Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society
27–29 May 2015
Bari • Italy

make learn
TIIM

Management, Knowledge and Learning
Joint International Conference 2015
Technology, Innovation and Industrial Management

THE LEAN-RESOURCES BASED CONSTRUCTION PROJECT PLANNING AND CONTROL SYSTEM

Tzu-An Chiang
Department of Business Administration, National Taipei University of Business, Taipei (100), Taiwan
phdallen@ntub.edu.tw

Z. H. Che
Department of Industrial Engineering & Management, National Taipei University of Technology, Taipei (106), Taiwan
zhche@ntut.edu.tw

Bo-Jing Zeng
Department of Industrial Engineering & Management, National Taipei University of Technology, Taipei (106), Taiwan

Abstract:
Construction project management systems nowadays focus on using the PERT/CPM technique to perform the project time control. However, project managers lack of benchmarking construction operations as the paragons at the construction project planning stage to plan construction project processes, estimate the minimum activity time and allocate lean resources to achieve the aim of time control of a construction project. To help construction project managers perform the construction project process planning and control, this research employs the efficient frontier to develop the lean-resources based construction project planning and control system (LRCPPCS). The LRCPPCS uses and analyzes the past history data to find the benchmarking similar construction activities to form the efficient frontiers. Through the efficient frontier, we can penetrate the relationship between resource allocations and activity times. If the result of construction project planning cannot satisfy the customer requirement, the process planning mechanism of a construction project can alter the activity times or resource allocations of a construction project to achieve the aim of a construction project by employing the lean resource allocation. If the delay of an activity of a construction project at the execution stage of a construction project, the process control mechanism of a construction project can modify the activity times and human resource allocations on a critical chain to reduce the delay risk of a construction project. In addition, the approach proposed in this research does not need a lot of the assumptions. Hence, the LRCPPCS can satisfy the practical requirement of construction project management.

Keywords: construction project management, construction project process planning, construction project process control, lean resource allocation, efficient frontier

1. INTRODUCTION

Nowadays construction projects are heading toward the large-scale and complication. As indicated by the research of Reichelt and Lyneis (1999), 86% of the large-scale development projects are excess of the budgets, and 55% of them have exceeded the time constraint. Therefore, a construction project manager needs to be equipped with the professional skill and management capability to execute the construction project management at every stage of the life cycle of the entire construction project. At the planning stage of a construction project, managers must determine the reasonable time and costs for the various construction activities and set up the sequence among various construction activities in the project. Therefore, the project management method and construction process planning mechanism must be properly used to achieve the objectives of construction project management.

At the execution stage of a construction project, the manager must carry out the construction project progress control through periodically monitoring the executive status of a construction project. In addition, a construction project manager also must re-estimate the completion time and the total cost of a construction project for any accidents. Once it is found that the construction project is delayed, the project manager must adjust the resource allocation for the subsequent process of a construction project to shorten the subsequent construction activity times. At the same time, a construction project manager must also control the budget of a construction project. Hence, the maximum cost-effective construction project activity should be given a top priority to add resources to decrease the activity time. Along with the promotion of the performance of an information system, the construction project management system has become an important tool for efficient and effective management of a construction project [Lee and Yu, 2012]. To help construction project managers deal with the abovementioned questions, a lean-resources based construction project planning and control system (LRCPPCS) is developed.

At the planning stage of a construction project, the system can help construction project managers estimate the minimum construction project activity time under limited resources and allocate the lean resources under the specific activity time. Moreover, a process planning mechanism of a construction project helps managers employ the benchmark construction activities as a paradigm to plan the process of a construction project and satisfy the time constraint of a construction project with lean construction resources. The execution stage of a construction project must monitor the executive status of the construction activities in real time. The LRCPPCS warns managers about the delays of construction activities and helps construction project managers adjust the resource allocations of subsequent construction activities of the critical chain by using the cost-time effectiveness analysis to achieve the objectives of a construction project with the minimum cost and time. Therefore, this research develops the LRCPPCS to help the construction industry to enhance the ability of construction project time management and cost control so as to boost the competitiveness of the construction industry.

