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Construction rescheduling based on a manufacturing rescheduling framework

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ABSTRACT

Changes during project execution frequently require schedule updating and rescheduling. However, few studies have discussed rescheduling issues or implemented rescheduling solutions for construction projects. This study investigates resource-constrained construction rescheduling issues using concepts associated with manufacturing rescheduling. Based on an initial schedule and actual progress, a novel rescheduling optimization model using Constraint Programming (CP) techniques is developed to reschedule projects. Two rescheduling methods: (1) complete regeneration (CR); and, (2) partial rescheduling (PR) while minimizing overall project variation are implemented in the proposed model to demonstrate the model capability and applications. PR requiring additional treatments to decrease overall project variation is performed using a novel constraint-release mechanism. Finally, using a case study, optimization results obtained using two rescheduling methods are analyzed and discussed.

1. Introduction

Rescheduling is common in project management, especially in the manufacturing industry. Generally, unexpected events adversely affect projects when necessary treatments are not adopted. Therefore, the dominant issues in rescheduling are how to adapt to a changing environment and reschedule incomplete work and resources.

A rescheduling problem consists of general scheduling problems that develop after a schedule is updated. Project information modifications and schedule updating may generate additional constraints due to the altered environment. Based on schedule updating results, rescheduling must rearrange incomplete work and resources while generating a practical schedule that meets the project goal. Compared to the manufacturing industry, construction projects have more unpredictable factors, such as environmental and productivity issues, that make maintaining schedules difficult. Although construction schedules are regularly updated and controlled during construction, few studies have investigated the effects of rescheduling issues on the rescheduling process. Therefore, applying manufacturing rescheduling concepts to the construction field is worthy of investigation.

This study presents an overview of construction rescheduling issues, including characteristics of construction rescheduling and appropriate rescheduling methods, and proposes a novel rescheduling mechanism for solving issues that cater to management needs.

2. Literature review

Rescheduling has been widely discussed in the manufacturing industry. Vieira et al. [1] defined rescheduling as the modification of an existing production schedule in response to disruptions or other changes. Additionally, Vieira et al. [1] proposed a framework for manufacturing rescheduling and defined terms in the rescheduling problem. Wu and Li [2] proposed a similar framework to Vieira et al. [1]. Joh et al. [3] identified characteristics of scheduling and rescheduling problems and developed a model for examining scheduling and rescheduling processes. Haldun et al. [4] analyzed four aspects of risk: cause, context, impact and inclusion to identify rescheduling factors. Yang [5], who demonstrated that new jobs always influence schedules, attempted to minimize the effects of negative disruptions through total cost optimization.

According to Vieira et al. [1], scheduling problems can be formulated as combinatorial optimization problems. Herroelen et al. [6] and Brucker et al. [7] collected, classified, and solved various scheduling optimization problems using mathematical models. According to Herroelen et al. [6], a resource-constrained project rescheduling problem can be preliminarily identified as a discrete time-resource trade-off problem. Additionally, Herroelen et al. [6] recommended using the branch-and-bound method to optimize the resource-constrained project rescheduling problem. Kelleher and Cavichiollo [8] demonstrated that a constraint-based approach is superior for generating schedules when combined with dependency analysis techniques based on reason maintenance systems and partial order backtracking.

To reduce rescheduling frequency, ElMekkawy and ElMaraghy [9] developed a deadlock-free rescheduling algorithm that used a heuristic routine to reschedule some jobs rather than all jobs. Yu et al. [10] applied

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an immune algorithm, which is a heuristic optimization algorithm, to solve a flexible dynamic scheduling problem.

The theory of constraints proposed by Goldratt [11] employed buffers to generate robust schedules that accommodated minor risks. Chua et al. [12] proposed a constraint-based project planning method with activity buffers. Hegazy and Petzold [13] proposed a genetic algorithm-based scheduling model and used buffers to determine the appropriate time to implement corrective actions.

3. Construction rescheduling

Table 1 classifies rescheduling problems and can be used as a reference for construction rescheduling problems. For classification details, refer to Vieira et al. [1]. The terms used in this study are quoted from Vieira et al. [1] as follows:

- *Rescheduling* is the process of updating an existing production schedule in response to disruptions or other changes. This includes arrival of new jobs, machine failures, and machine repairs.
- *Rescheduling environment* identifies the set of jobs that the schedule should include.
- A *Rescheduling strategy* describes whether or not production schedules are generated.
- A *Rescheduling policy* specifies when and how rescheduling is done. The policy specifies the events that trigger rescheduling.
- *Rescheduling methods* generate and update production schedules.
- *Complete regeneration* reschedules the entire set of operations (jobs) not processed before the rescheduling point, including those not affected by the disruption.
- *Partial rescheduling* reschedules only the operations affected directly or indirectly by the disruption.

3.1. Characteristics of construction rescheduling

Compared with manufacturing, construction environments have more uncertainties such as relatively long project durations and issues related to subcontracting, outsourcing, and weather. To identify construction rescheduling characteristics, rescheduling factors that alter a project environment must first be recognized. Some factors that distinguish construction rescheduling issues from those in the manufacturing industry are as follows:

(1) Productivity variation

Manufacturing projects depend on linear operations, and products are manufactured using standardized methods. Therefore, productivity has minimal variation. However, in the construction industry, supply sources typically vary, and outsourcing options are generally available. Moreover, resource and work methods impact productivity and activity duration. Assessing productivity is critical in construction project scheduling during the planning stage. During construction, maintaining a productivity level that adheres to the initial schedule is extremely important.

(2) Operational environment

Compared with manufacturing operations in factories, construction operations are typically performed outdoors and influenced significantly by numerous external factors such as weather and temperature. These uncertainties may alter an environment making productivity difficult to maintain.

(3) Demand–supply relationship

Most rescheduling factors in the manufacturing industry are related to uncertain customer demands; conversely, the principal rescheduling factors in construction projects are due to production processes. In the construction industry, planners must manage projects in response to uncertainties occurring during construction. The primary goal of construction planners is to complete a project before its due date and to execute most activities according to contracts. When uncertainties occur, planners must execute effective reactions and adjustments based on actual progress. Project tasks must be monitored, controlled, updated, and even rescheduled during construction.

Therefore, factors impacting project schedules in manufacturing and construction industries differ fundamentally.

3.2. Definition of rescheduling in construction

This work classifies and discusses construction rescheduling characteristics as the following (Table 1):

Deterministic environment. Based on the predictability of the tasks required, the rescheduling environment for construction projects is deterministic because a schedule consists of certain activities awarded to contractors on a fixed basis. A completed project design identifies all tasks and itemizes contract content. As a situation in which work content rarely changes, construction projects are typically scheduled and executed in a deterministic environment.
Predictive–reactive strategy. Deterministic environments frequently employ a predictive–reactive strategy to generate and update an initial schedule for most rescheduling problems (Vieira et al. [1]). A

Table 1
Classification of construction rescheduling (modified from Vieira et al. [1]).

Rescheduling environments				
Static		Dynamic		
Deterministic	Stochastic	No arrival variability	Arrival variability	Process flow variability

Rescheduling strategies				
Dynamic		Predictive–reactive		
Dispatching rules	Control-theoretic	Rescheduling policies		
		Periodic	Event-driven	Hybrid

Rescheduling methods				
Schedule generation		Schedule repair		
Nominal schedules	Robust schedules	Right-shift rescheduling	Partial rescheduling	Complete regeneration
			Construction industry	