BIM based Schedule Control for Precast Concrete Supply Chain

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Abstract - Development of the schedule control of precast concrete supply chain has been studied. Main idea was to use BIM model created by structural engineer as a user-interface for schedule control, for saving different status information of the real-time schedule situation of the propagation of structural design, element manufacture, delivery and site erection directly to the BIM model by using a cloud-based networked service. Some of the missing software applications were programmed by the software companies participated in the project. Experiments were done in a real construction project in Finland, where the information from design, prefabrication, delivery and erection phases was synchronized between the stakeholders by using the cloud service. The most important observations and results are introduced and analyzed. A future model for intelligent BIM based schedule control concept is concluded.

Keywords - BIM, supply chain, schedule control, precast concrete

1 Introduction

Since the use of building information modelling (BIM) to design tasks has increased a lot in most industrialized countries, more and more attention has been paid to BIM model utilization in production phases, such as prefabrication, transportations and on-site assembly and erection works. Schedule control is one of the key management issues in the control of BIM based production flow. Traditionally schedule planning is made using special schedule software such as Microsoft Project, Primavera's Project Planner, Vico Control, etc.

The extension of CAD based design to schedule management has been studied and developed as a part of so called 4D CAD research area. The main idea has been in combining 3D CAD models with construction activities to display the progression of construction over time (visual intelligence for construction management). 4D models have used to link components in 3D CAD models with activities from the design, procurement, and construction schedules. The final 4D production model allows stakeholders to view the planned construction on the screen and to review a 3D CAD model for any day, week, or month of the project. Stanford University has also developed a special 4D interface for the interactive use of 4D models for planned schedule examinations. [4] Even though the construction industry has used BIM-based schedule management for year, an automatic information flow management between the project's stakeholders has not been generalized.

Newt Finnish BIM guidelines (COBIM) require that the critical installation dates for designated structures and systems needs to be saved in the building information model. The BIM-based schedule must also be distributes for other parties' use in an agreed format. Model views must be shared with other parties without the need for separate BIM-based software. [2]

Precast concrete elements, precast concrete wall panels or other components are usually fabricated in a central plant where industrial production techniques are used, then hauled to the construction site and erected.

The information flow during supply chain of the precast building element is important. Traditionally the propagation of design, prefabrication, delivery and erecting information has been handled by traditional methods, such as e-mail, phone and by fabricators project portal. Generally, traditional forms of information dissemination in construction industry are seen ineffective and time-consuming. [1][3][5][8]

By using 4D CAD / BIM models combined with cloud service, information batches as called as statuses of building element give important information for project stakeholders of the propagation of the supply chain. Each building element can be followed in the supply chain individually. The status information in the precast building element supply chain is divided usually in four phases: design, fabrication, delivery and erection.

The aim of this research was to study the BIM-based supply chain management of precast concrete elements.

2 Methods

Scheduling has to be integrated as a part of the BIM-based supply chain management. The schedule changes in the supply chain have to be linked to the scheduling program used. All the delays on the critical path should to be visualized in the modelling program (integrated modelling and scheduling).

In the experiments, the main idea was to use BIM model created by structural engineer (used Tekla Structures) as a user-interface to the schedule control, save different status information of the real-time schedule situation of the propagation of structural design, element manufacture and site erection directly to the BIM model by using a cloud based networked service. Experiments were done in a real construction project in Finland, where the information from design, prefabrication, delivery and erection phases was synchronized between the stakeholders by using the cloud service.

The basis of the data transfer was an online information management system, Trimble Connected Community (TCC) cloud service, through which Extensible Markup Language (XML) files containing status updates were transferred. To mitigate the risk of losing traceability of the precast elements the precast elements were tracked by Globally Unique Identifiers (GUID) through the supply chain.

An example of the XML language is shown in Figure 1. In the code each attribute has a UDA (User Defined Attribute) name, for example “PLANNED_END_DEL”, type “DATE” and value “2013-10-07T00:00:00”. Value indicates both date and time.


```
<?xml version="1.0" encoding="utf-8" ?>
- <StatusSharing xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www...
  - <ModelObject Guid="ID4F41EDF8-0000-0931-3133-323937343833">
    - <Attributes>
      - <Attribute>
          <Name>FAB_DESIGN_STATUS</Name>
          <Type>STRING</Type>
          <Value>2</Value>
        </Attribute>
      - <Attribute>
          <Name>FAB_STATUS_CONC</Name>
          <Type>STRING</Type>
          <Value>10</Value>
        </Attribute>
      - <Attribute>
          <Name>PLANNED_END_DEL</Name>
          <Type>DATE</Type>
          <Value>2013-10-07T00:00:00</Value>
        </Attribute>
      </Attributes>
    </ModelObject>
```


Figure 1. An example of XML language in Status exchange.