2. LITERATURE REVIEW

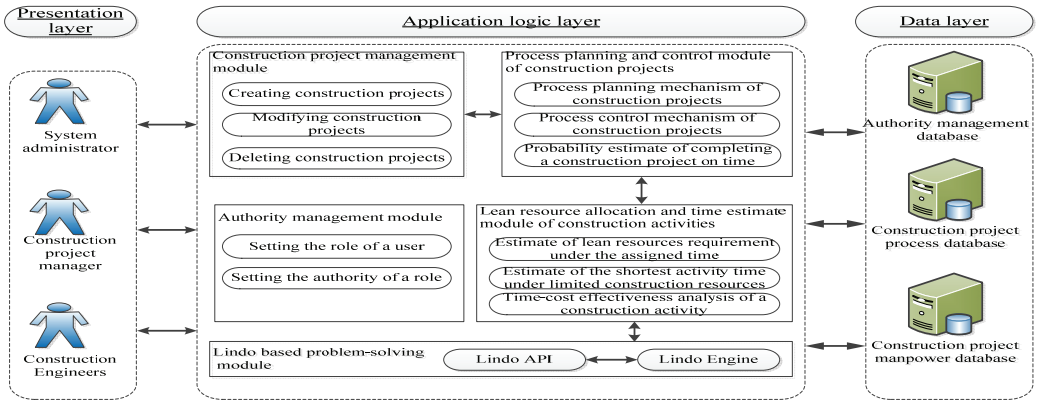
The effectiveness of traditional tools and technologies for project cost control is not very significant, and the resources allocation problems have not been taken into consideration. Therefore, Kumar and Ganesh (1998) used Petri Nets to help with resources allocation. In addition, some scholars have used heuristic algorithms to solve the project resources management problems. For example, Özdamar (1999) used three kinds of genetic algorithms to solve the project scheduling problem with limited resources, and it was found that the hybrid genetic algorithm can obtain better solutions within a reasonable time. Whitehouse et al. (2002) regarded the project scheduling problem with limited resources as a combinatorial problem, and used Meta-RaPS for resources allocation. However, there are still a lot of assumptions and limitations for the abovementioned heuristic algorithm based project management methods. Meanwhile, the solution of resource allocation for a project may not be an optimal solution. Zhu et al. (2005) developed the start-end sequential project scheduling method with limited resources, and the mixed integer programming was used for solving this problem. Vanhoucke and Vandevoorde (2007) used the simulation method and earned value (FV) metrics to predict the project time. Shou (2007) developed a bidirectional ant colony algorithm for searching all feasible project schedulings without violating the resource limitations. However, the aforementioned methods require the project managers to decide the time and resources for every activity. In addition to the use of heuristic algorithms, some scholars applied the simulation approaches to simulate the required time and cost of a project. Kurihara and Nishiuchi (2002) used the Monte Carlo to estimate the project time

and the required capital investment. Bowman (2006) used the simulation approach to estimate the required information for all projects' activities and investigated the impact of the changes to specification limits on the costs of projects and the probability of project being completed on time.

3. THE ARCHITECTURE OF THE LRCPPCS

The conceptual architecture of lean-resources based construction project planning and control system are as shown in Figure 1. The architecture of this system can be divided into three layers, i.e., (1) the presentation layer, (2) the application logic layer, and (3) the data layer. The function modules of all layers are as described below.

