REDUCING PRECAST FABRICATION INVENTORY

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ABSTRACT

The objective of this study is to develop a framework for reducing precast fabrication inventory. The framework consists of three components. A time buffer evaluation is used to avoid fabricators losing capacity by considering demand variability. The second component, due date adjustment, shifts production curve closer to erection dates to reduce inventory. The third scheduling component arranges production sequences to achieve multi-objectives using genetic algorithms. The developed framework could reduce the level of finished goods inventory without changing production resources. It could also be used as a tool for creating and maintaining stability while attacking variability.

KEY WORDS

Precast fabrication, demand variability, inventory, scheduling.

INTRODUCTION

Precast fabricators face numerous challenges as they strive for business success. Among them, demand variability is arguably the biggest headache (Ballard and Arbulu 2004, Ko and Ballard 2005). One way to protect fabricators against the impact of demand variability is to finish products relatively later to delivery dates. Thus, risks of changes in delivery schedules and falling victim to design changes can be reduced (Ko and Ballard 2004). However, how much later relative to the required delivery date fabricators can still deliver products on time but reduce the level of finished goods inventory is a question.

According to the buffering law, systems with variability must be sheltered by some combination of inventory, capacity, and time (Hopp and Spearman 2000). The root method for solving problems induced by variability is to eliminate it (Khan 2003). Precast fabricators thus should constantly endeavor to reduce variability. Meanwhile, before variability has been totally removed, proper buffers are necessary to protect fabricators from the impact of changeability in demand. To deliver products on time (or Just-In-Time), a time buffer with a smaller inventory is needed. Otherwise, precast fabricators lose capacity due to overtime vicious cycles induced by variability.

Weekly work plan is one of the most important tasks when applying lean concepts in precast concrete fabrication (Ko and Wang 2008). Different plans can induce different throughput. Engineers therefore endeavour to finish products with a

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minimum makespan. To enhance competitiveness, foremen face the challenge to satisfy multiple objectives since one objective may conflict with the others. Current practice of making weekly work plan depends on foremen’s experience. However, manually arranging plans frequently results late delivery and wastes production resources (Dawood 1993, Chan and Hu 2002). Recently, researchers have started on using computational techniques to deal with scheduling issues.

The objective of this study is to develop a framework for precast fabricators to reduce the level of finished good inventory. Fuzzy logic and multi-objective genetic algorithm are adapted to achieve this goal. This paper first introduces the process of precast fabrication. A production strategy corresponding with research method is then proposed to reduce the inventory level. To carry out the production strategy, a framework is developed. Three components of the framework are discussed.

RESEARCH METHOD

To fulfil an erection schedule, precast fabricators start manufacturing as soon as they receive design information. However, this practice results in accumulated inventory considered as “the root of all evil” (Spearman 2002, Pulat and Pulat 1992). Change orders, categorized as demand variability, are among the largest sources of cost inflation on construction projects (Riley 2005). Elements fabricated before they are needed frequently falls victim to change orders, such as modifications in size, quantity, and delivery date.

This research establishes the framework for reducing precast fabrication inventory using a production strategy. This strategy used to reduce inventory and protect fabricators against the impact of demand variability is to finish production later relative to required delivery dates, as illustrated in Fig. 1, where the adjusted production curve is “pulled” relatively close to the erection curve (the middle s curve). To avoid insufficient capacity fabrication, the production curve is cushioned with a time buffer. For the time t shown in Fig. 1, an inventory level is decreased from i to i_a. The time of finished goods inventory awaiting delivery is shortened from b to a time buffer designated b_a. By adopting this strategy, both the inventory level and the impact of demand variability can be reduced without neither increasing production rate nor number of molds.

