Reducing Finished Goods Inventory for Precast Fabricators

Chien-Ho Ko [1], Sheng-Hsiung Tien[2], Yung-Cheng Shen[3], and Hao-Hsiang Liao[4]

Abstract

The objective of this study is to develop a framework for precast fabricators to reduce the 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.

Keywords: 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 of the ways to protect fabricators against the impact of demand variability is to finish products later relative to delivery dates. Thus, risks of changes in delivery schedules and manufacturing a product that is either not yet needed or 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.

The objective of this study is to develop a framework for precast fabricators to reduce the level of finished goods 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 is then proposed to reduce the inventory level. To carry out the production strategy, a framework is developed. Three components of the

[1] Associate Professor, Department of Civil Engineering, National Pingtung University of Science and Technology, 1, Shuefu Rd., Neipu, Pingtung 91201, Taiwan, Tel: +886-8-7703202, Fax: +886-8-7740122, E-mail: ko@mail.npust.edu.tw.

[2] Graduate Student, Department of Civil Engineering, National Pingtung University of Science and Technology, 1, Shuefu Rd., Neipu, Pingtung 91201, Taiwan, E-mail: chia5017@ms45.hinet.net.

[3] Undergraduate Student, Department of Civil Engineering, National Pingtung University of Science and Technology, 1, Shuefu Rd., Neipu, Pingtung 91201, Taiwan, E-mail: b9733041@mail.npust.edu.tw.

[4] Undergraduate Student, Department of Civil Engineering, National Pingtung University of Science and Technology, 1, Shuefu Rd., Neipu, Pingtung 91201, Taiwan, E-mail: b9833041@mail.npust.edu.tw.

framework are discussed. Finally, application of the developed framework is explained using a real precast production project.

Precast Production Process

Precast fabrication can be divided into six steps: namely 1) mold assembly, 2) placement of reinforcement and all embedded parts, 3) concrete casting, 4) curing, 5) mold stripping, and 6) product finishing, as depicted in Fig. 1. Unlike regular production systems, precast elements are produced stationary as opposed to conveying by belts due to their huge volume and heavy weights. Therefore, fabrication jobs are completed by mobile crews. The mold assembly activity provides a specific dimension. In general, fabricators use steel molds for the purpose of reuse. Precast element primarily contains two kinds of materials, i.e., concrete and steel bars. Reinforcements and embedded parts are placed in their positions after the mold is formed. Embedded parts are used to connect and fix with other elements or with the structure when the precast elements are erected. The concrete is cast when the embedded parts are in their positions. To enhance the chemistry solidifying concrete, steam curing is implemented; otherwise, the concrete requires weeks to reach its legal strength. Moving, erecting, or erecting elements before the legal strength is reached may cause damage. The molds can be stripped after the concrete solidifies. Due to the cost of developing steel molds, fabricators reuse them once they are stripped. The final step in production is finishing. Minor defects such as scratches, peel-offs, and uneven surfaces are treated in this step. Afterwards, precast elements are stored in the yard awaiting delivery to construction site.

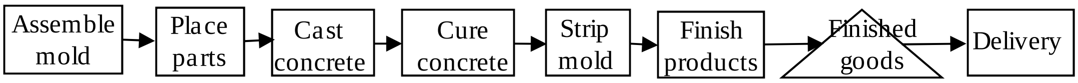

Figure 1. Precast Production Process

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.

A 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. To avoid out-of-capacity fabrication, the production curve is cushioned with a time buffer. For the time t shown in Fig. 2, 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.

