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GA-based decision support systems for precast production planning

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ABSTRACT

Appropriate production plans can produce effective resource utilization and minimize waste. However, most precast fabricators currently propose production plans depending on the rule of thumb, resulting in squandered resources and postponed delivery. Computerized scheduling techniques provide more precise outcomes than manual scheduling. The objective of this study is to develop GA-based Decision Support Systems (GA-DSS) to assist production managers in arranging production plans. This research first establishes a flowshop sequencing model based on the current production status by considering the buffer sizes between production stations. A multiple objective genetic algorithm is then applied to search for solutions with minimum makespan and tardiness penalties. The GA-DSS performance is verified using two examples. The results demonstrate that the proposed system can offer appropriate production plans. By taking buffer sizes into consideration more reasonable and feasible production sequences can be achieved.

1. Introduction

The formwork method has been applied in building construction for a long period of time. However, this traditional construction method is not competitive as the labor costs and schedule inefficiency rise each year. Therefore, the formwork method has been gradually replaced by precast construction technologies to overcome the labor shortage and environmental uncertainty problems on building sites [1].

Precast construction is an enhanced method accomplished by erecting prefabricated concrete elements [2]. To support a construction schedule, precast fabricators deliver elements to a site according to an erection schedule. Making production plans is one of the most important tasks in manufacturing. Throughput, makespan, and waiting time are dominated by production plans. To enhance fabricator competitiveness, production planers face the challenges of satisfying multiple objectives in which one objective may conflict with the others [3].

Technology development in the manufacturing industry has focused attention on the inefficiencies of traditional scheduling in dealing with current complex production systems. As the scheduling problems become more complicated, the optimized solution cannot be achieved within a reasonable time. Therefore, studies on scheduling have shifted to applying heuristic algorithms to obtain near-optimal solutions within a short time.

Leu and Hwang [4] regarded the three working zones in a precast factory as a flowshop sequencing model. A genetic algorithm was applied to achieve the solution for this model with minimum makespan. In another research [5] written by the same authors, a genetic algorithm was tested in several projects to minimize the time spent producing precast elements. Chan and Hu [6] applied the conventional flowshop sequencing scheduling method as the basic production model, which was adjusted depending on different precast production process features. The work activities in their model were redefined into two types, interruptible and uninterruptible activities. The work day was divided into two sections, working and non-working hours. A genetic algorithm was used in their study to search for better production sequences. In the research conducted by Benjaoran et al. [7], the Bespoke Precast Flowshop Scheduling Model (BP-FSSM) was established, in which the features of production methods in prefabrication factories were considered. A Multi-Objective Genetic Algorithm was also applied to achieve a solution in their work. However, precast fabrication requires a rather large manufacturing space. Previous studies ignored the buffer size between work stations, resulting in unrealistic production plans.

The objective of this study is to develop a GA-Based Decision Support System (GA-DSS) to assist production managers in making appropriate production plans. A limited buffer size between stations is considered in this system. This paper first introduces multi-objective genetic algorithms. Current precast production practices are then discussed. Section 4 presents the precast production process using mathematical forms. A decision support system is developed in section 5 to facilitate decision making. A case study is used to validate the applicability of the developed system. Finally, conclusions induced from the experiment are documented.

2. Multi-Objective GA

The Multi-Objective Genetic Algorithm (MOGA) has been extensively adopted in numerous multi-objective decision making analyses

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[8–11]. MOGA has turned into one of the most eminent solutions for multiple objective scheduling [12]. This algorithm was first suggested and worked out in 1984 by David Schaffer [13]. Several algorithms were proposed after Schaffer's work. One of the most popular was established by Murata and Ishibuchi [14]. Their algorithm was developed based on an evolutionary process to search for multi-objective optimization for Pareto solutions. A Pareto-optimal solution is defined as one that is not dominated by any other solutions to the multi-objective optimization problem. Murata and Ishibuchi's MOGAs consist of two strategies. The first transforms multi-objectives into a single objective by randomly assigning weights for each objective. This strategy is used to search for an optimum solution in the search space through diverse directions, as demonstrated in Fig. 1. The second approach is an elite preservation strategy used primarily to avoid losing excellent chromosomes during the evolutionary process. A number of chromosomes are randomly selected from the Pareto solutions for survival.

Ishibuchi and Murata [15] proposed a Multi-Objective Genetic Local Search (MOGLS) algorithm based on MOGAs by including a local search. The MOGLS was validated using multi-objective scheduling problems, i.e., to minimize both makespan and schedule delays. Their experiments showed that MOGLS can find a better Pareto front than algorithms using other methods. This study therefore adopts the MOGLS [15] as a prototype for arranging production plans.