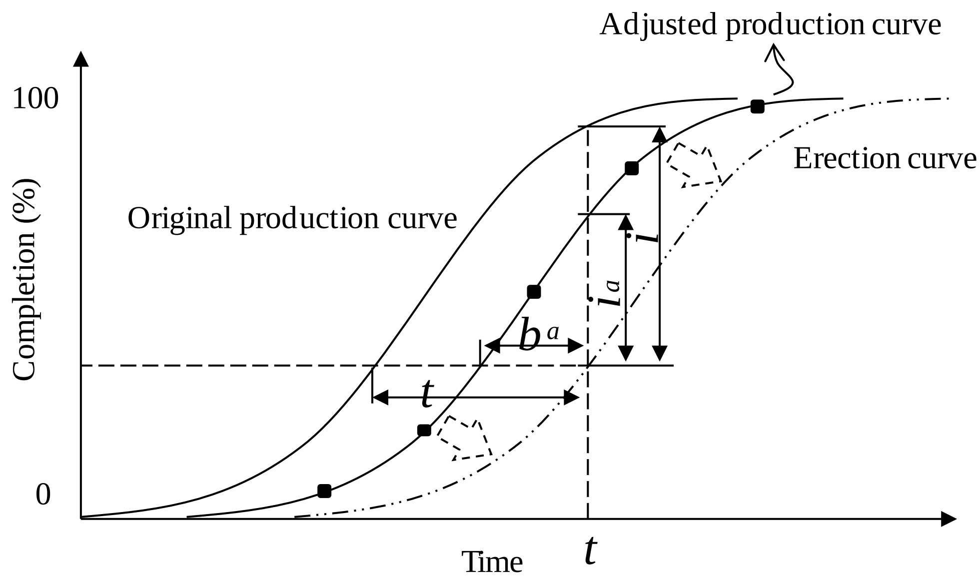

Figure 1: Production strategy use to reduce inventory level

FRAMEWORK OF REDUCING INVENTORY

According to the production strategy shown in Fig. 1, this study proposes a framework to reduce level of finished goods inventory using three steps, as shown in Fig. 2. The first step is to evaluate a time buffer using fuzzy logic. Fabrication due dates are then adjusted using the inferred buffer according to the production strategy. Finally, production sequences are arranged using a multi-objective genetic algorithm. Each step is explained as follows.

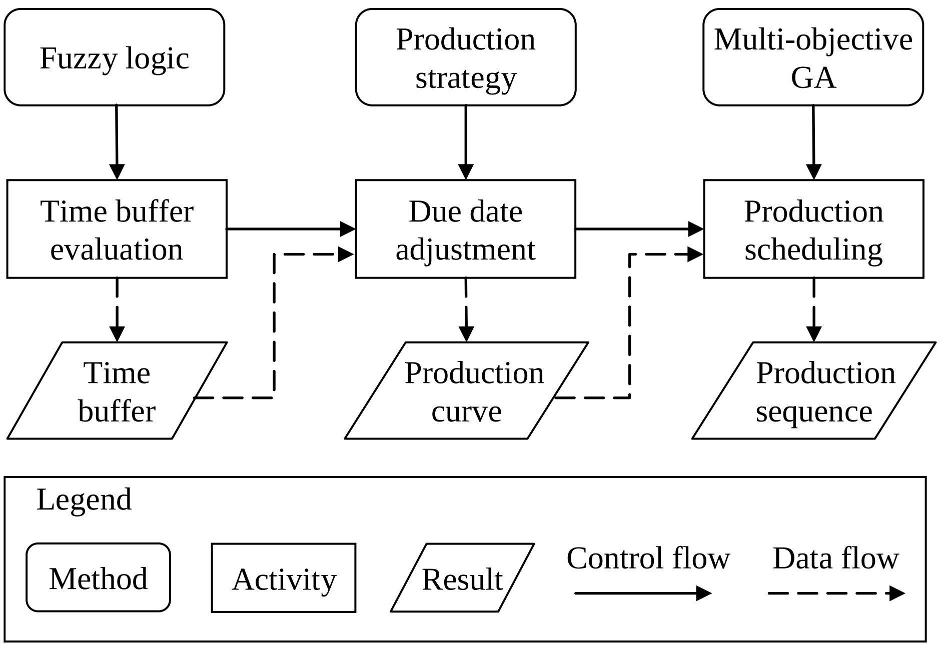

Figure 2: Framework of reducing inventory

FUZZY LOGIC

Buffer evaluation is complex and time consuming. Uncertain and imprecise information are encountered while evaluating time buffer. In practice, factors inducing variability are difficult to be quantified. Fuzzy Logic (FL) has been proven as an effective method to process uncertain information and complex systems (Ko 2006, Al-Humaidi and Hadipriono Tan 2010). As a result, this research adopts FL to evaluate the required time buffer for demand variability. FL was first developed by Zadeh in 1960s for representing uncertain and imprecise information. In a wide sense, fuzzy logic is synonymous with fuzzy set theory; that is, the theory of classes with unclear boundaries. In a narrow sense, fuzzy logic is a logic system that intends to serve as a logic of approximate reasoning (Zadeh 1994). Classical logic (two-valued logic) assumes that every proposition is either true or false. This basic assumption has been questioned. Unlike classical logic, fuzzy logic is viewed as an extension of multi-valued conventional logic. FL simulates the high-level human decision-making process, which aims at modelling the imprecise modes of reasoning to make rational decisions in an environment of uncertainty and imprecision. It provides approximate but effective descriptions for highly complex, ill-defined, or difficult-to-analyze mathematical systems. A general Fuzzy Logic System (FLS) contains four major components: fuzzifier, inference engine, rule base, and defuzzifier, as shown in Fig. 3.

