EXPLORING LEAN AND BIM: IMPROVING THE PERFORMANCE OF ENGINEER-TO-ORDER CONCRETE PREFABRICATED SYSTEMS

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1 Background and Research Aim

The growing need to reduce the duration and cost of construction projects, as well as to improve building quality and working conditions, has encouraged the adoption of prefabricated building systems. However, the adoption of those systems requires intense exchange of information between the construction site and the plant in order to synchronize the production of components, logistic operations and site assembly. These occurs especially in an engineer-to-order (ETO) environment, in which the level of uncertainty tends to be high. The literature suggests the use of Building Information Modeling (BIM) to facilitate the sharing of information and to support decision-making in this type of environment, as well as the application of Lean Production concepts and principles. The aim of this study is to propose a set of guidelines for the use of 4D BIM and Lean Production concepts and principles to support logistics management in engineer-to-order prefabricated concrete systems. Those guidelines were classified into two categories: standardization of logistics processes, and adoption of pull production.

2 Research Method

Design Science Research (DSR) was the research approach adopted in this investigation. The research process was divided into the following phases: understanding the problem, development of the artefact, and analysis and reflection. It was conducted in close collaboration with the Company A, similarly to an action research process. Company A delivers complete solutions of prefabricated concrete structures for building projects in Brazil, often involving customised components. This research study was focused on the delivery of prefabricated concrete structures for a university building project, located in Porto Alegre. The study lasted 11 months, covering the whole period of site assembly. Multiple sources of evidence were used in this investigation: unstructured interviews with production managers, document analysis (schedules, drawings, etc.), participant observations in four short-term planning meetings, and direct observation in the concrete prefabrication plant (2 visits) and in the construction site (25 visits), and three workshops with representatives of Company A.

3 Research Findings

Standardization of logistics process:

1. Define the scope of information for developing the 4D BIM model

The model should contain a scope of well-defined, useful and comprehensible information to support decision-making by all users. The main potential user is the site management. However, other possible users may participate of planning meetings, such as other managers of the company, representatives from other companies and subcontractors involved in the project, foreman and assembly trades representatives. The 4D BIM model typically contains information about the prefabricated components, including component identification data, location and orientation of the component according to the defined axes, temporary facilities, pathways and main equipment. The level of development of the BIM model was defined according the aim of the 4D models, because

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this has implications on the time spent on creating the 4D model. It is necessary to create a coding system for the components and for assembly activities, in order to facilitate information exchange and update. Again, colour coding can be adopted for work packages, which makes it easier to identify assembly batches.

2. *Find consensus in collaborative processes*

4D modelling should support collaboration between different stakeholders in planning meetings, so that the decisions about standard procedures are consensual. The use of BIM can also potentially result in better understanding of the assembly processes by stakeholders. The collaboration between stakeholders can contribute to increase plan reliability.

3. *Use visual tools for disseminate information*

Besides the visualization of the model in a digital form, visual tools can be used to disseminate relevant information. Snapshots can be created for representing specific details, and used to control the assembly process by comparing 4D models and real activities. Thereby, process transparency is increased, contributing to the rapid detection of possible deviations.

Adoption of pull production

4. *Analyse system status and control work-in-progress*

The existence of variability and uncertainty in the construction site, such as changes in the assembly sequence, interferences by other processes, design changes, demand frequent updates in the long-term plans. Thus, it is necessary to define confirmations points in the production of components at the manufacturing plant, and in the delivery of components at the construction site. Those confirmation points avoid the need to increase work-in-progress and the amount of components stored at the plant yard and at the construction site. For those confirmations to occur, the status of the assembly process as well as of the production of components need to be considered, according to the concept of pull production proposed by Hopp and Spearman (2000)[5].

5. *Integrate the use of BIM 4D models and logistics decisions to different levels of production planning and control*

At the long-term level, the main decisions are concerned with the division of the project into stages and definition of the sequence of large assembly batches. Based on those decisions. it is possible to define deadlines and this information is used by the plant to reserve the necessary capacity to fulfil the site demand. At the medium-term level, constraint analysis related to site logistic processes should be undertaken. At this level, the assembly sequence can be defined at a high level of detail, because is necessary to define assembly batches and, consequently, fabrication and transportation batches. Theses batches should be relatively small and flexible considering fabrication, transportation and assembly capacities. Lastly, at the short-term level some definitions about work packages should be made, and the delivery of components need to be confirmed according to production status.

6. *Integrate fabrication and assembly information*

Considering the need to use information from design, the assembly process status, and the availability of components for delivery by the plant, information technology and, particularly, BIM models play a key role in the integration of up-to-date information from different sources to support decision-making.

4 CONCLUSIONS

The main contributions of this study are related to the use of BIM 4D for standardizing logistics operations, and for managing information related to system status. By using BIM integrated with data from site assembly and production of prefabricated components at the plant in real time, the exchange and update of information become more reliable, enabling the synchronization between the prefabrication of components and site assembly.

[5] Hopp, W.J., Spearman, M.L., 2000. Factory Physics.