Figure 1: The conceptual architecture of lean-resources based construction project planning and control system



Presentation layer: the users of the lean resources based construction project planning and control system can be divided into system administrators, construction project managers, and construction engineers. Different user interfaces will be provided for different users' roles. The main function of the user presentation layer is to pass the user commands, to communicate with the application logic layer, and to provide the users with the required information of construction project management. Construction project managers can use the lean resources based construction project planning and control system to carry out the construction project process planning, and display the time and resources allocation of each construction activity to construction project managers. The construction engineers can use the system to figure out the construction projects they participated in and which the construction activities should be carried out. In case of delay of a construction project, this system will notice the construction engineers and send the report of delayed construction activities back to the construction project manager. In addition, the system will automatically assess whether or not the time and resource allocations of subsequent construction activities on the critical path should be adjusted.

Application logic layer: the application logic layer contains 5 modules, i.e., (1) the authority setting module of users, (2) the module of construction project management, (3) the process planning and control module of construction projects, (4) lean resource allocation and time estimation module of construction activities, and (5) Lindo solving module.

The authority setting module of users lets system administrators establish the different users' roles and role's setting of each user. Therefore, system administrators have the highest authority who can execute the functions of all roles in this system and are responsible for the system maintenance. The construction project management module lets project managers create new construction projects, modify construction projects, and delete construction projects. In addition, construction project managers can utilize the module to manage the roles and responsibilities of all participants of a construction project and to set up the authority of individual user. This study applies the method proposed by Trappey et al. (2007) to develop the construction project planning and control module. This module helps construction project managers complete the estimation of construction project time and allocate lean resources in order to achieve the objectives of construction project. At the execution stage of a construction project, the project process is monitored by the control mechanism of the construction project process. Once the construction project is delayed, the control mechanism of the construction project process evaluates whether or not the times and resources allocations of construction activities on the critical path of a project need to be adjusted. If the subsequent

construction project process needs to be adjusted, the lean resource allocation and activity time estimation module can be used for optimized adjustment of subsequent construction activities. The lean resources allocation and time estimate module includes the estimate of lean resources requirement under the assigned time, the estimate of the shortest activity time under limited construction resources, and the time-cost effectiveness analysis of a construction activity. Figures 2 and 3 show the planning and control mechanisms of a construction project respectively. Lindo problem-solving module is responsible of the calculation of the mathematical models to provide the lean resources allocation and the time estimation of construction activities.

Data layer: the data layer consists of (1) authority management database, (2) construction project process database, 3) construction activity database, and (4) construction manpower database. The authority management database is mainly for storing the various roles and authorities of construction project personnel. The construction project process database saves the construction project processes and the times and resources allocations of construction activities so as to provide managers with the required data for the planning and control of construction project process. The construction manpower database provides the amounts of various manpower resources of the construction company.