3. Precast production practice

This section explains the current precast production practices. In the construction process precast elements are made using a highly customized process. There are two phases within this process, the design and fabrication phases. In the design phase, designers translate the customers' demands into physical shop drawings before the precast elements are fabricated. Communications and negotiations are necessary to ensure that the clients' needs have been fulfilled. After confirmation by the clients, the drawings are used in the second phase to fabricate the design elements. The focus of this study is on the fabrication phase, which is conducted after the design phase but before the hoist elements on construction sites.

Elements are fabricated using various types of steel molds depending on the precast factory design. How the precast industry uses steel molds is identical to other manufacturing industries. In general, the precast manufacturing industry can be roughly divided into two methods based on the plant layout. The first is the comprehensive method, while the second is the specialized method [16].

All manufacturing procedures are conducted using the same team at the same place in the comprehensive manufacturing method. After finishing all procedures for one element, the team moves to another station to work on the next work piece. The layout for this method is shown in Fig. 2.

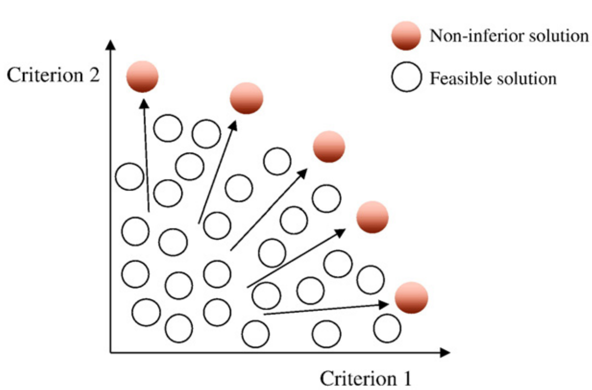

Fig. 1. Multi-objective genetic algorithms searching concept.

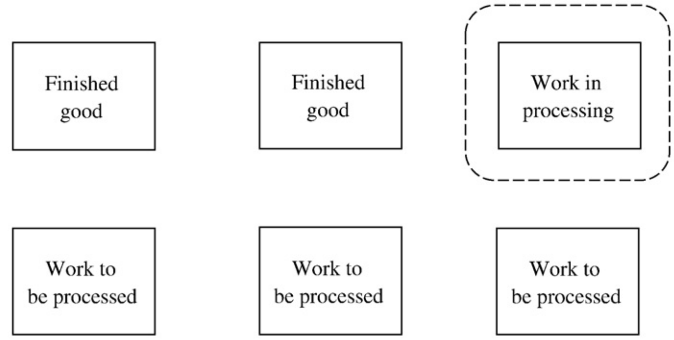

Fig. 2. Comprehensive production method.

The specialized method divides the process into several subroutines. Various stations are set up to work on different subroutines. These stations are operated by different teams. An element is fabricated by running it through all stations. The work piece movement between stations takes time, but higher efficiency in labor utilization and resources is achieved. This is the reason why this method has been utilized in many previous studies on production scheduling in factory fabrication systems. The specialized method is therefore adopted in this study. The station layout is presented in Fig. 3.

As in other manufacturing industries, precast element fabrication requires resources for production, including manpower, steel molds, and production lines. Facilities like the Overhead Monorail System and steamers are part of the production line. Among the three types of resources, production lines are less flexible because of the huge mass of the precast elements. The precast element production demands a lot of space and the precast elements are too heavy to be easily moved. The Overhead Monorail System is necessary, with production lines usually designed and built at the same time the factories are constructed.

Manpower and steel molds are the other two important resources in the precast production process. Despite the introduction of many automatic production systems in the precast industry in recent years, a large amount of manpower is still required in production. The number of working hours is a key factor that influences makespan. Several issues must be taken into consideration in working hours decision making, such as the amount of labor, worker inclination, and related regulations.

The first decision to be made in the precast production process is the number of molds. As in other manufacturing industries, the mass production of standardized elements is conducted in the precast industry as well. Due to the high cost of steel molds, the difficulty in shifting, and the great variety of elements, one single mold is not able to produce all types of elements. Therefore, to effectively reduce the cost, fabricators usually produce all construction elements via a limited amount of molds. The mold cost, site rental expense, and mold exchange should be taken into account when the number of molds is decided.

In addition, the production sequence is also a critical factor related to makespan. A well-planned sequence is helpful in utilizing resources more efficiently and reducing idle time during the production process.

The amount of resources is influenced by many objective and subjective factors which cannot be controlled exactly by production managers. Thus, greater emphasis is placed in this study on the production sequence, which is more controllable for production managers. The current production plans are based mostly on the rule of thumb, but the outcomes may not certainly reach their goals. Hence, proposing production schedules using systematic methods has become a main research task [4–7].