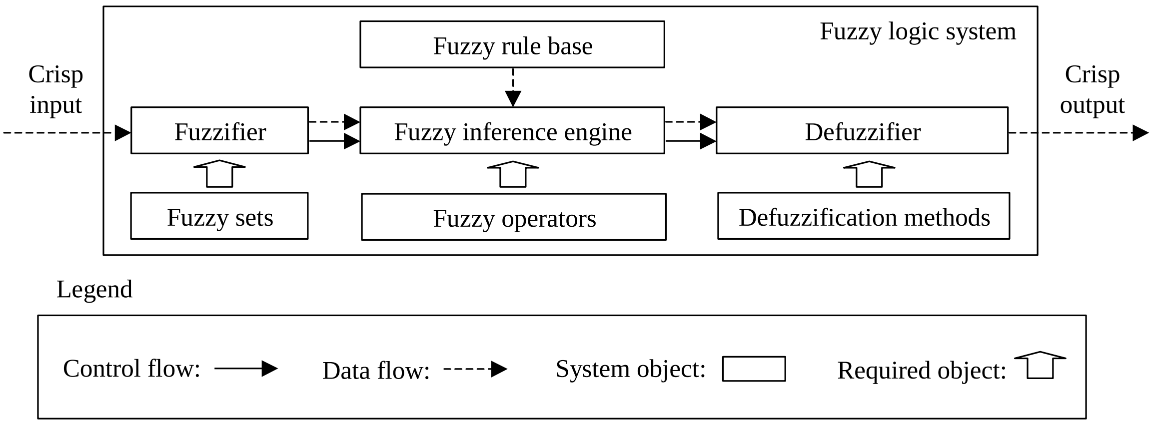

Figure 3: General schema of a typical fuzzy logic system

TIME BUFFER EVALUATION

Applying a production strategy that finishes production later relative to the delivery date, can ideally reduce the finished goods inventory. Unfortunately, variability such as late material supply, lost productivity, unplanned machine down time, and variation in setup times (molds) exists everywhere in the precast production system. Fabricators may be pushed out of capacity if every element is fabricated just-in-time. A proper time buffer between the delivery date and production due date is therefore necessary, just-in-case. Demand variability is arguably the biggest headache when fabricators strive for business success. To avoid producing products that succumb to demand variability, elements should be fabricated later relative to the delivery dates. In contrast, for a situation in which the demand variability is relatively less, production loading can be mitigated if elements are fabricated relatively earlier. This allows fabricators to have more capacity for prior jobs.

DUE DATE ADJUSTMENT

A time buffer evaluated in the previous section is regarded as a cushion to avoid having the fabricator becoming insufficient capacity. To support the erection schedule with less inventory, production due dates are adjusted back forward with the evaluated buffer. The derived adjusted production curve thus shifts closer to the erection curve.

MULTI-OBJECTIVE GENETIC ALGORITHMS

This study adopts the Multi-Objective Genetic Local Search Algorithm (MOGLS) proposed by Ishibuchi and Murata (1998) to search for optimum work plans. The evolutionary process of MOGLS is represented in Fig. 4. Factors effect precast makespan include production resources and production sequence. Some production resources such as number of cranes and factory size cannot be changed by foremen. Others such as buffer size between stations, mold number, and working hours can be determined (Ko and Wang 2008). To provide an equal chance for every state space, a set of initial solutions are randomly generated. When calculating objective function, chromosomes are decoded corresponding with precast production p. To make sure that derived solutions conform to the definition of Plato solution, every generation has to update Plato solution pool. To evaluate the fitness of each chromosome, objective value is converted to fitness value. In multi-objective programming, since distribution of each objective value is deferent, each objective value is normalized in advance. Selection operator is used to select chromosome according to its fitness. Higher fitness value has higher chance for survival. GA extends searching space by crossover operator. The operator produces next generation by exchanging partial information of parents. The mutation operator produces spontaneous random changes in various chromosomes. It protects against premature loss of important notations. Elitism has been proven successful in GA. It survives a certain amount of Plato solution to the next generation. Replacement is a process that produced chromosomes eliminate parent chromosomes. In the process, previous population is renewed by generated offspring.