Figure 2: The mechanism of the process planning of a construction project

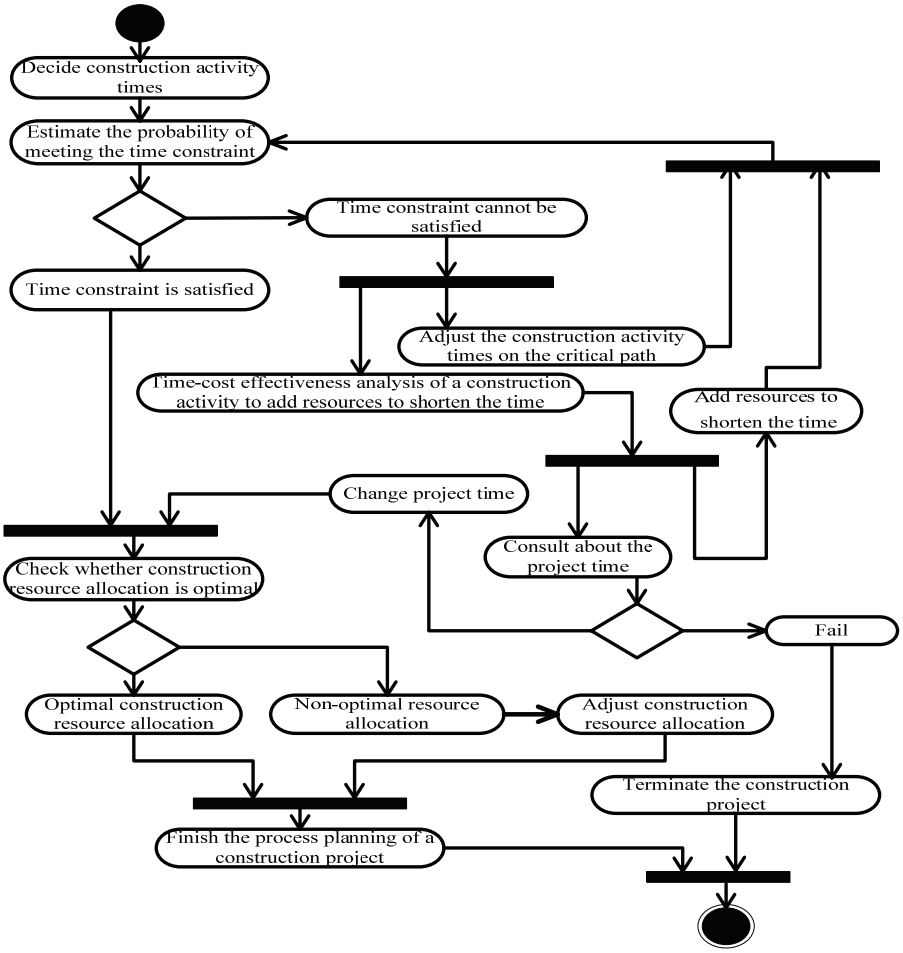
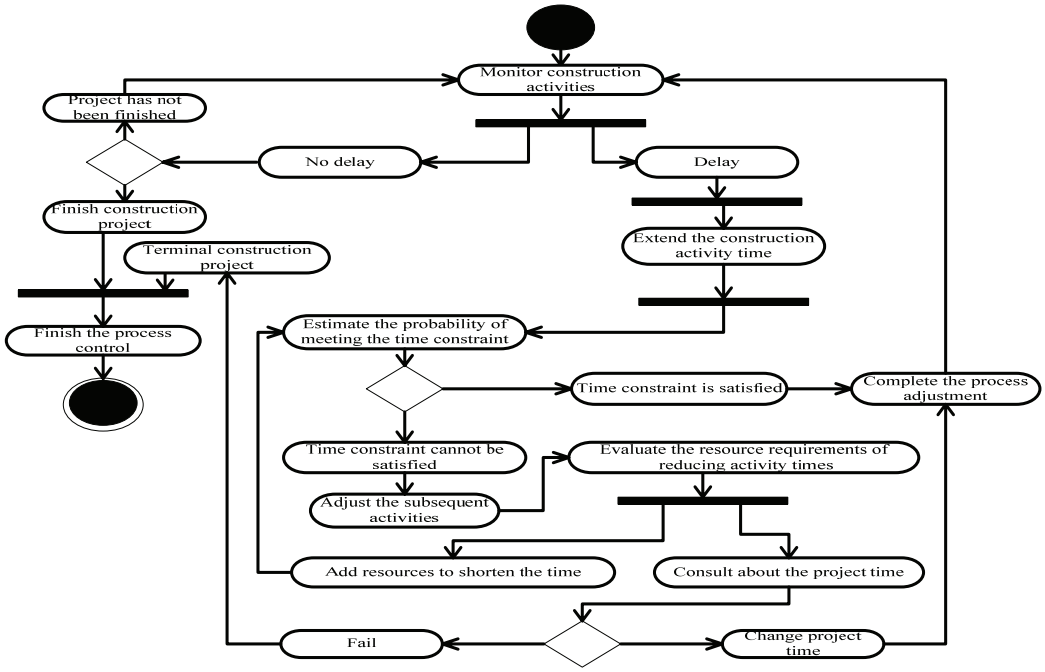


