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Intelligence approach to production planning system for bespoke precast concrete products

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Abstract

Bespoke precast concrete products are widely used components of construction projects. These products implement the offsite prefabrication technology that offers a unique opportunity for innovation and cost savings for construction projects. However, the production process from design to manufacturing contains uncertainties due to external factors: multi-disciplinary design, progress on construction site. The typical workload on bespoke precast factories is a complex combination of uniquely and identically designed products, which have various delivery dates and requirement of costly purpose-built moulds. In this context, this research is aimed to improve the efficiency of the process by addressing the production planning because it has a significant impact to the success of the production programme. An innovative planning system and its prototype called 'Artificial Intelligence Planner' (AIP) are developed. AIP is capable of two functionalities. The first is a data integration system that encourages the automation in the planning process. The other is a decision support system for planners to improve the efficiency of the production plans. These functionalities reinforce each other to deliver optimum benefits to precast manufacturers. AIP have employed artificial intelligence technologies: neural network and genetic algorithm to enhance data analyses for being a decision support for production planning. The outcomes of the research include shortened customer lead-time, in-house repository of production knowledge, and achievement of the optimum factory's resource utilisation.

Keywords: Precast concrete products; Production planning; Artificial intelligence; Offsite prefabrication

1. Introduction

The precast industry is a major supplier of offsite-prefabricated components to the construction industry. The construction of a building can be regarded as an assembly of hundreds of different designs and delivery dates of 'bespoke' precast concrete units. This demand creates the difficulty in the bespoke precast production. 'Bespoke' precast production system is in 'make-to-order' or 'engineer-to-order' style. Bespoke precast production has a major distinction from ordinary 'mass production' that every time the process is started from new product design. The complexity of bespoke precast production is based on this ground. Since the production is less uniform, the 'learning curve' is hard to establish and the automation is hardly implemented to assist the process. The optimum resources utilisations are serious issues of precast manufacturers. The production planning of this product kind requires sophisticated management and it is a key of the success of the delivery program, customer lead-time competitiveness, and the effective utilisation of purposed-built precast mould. Despite these, the current practice of the production planning is very plain and effortful. The earliest due date rule (EDD) is traditionally being used by the bespoke precast industry as a scheduling method. It is a simplified method regardless of resources considerations [1].

The aim of this research is to develop a new (semi-automatic) planning system to manage bespoke precast production called the 'Artificial Intelligence Planner' (AIP). AIP is designed to assist the production planning process. It functions as data integration and decision support system

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that supports the automation in the planning process and increases the efficiency of production plans. AIP employs a kind of technologies called ‘artificial intelligence’ (AI). AI typically is composed of sophisticated algorithms, which have the ability of analysing and processing data similar to human’s intelligence. AIP powered with these AI technologies can be implemented by planners as a decision support system and help reduce human involvement (consequently, increase automation) in the planning process. In fact, the AI technologies have been introduced to the construction and manufacturing industries for many decades. Its successful applications and usefulness have been presented in many research studies and are increasing by the time. Two AI used in AIP are ‘neural networks’ (NN) that is applied to estimate the manufacturing time required for any unique product design and ‘genetic algorithm’ (GA) that is used in the scheduling optimisation to search for optimal results. In addition, this AIP system conforms to IFC (Industry Foundation Classes), which is the ongoing development aimed to integrate all processes of the whole life cycle of construction projects. The application of AIP can help include a part of precast concrete usages and managements [21].