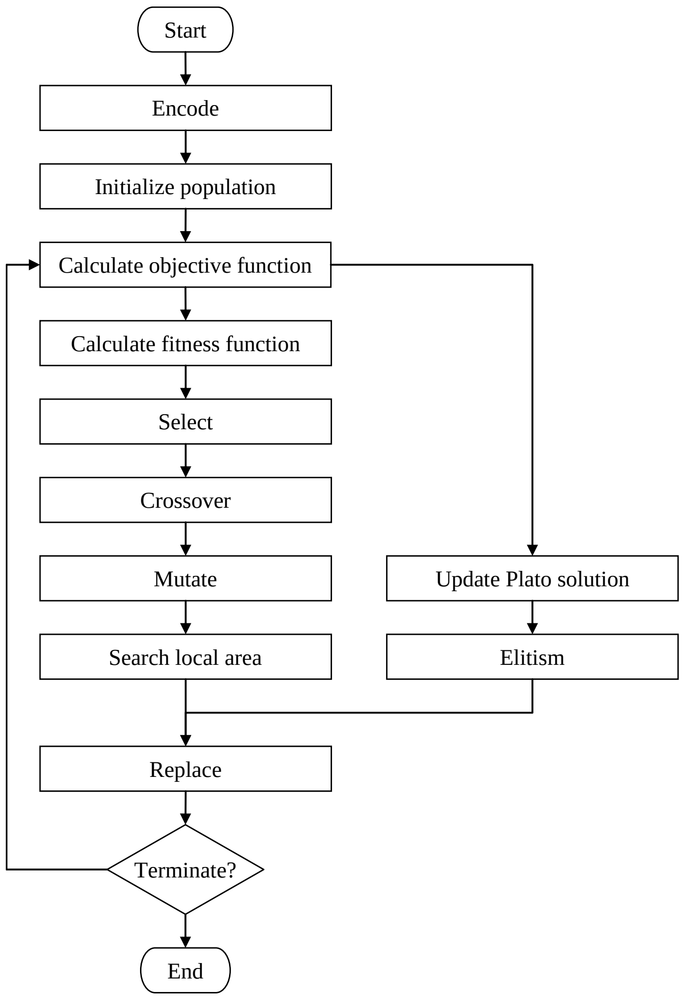

Figure 4: MOGLS evolutionary process

PRODUCTION SCHEDULING

Once the production due dates have been determined, the next issue is how to finish products according to the due dates. This goal cannot be achieved without production schedules. Applying computational methods in recast production scheduling evolves from computer simulation to genetic algorithms (Dawood 1993, Dawood and Neale, 1993, Dawood 1996). Previous studies showed that production resources have a crucial impact on throughput. In addition, precast production is a flowshop sequencing problem that can be solved using computational methods. Genetic algorithms have been proven a promising method for arranging precast production schedules (Chan and Hu 2002, Leu and Hwang 2001, Leu and Hwang 2002, Benjaoran et al. 2005, Vern K and Gunal 1998). This study adopts MOGLS proposed by Ishibuchi and Murata (1998) as a prototype algorithm to search for optimum production schedules.

CONCLUSIONS

This paper presented a framework to reduce the level of finished goods inventory by integrating artificial intelligence techniques. A production strategy that finishes products later relative to the erection dates is proposed to reduce the inventory level.

To avoid having the fabricators becoming insufficient capacity due to late production due dates, a time buffer was evaluated by considering the demand variability. A multi-objective genetic algorithm was then used to search for production sequences to fulfil the production goal.

Most precast fabricators generate a substantial finished goods inventory to satisfy the customer's demand. The proposed framework could reduce the finished goods inventory level using a supportive production plan. Moreover, the framework used to shift the production curve closer to the erection dates could reduce the risk of fabricator exposure to the impact of demand variability.

The proposed buffer strategy could be used as a tool for creating and maintaining stability while attacking variability while also constantly re-evaluating the required buffer based on the reduced variability. Future research could improve this method to attack all forms of variability within the precast production through continuous improvement and Lean Production design techniques as well as variability within demand.

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