Figure 3: The mechanism of the process control of a construction project



4. CASE STUDY

This study employs a construction project as an example to verify the practical contribution of this system. The PERT chart of this construction project is shown in Figure 4. According to the process planning mechanism of a construction project, the project activity times must be determined at the planning stage of a construction project process before estimating the probability of meeting the time constraint of a construction project. Table 1 shows the time and resource amounts of each construction activity given by the construction project manager. Ot, mt and pt represent the optimistic time, most likely time, and pessimistic time respectively. ht and ft explain the working times of the human resource and the construction facility for each construction activity respectively.

The probability of completing the construction project within 150 days is 0.8274. However, the customer requires the probability of completing the construction project is 0.9. As a result, the LRCPPCS system automatically optimizes the times of construction activities and changes resource allocation of this construction project to make the probability of completing the project to become 0.9083 as shown in Figure 5.

Figure 4: The PERT chart of the construction project

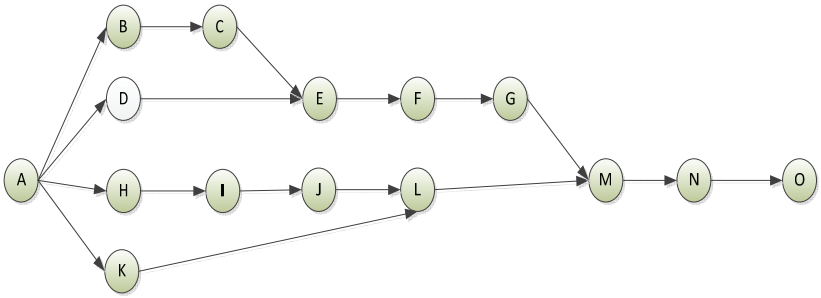
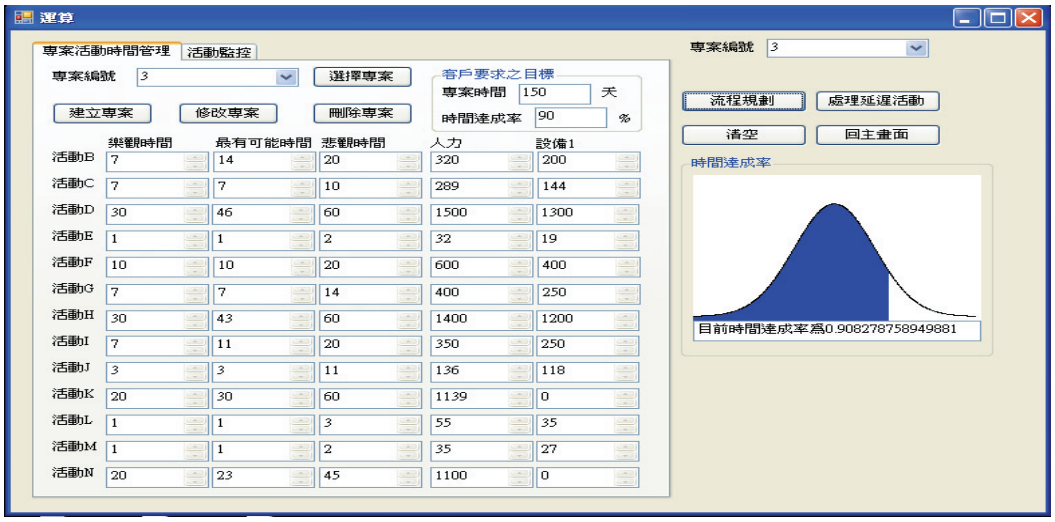


Table 1: Times and human resource requirements of each activity for the construction project

