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# Model-based dynamic resource management for construction projects

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**Abstract**

Excess resource idling can result in cost overruns, while low resource coverage or long lead-time in resource acquisition can delay the project schedule. Therefore, systematically managing this tradeoff is critical to ensure project delivery in time and within budget. In addition, to provide practically useful guidelines and tools, the dynamic construction process needs to be realistically represented. As an effort to address these issues, a model-based dynamic approach is proposed for construction resource management. The dynamics of construction progress and the tradeoff with resource coverage are identified. Then, the dynamic resource management model that has been developed using system dynamics is described. By simulating the model with heuristic and industry data, the effect of resource coverage on project performance is quantified and policy implications are obtained for dynamic resource management. Finally, the use of the model as an automated tool is demonstrated.


*Keywords:* Resource management; Simulation; Feedback; Resource coverage; System dynamics

## 1. Introduction

Construction progress is constrained by either work availability or resource availability. Work availability at a certain progress is governed by the work dependency [1] within the same activity ('internal work dependency', e.g., structural steel erection on the second floor can start only after completion of the first floor work) or between activities ('external work dependency', e.g., a finish-to-start relationship between foundation and excavation). Since work dependencies are determined by the nature of work, they are normally beyond the project manager's control. In contrast, resource availability is more likely determined by resource plans and managerial decisions, which can be made independent of the construction system. This fact suggests that construction management is nothing but resource management.

For this reason, most project management text books (e.g., [2–5]) recognize resources as the key to meeting a project schedule, addressing their significant impact on the construction system. In the same context, the importance of resource management has been emphasized in the literature [6–9]. Various methods and formulations have been also suggested for effective

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resource management. For example, Padilla and Carr [10] developed a simulation model to dynamically allocate given resources to construction activities. Karaa and Nasr [6], and Senouci and Adeli [11] proposed mathematical formulations to optimize resource utilization. The models developed by Chan et al. [12] demonstrated that model-based resource leveling and constrain-based scheduling are useful in shortening project duration. For the same purpose, comprehensive algorithms and neural dynamic models were also elaborated [7,8,13]. These researches demonstrated how resource-driven planning could enhance project performance and contributed to establishing a basis for construction resource management.

Despite their different views and approaches, the previous researches commonly focused on minimizing resource idling and waste. As will be discussed, excess resource idling and waste can result in cost overruns, while low resource coverage or long lead-time in resource acquisition can delay the project schedule by creating resource bottlenecks. Therefore, systematically managing this tradeoff at either planning or control stages is critical to ensuring project delivery is in time and within budget. In addition, to provide practically useful guidelines and tools, the dynamic construction process needs to be realistically represented.

In this paper, a model-based dynamic approach is proposed for construction resource management. Following a brief introduction of system dynamics, the research methodology, the dynamics of construction progress and its determinants are discussed. Then, having identified the tradeoff associated with resource coverage, and work dependencies involved in construction, this paper describes the dynamic resource management model developed using system dynamics. By simulating the model, it examines the effect of resource coverage on project performance and obtains policy implications for dynamic resource management. Finally, it is demonstrated how the model supports their application as an automated tool.

## 2. Research methodology: system dynamics

Since it was developed in the late 1950s, system dynamics has been used to analyze industrial, economic, social and environmental systems of all kinds [14]. With its analytic capability, system dynamics provides an analytic solution for complex and non-linear systems. For this feature, a dynamic modeling approach based on system dynamics is well suited to dealing with complex construction problems, which has been demonstrated in some researches on construction management [15,16].

System dynamics modeling uses causal loop diagramming to represent a modeler's understanding on the system. In a causal loop diagram, variables are connected by arrows that denote the causal influences between variables (indicating the same direction of change with a positive polarity and the opposite direction with a negative polarity, [17]). For example, Fig. 1a represents the causal relationships between construction progress and schedule pressure. Suppose that the construction project is behind schedule. Under schedule pressure, the project manager may try to catch up the delayed schedule by adopting overtime. This managerial action can facilitate the construction progress with the increased work hour, and accordingly reduce schedule pressure. However, lasting overtime may cause workers' fatigue, which possibly lowers work quality [18] and subsequently counteracts the construction performance enhanced by the

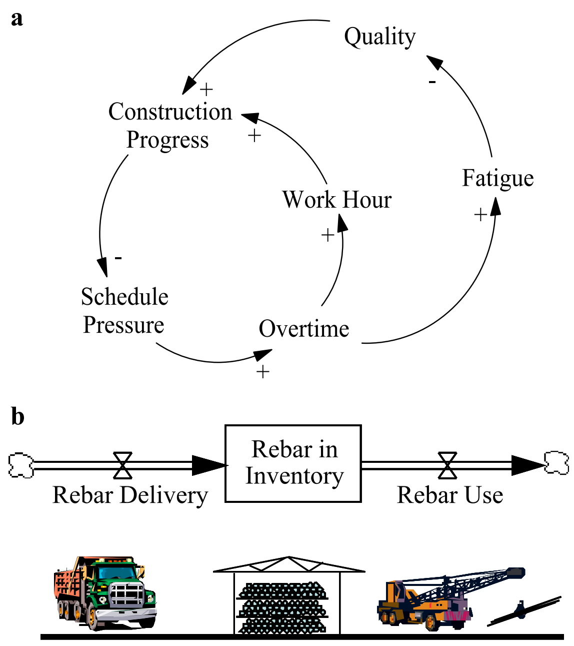


Fig. 1. (a) Example of causal loop diagram. (b) Example of stock and flow structure.