 1997.

[11] E. Mezura-Montes, M. E. Miranda-Varela, and R. del Carmen Gómez-Ramón, "Differential evolution in constrained numerical optimization: An empirical study," *Information Sciences*, vol. 180, pp. 4223-4262, 2010/11/15/ 2010.

[12] N.-D. Hoang, Q.-L. Nguyen, and Q.-N. Pham, "Optimizing Construction Project Labor Utilization Using Differential Evolution: A Comparative Study of Mutation Strategies," *Advances in Civil Engineering*, vol. 2015, p. 8, 2015.

[13] N.-D. Hoang, "NIDE: A Novel Improved Differential Evolution for Construction Project Crashing Optimization," *Journal of Construction Engineering*, vol. 2014, p. 7, 2014.

[14] R. Tanabe and A. S. Fukunaga, "Improving the search performance of SHADE using linear population size reduction," in *2014 IEEE Congress on Evolutionary Computation (CEC)*, 2014, pp. 1658-1665.

[15] R. Tanabe and A. Fukunaga, "Success-history based parameter adaptation for Differential Evolution," in *2013 IEEE Congress on Evolutionary Computation*, 2013, pp. 71-78.

[16] K. Price, R. M. Storn, and J. A. Lampinen, *Differential Evolution - A Practical Approach to Global Optimization*: Springer-Verlag Berlin Heidelberg, 2005.

[17] T.-D. Nguyen, T.-H. Tran, H. Nguyen, and H. Nhat-Duc, "A success history-based adaptive differential evolution optimized support vector regression for estimating plastic viscosity of fresh concrete," *Engineering with Computers*, December 18 2019.