Structural designer’s and contractor’s status updates were entered manually into Tekla Structures UDA tab pages. Installed external TS Status Sharing extension operated as collecting and synchronizing tool between TS native model and the cloud service. The Status Sharing tool maps and writes above-mentioned code from all the building elements which have the certain attribute information. Transferred attributes can be settings as shown in Figure 2. Stakeholders can act also only as a recipient part, which enables utilization also for project’s customer.

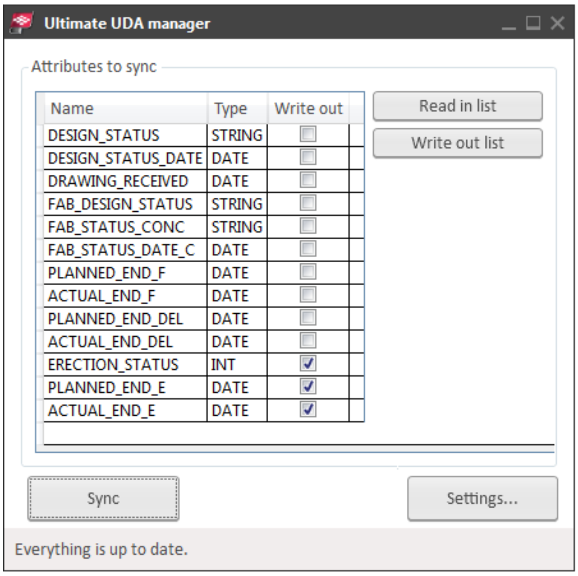

Figure 2. User interface of Tekla Structures’ Status Sharing tool.

A link to collect the status information from precast manufacturer’s ERP (Enterprise Resource Planning) was created in order to automatize the exchange of fabrication and delivery information to the cloud service. The link was coded to the database of ERP in PL/SQL. On the basis of defined project, the link was ordered to collect all demanded statuses from the ERP by GUID. Collected data was used to create a XML-file which complied with TS definition. XML-file was written by using the UTF-8 character set. The fully automatic and daily file transfer to TCC was completed by using FTP-application.

The exchange of status information was tested between the structural engineer, the manufacturer and the general contractor. The method was tested in 2013 in the pilot project (As Oy Kauniasten Kvartetti, Kauniainen, Finland), where the information from the design, fabrication, delivery and erection phases was synchronized between the stakeholders by using the cloud service (*Figure 3*). [6]

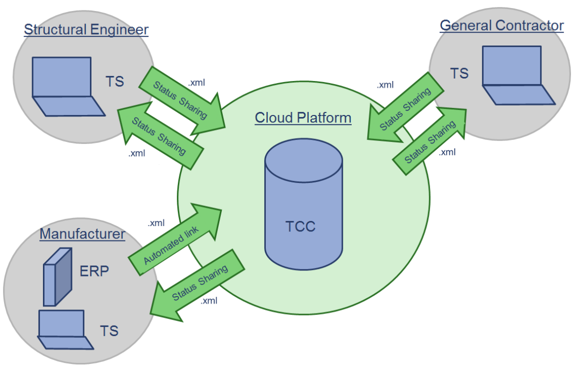

Figure 3. The system used to the status information exchange.

The status information was manually entered into the modelling program in the structural engineering office and in the construction site. An automated link was created between the manufacturer's ERP and the cloud service in order to automatize the exchange of the fabrication information. All status information was readable and visualized in the participant's Tekla model using predefined color-coded visualizations (*Figure 4*).

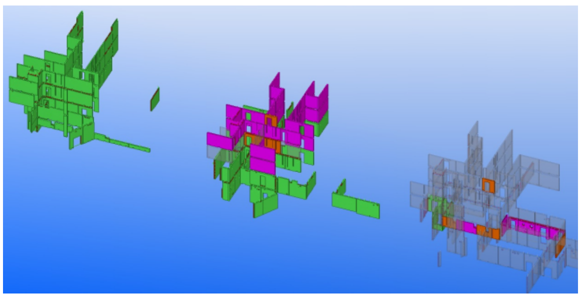

Figure 4. An illustration about the schedule situation (green – erected, blue – design delayed, light brown – fabrication delayed, pink – delivery delayed, orange – erection delayed), As Oy Kauniaisten Kvartetti, Kauniainen.

The most important target in the scheduling process of precast concrete elements (Table 1) was the sending of fabrication drawings to the factory (4-6 weeks before delivery) by the structural engineer and the sending the erection plan to the factory by site personnel (3-4 weeks before delivery). Site personnel ordered the elements on site 1-2 weeks before deliver by email. As the separate scheduling software, Vico Control program was used to make a master schedule of the project. On the basis of Vico's schedule, more accurate element-specific schedule was done in Tekla Structures (TS).

To ensure a functional supply chain, anticipation needs for the scheduling has to be done carefully. Time value attributes in BIM offer considerable scope into advanced project management. This leads to a chance to calculate predictions of probable duration of the project. Simple assessments of each task durations are adequate in first step. Furthermore, risk analyses could be put into practice using standard methods of probability calculus in some extent. *Table 1* presents values for scheduling.