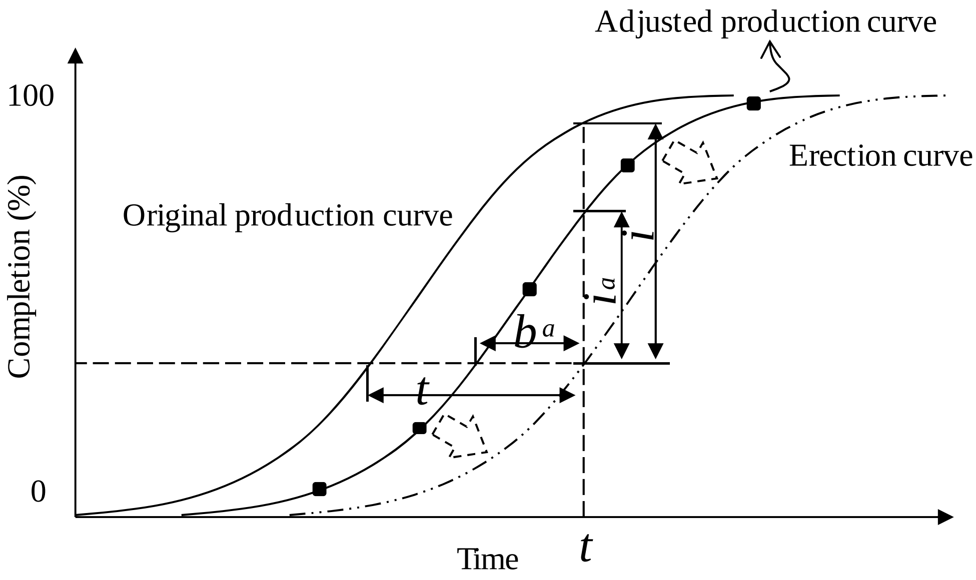

Figure 2. Production Strategy (adopted from Ko, 2010)

Framework of Reducing Inventory

This study proposes a framework to reduce level of finished goods inventory using three steps, as shown in Fig. 3. 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. The details for each step are explained as follows.

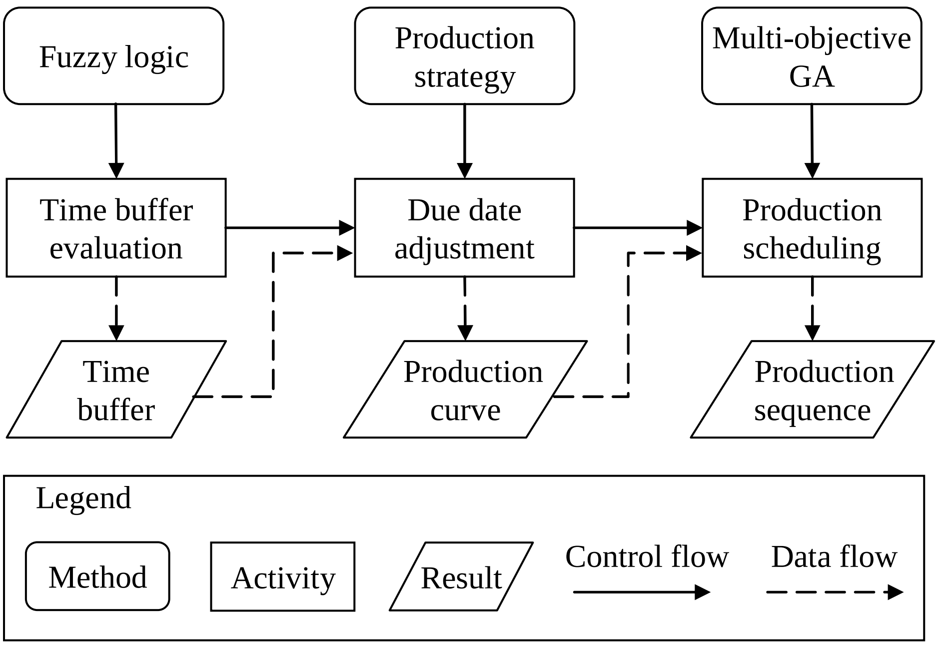

Figure 3. Reducing Inventory Framework

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 out of capacity. To support the erection schedule with less inventory, production due dates are pulled with the evaluated buffer. The derived adjusted production curve thus shifts closer to the erection curve.

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.

Case Study

One real case, a furniture mall constructed from precast components, is used to demonstrate the applicability of the proposed framework. This four-story, one-basement shopping mall has a construction budget of US$ 5.7 million. B1F has 195 major and 290 minor beams but no precast columns. The mall also has a mezzanine, denoted as M1F, between the first and the second floors.

The time buffer is evaluated by considering the demand variability using fuzzy logic. This studied case is a shopping mall with single ownership, constructed using precast columns and beams (structural elements). Production due dates are adjusted closer to the delivery dates. To avoid the fabricator being out of capacity, the time buffers inferred are regarded as a cushion between the delivery dates and production due dates. This project includes 1988 precast elements, which is difficult to manually arrange the optimum production sequences. This study thus arranges the production sequences using multi-objective genetic algorithms. A production sequence analyzed using genetic algorithms.