Activity name	ot	mt	pt	Human resource	ht	Facility resource	ft
B	7	14	20	Manpower A	500	Facility A	300
C	7	7	10	Manpower B	400	Facility A	200
D	30	50	60	Manpower C	1500	Facility A	1300
E	1	1	2	Manpower D	50	Facility A	30
F	10	14	20	Manpower E	500	Facility A	300
G	7	10	14	Manpower B	400	Facility B	250
H	30	45	60	Manpower C	1400	Facility C	1200
I	7	14	20	Manpower C	350	Facility C	250
J	3	4	11	Manpower C	150	Facility C	130
K	20	30	60	Manpower D	1300	None	0
L	1	2	3	Manpower D	55	Facility B	35
M	1	1	2	Manpower B	50	Facility B	30
N	20	30	45	Manpower E	1100	None	0

Figure 5: The optimal time and lean resource allocation of the construction project



5. CONCLUSION

The planning and control of time and resources of a construction project is critical to the competitive edge of a construction company. However, construction project managers usually use the subjective judgment and past experience to estimate the time and resources requirements of construction activities. In addition, the project management methods in the past only focus on the process planning stage of a construction project. The subsequent construction project process cannot be optimized when facing unexpected situation at the execution stage of a construction project. In light of this, this study develops LRCPPCS to help construction project managers use the lean method to allocate construction resources at the planning stage of construction projects while meeting the time constraint of a construction project. In response to the delayed activities at the execution stage of a construction project, the LRCPPCS can make the real-time judgment on whether or not the resource allocations for activities on the critical chain of a construction project need to be adjusted to satisfy the time constraint of a construction project with the lean construction resources.

ACKNOWLEDGEMENTS

This research received partial financial supports from the Ministry of Science and Technology under Contract No. NSC 102-2622-H-141 -002 -CC3 and MOST 103-2221-E-141-002-.

REFERENCE LIST

1. Bowman, R. A. (2006). Developing activity duration specification limits for effective project control. *European Journal of Operational Research, 174* (2), 1191–1204.
2. Kumar, A. V. K., & Ganesh, L. S. (1998). Use of petri nets for resource allocation in projects. *IEEE Transactions on Engineering Management, 45* (1), pp. 49–56.
3. Kurihara, K., & Nishiuchi, N. (2002). Efficient Monte Carlo simulation method of GERT-type network for project management. *Computers and Industrial Engineering, 42* (2-4), 521–531.
4. Lee, S. -K., & Yu, J. -H. (2012).Success model of project management information system in construction. *Automation in Construction, 25*, 82–93.
5. Özdamar, L. (1999). A genetic algorithm approach to a general category project scheduling problem. IEEE Transactions on Systems, Man and Cybernetics Part C: *Applications and Reviews, 29* (1), 44–59.
6. Reichelt, K., & Lyneis, J. (1999). The dynamics of project performance benchmarking the drivers of cost and schedule overrun. *European Management Journal, 17*(2), 135–150.
7. Shou, Y. (2007). *A bi-directional ant colony algorithm for resource constrained project scheduling.* IEEE International Conference on Industrial Engineering and Engineering Management, 1027–1031.
8. Trappey, A. J. C., Chiang, T. A., Chen, W. C., Kuo, J. Y., & Yu, C. W. (2007). *A DEA Benchmarking Methodology for New Product Development Process Optimization*. the 14th ISPE International Conference on Concurrent Engineering: Research and Applications São José dos Campos, Brazil, July 16–20.
9. Vanhoucke, M., & Vandevoorde, S. (2007). A simulation and evaluation of earned value metrics to forecast the project duration. *Journal of the Operational Research Society, 58*, 1361–1374.
10. Whitehouse, G. E., Depuy, G. W., & Moraga, R. J. (2002). *Meta-RaPS approach for solving the resource allocation problem*. World Automation Congress, Proceedings of the 5th Biannual.
11. Zhu, G., Bard, J.F., & Yu, G. (2005). Disruption management for resource-constrained project scheduling. *Journal of the Operational Research Society, 56*, 365–381.