2. Artificial Intelligence Planner (AIP) approach

Operations of AIP start from gathering input data to finally arrange efficient production plans. Fig. 1 illustrates an overview system model of AIP. The primary input data of the bespoke precast production process come from the external sources (project designers and contractors of construction projects). These are project drawings, product specifications, and construction schedules. In a dynamic environment, the precast product designs and delivery schedules are created to conform to both external input data. The bespoke precast concrete production process mainly includes product design, production planning, and manufacturing. The production planning is further broken down into three elementary tasks including quantity take-off (preparation of material and job lists from designs and specifications), productivity estimation, and production scheduling. AIP consists of components that are designed and developed to assist these particular planning tasks: they are namely ‘Graphic Data Extractor’ (GDE), ‘Processing-Time Estimator’ (PTE) and ‘Production Scheduler’ (PS). GDE is designed to assist the product design for the quantity take-off task; PTE is assigned to assist the productivity estimation; and PS is for the production scheduling tasks. The details of development of these components are described in the following sub-sections. Also, the AIP system implements data integration technology through the ‘Central Database’ (CDB) to manage historical and current project data. The data in AIP’s transactions of current project are integrated and consistent while historical data can be analysed and used. The ultimate outcome of the system is the high quality of precast products resulting from short customer lead-time, effective factory resource utilisation, and satisfaction of delivery requirements.

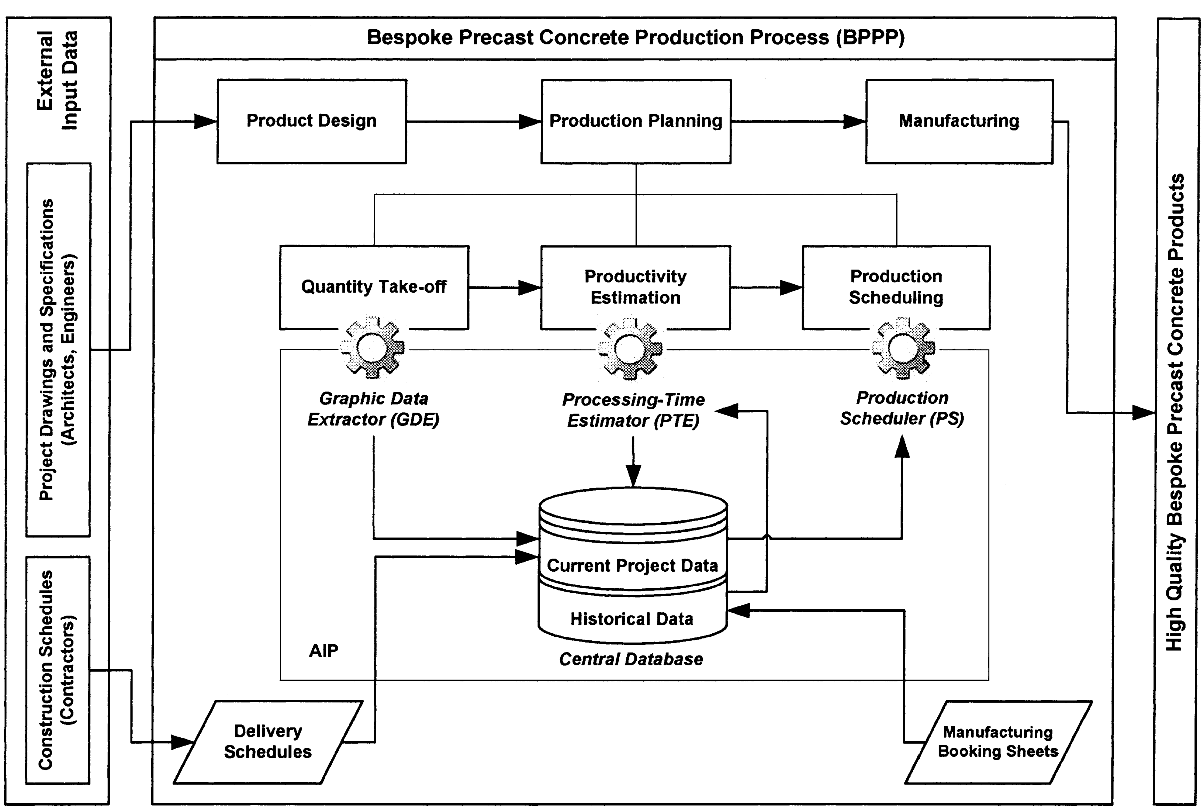

Fig. 1. Overviews of the bespoke precast concrete production and the system model of AIP.