The original production due dates, adjusted production due dates, and actual erection dates are graphically compared in Fig. 4. An average of 16% finished goods inventory is reduced using the proposed framework.

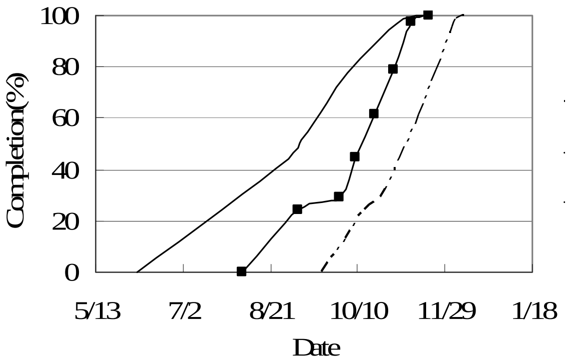

Figure 4. Comparisons of Original Production due Date, Adjusted Production due Date, and Erection Dates

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 out of 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 finished goods are one kind of inventories in the precast fabrication. In the future, the work-in-progress could be further studied.

Acknowledgements

This research was funded by grant NSC 97-2221-E-020-036-MY2 from the National Science Council (Taiwan), whose support is gratefully acknowledged. Any opinions, findings, conclusions, or recommendations expressed in the paper are those of the authors and do not reflect the views of the National Science Council. The authors would like to thank the investigated precast fabricator for supporting this study. Partial analyses are carried out through the assistance of Yu-Chun Chen and Shu-Fan Wang for which is grateful.

References

Ballard, G. and Arbulu, R., 2004. Taking Prefabrication Lean. *Proceedings of the 12th annual conference of the International Group for Lean Construction*. Elsinore. Denmark.

Benjaoran, V, Dawood, N and Hobbs, B., 2005. Flowshop scheduling model for bespokeprecast concrete production planning. Journal of Construction Management and Economics, 23 93-105.

Chan, W.T. and Hu, H., 2002. Constraint programming approach to precast production scheduling, *Journal of Construction Engineering and Management*, 128 513-521.

Dawood, N.N., 1993. Knowledge elicitation and dynamic scheduling using a simulation model: An application to the precast manufacturing process. *Proceedings of the Civil-Comp93. Part 4: Knowledge Based Systems for Civil and Structural Engineering*, 73.

Dawood, N.N. and Neale, R.H., 1993. Capacity planning model for precast concrete building products. *Journal of Building and Environment*, 28 81-95.

Dawood, N.N., 1996. A simulation model for eliciting scheduling knowledge: an application to the precast manufacturing process. *Journal of Advances in Engineering Software*, 25 215-22.

Hopp, W.J. and Spearman, M.L., 2000. *Factory Physics: Foundations of Manufacturing Management*. 2nd edition. New York: McGraw-Hill.

Khan, A., 2003. The role of inventories in the business cycle. *IEEE Engineering Management Review*, 31(4): 39.

Ko, C.H. and Ballard, G., 2004. *Demand variability and fabrication lead time: Descriptive research. phase I*. Technical Report. University of California at Berkeley. Berkeley. CA.

Ko, C.H. and Ballard, G., 2005. Fabrication lead time and demand variability: An empirical study. *Proceedings of the Construction Research Congress*, American Society of Civil Engineers. San Diego. CA: 17-21.

Ko, C.H. 2010. An integrated framework for reducing precast fabrication inventory. *Journal of Civil Engineering and Management*, 16(3) 418-427.

Leu, S.S. and Hwang, S.T., 2002. GA-based resource-constrained flow-shop scheduling model for mixed precast production. *Automation in Construction*, 11 439-452.

Pulat, B.M. and Pulat, P.S., 1992. A decoupling inventory model and an application. *IEEE Transactions on Engineering Management*, 39(1) 73-76.

Riley, D.R., Diller, B.E., and Kerr, D., 2005. Effects of delivery systems on change order size and frequency in mechanical construction. *Journal of Construction Engineering and Management*, 131(9) 953-962.

Spearman, M.L., 2002. *To pull or not to pull. what is the question? Part II: making lean work in your plant*. White Paper Series. Factory Physics. Inc.: 1-7.

Vern, K. and Gunal, A., 1998. Use of simulation for construction elements manufacturing. *Proceedings of the Winter Simulation Conference*, 2 1273-1277.