Table 1. Anticipation needs for the scheduling of precast concrete elements.

Main phases of supply chain for precast concrete	**Weeks before the start of the delivery**
- Tender inquiries of the separately detailed concrete elements	13-18
- Delivery contract	10-15
- Kick-off meeting for the separately detailed concrete elements,	12-14
- Source data for the design	9-14
- Schedule for separately detailed concrete elements	9-14
- Information about special material and deliveries	8-10
- Element diagrams	8-9
- Exploratory elements	6-7
- Kick-off review for the example of the concrete element	5-6
- Shop drawings by sections, Starting the fabrication, Rough installation schedule	4-6
- Erection plan by the sectors and stories	4-6
- Kick-off meeting for installation	1-2

3 Results

The experiences of the method were very encouraging. The exchange of status information succeeded with stakeholders. The main objectives were achieved – the exchange of status information was easy-to-use, adequate real time and reliable. Reliable, transparent and daily exchange of the status information substantially improved the information flow between the stakeholders. The project stakeholders were able to follow daily design, fabrication, delivery and erection progression of the construction project. Progress information was valuable for all the participants of the project. The structural engineer was able to find out if there was still a possibility to change the plans before the element was fabricated. The precast manufacturer's main target was to produce reliable data for the use of other stakeholders. Also, the precast manufacturer had an easy method to follow the design phase and also the planned erection dates in order to space out the fabrication. The method to track precast concrete elements onsite has been changed from the use of spreadsheets and color-coded drawings to the real time, transparent method, where site personnel can see at a glance if the manufacturer is producing elements in the correct construction sequence and on schedule.

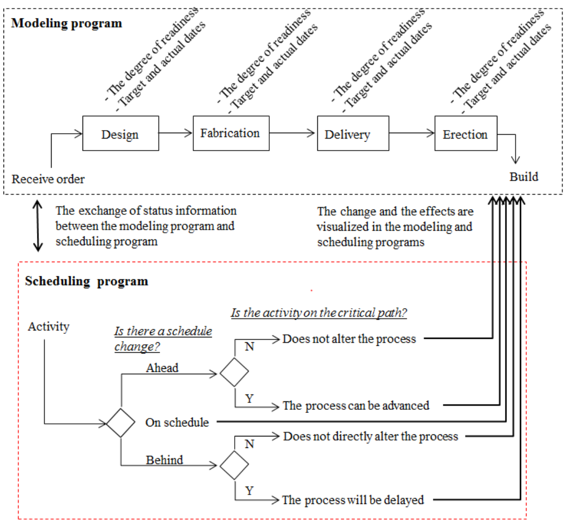

Figure 5. An integrated modelling and scheduling.

The next step to improve the scheduling process is to integrate the real-time status information exchange to scheduling program in order to affect the schedule when changes occur. Principle of a future model for intelligent, integrated and social BIM-based design and schedule software is presented in Figure 5. On the basis of status updates, the method would enable the automatic comparison of the changes in the precast supply chain with the project schedule, and the effects of the changes, such as design-delays, could be estimated and visualized. At the moment only the colour visualization of delayed building elements is possible.

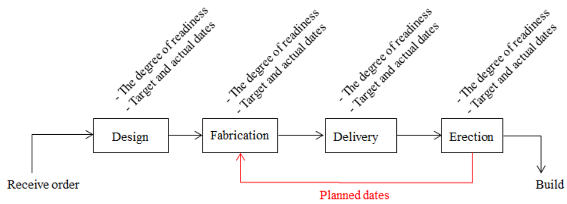

Figure 6. Exchange of status information leaves more time to make last-minute changes to the fabrication process.

Also, as the site personnel are obligated to inform the manufacturer about the schedule changes in erection order, BIM-based status information exchange provides a tool to leave more time to make last-minute changes to the fabrication and delivery processes (Figure 6).

Also, the method should enable to verify, which elements has been given a new status. A way to inform the viewer that something has changed is needed. Only visual detection is allowed right now.

4 Conclusion

The experiments using the status information exchange system introduced were successful. The exchange of the status information into the BIM-based supply chain process can be easily implemented. In Finland, the exchange of status information into BIM-based supply chain process has already been successfully implemented. When status information production is properly configured, the cloud based approach enables unlimited numbers of information producers and consumers. Moreover, it does not depend on specific features of any cloud service of ERP system but should be possible to implement with any of them.

In control of the schedule, the saving of different status information into building information model facilitates the tracking of schedule situation in design, fabrication, transportation and site erections. However, the information entering remains manually in the designing and erection phases. In future, in order to ease the information management, the information entering phase should take place as a natural part of normal processes. Huge potential is seen in the integration of BIM-based design software and commercial schedule software is a soluble problem. Integration and comparison of the changes in the supply chain to the project schedule require more investigation. Especially integrating scheduling software using efficiently BIM information and the method described above is seen to have great potential to improve schedule control in building sector.

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