MODEL-BASED PRODUCTION FOR ENGINEERED-TO-ORDER JOINERY PRODUCTS

Niclas Björngrim[1], Lars Laitila[2], Samuel Forsman[3], Peter Bomark[4]

ABSTRACT: When supplying Engineered-To-Order (ETO) joinery products to the construction industry, the manufacturer often takes responsibility for the whole value stream, from request for quotation to final assembly on the construction site. There are, however, gaps in the information flow between each actor in the internal supply chain, leading to quality concerns. One of the issues comes from the lack of routines concerning documentation of both changes and additions to the original plan. To make up for the lack of documentation, the craftsmen rely on their skills and experience, often leading to unnecessary and time-consuming *ad hoc* solutions. Each actor in the chain spends time rediscovering previously known information instead of referring to the documentation. In this paper we suggest a model-based approach, utilizing information and communication technologies (ICT) that enables improved dissemination of relevant information to the involved actors.

KEYWORDS: ETO joinery production, Model-based production, information and communication technologies (ICT)

1 INTRODUCTION [1]

When supplying ETO joinery products for the construction industry, the ETO joinery-products supplier often has responsibility for the whole value stream from quote/order through surveying, production preprocessing, manufacturing, logistics and final assembly on the construction site [1, 2]. Important information in the supply chain is lost and does not reach all the actors involved in the internal supply chain. Forsman *et al.* [2] found that there is a large amount of waste present when supplying joinery products for construction and suggests that information and standardization in communication are main areas for improvement. The joinery-product suppliers' process could be enhanced by utilizing 3-D measurement techniques and information and communication technologies (ICT) tools such as Building Information Model (BIM) [3], Last planner [4], Line of Balance (LoB) together with 4-D CAD [5], *etc*. These tools could help increase dissemination of information in the joinery-products suppliers' internal value stream. BIM is interesting for the information sharing. However, the information in 3-D BIMs does not generally contain details of a facility and therefore does not reflect how the building actually was built [6]. Joinery-products suppliers need as-built information rather than planned spatial spatial information as a basis for production. The objectives of this paper are to introduce a more efficient information carrier than 2-D drawings. A 3-D model based approach is proposed.

2 METHOD

The focus in this study has been on gaining detailed understanding of the information flow in the value stream for ETO joinery-product supplier supplying to construction. A Swedish ETO joinery-products supplier has been observed through one of its projects. The studied joinery-product supplier is a Swedish association consisting of ten production companies and a co-owned

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sales company. Attention has been paid to the information flow from quote/order, surveying, production preprocessing, manufacturing and logistics to final product assembly on the construction site. During surveying, the information needed for defining the products is acquired, and this information is assumed to be of major importance. The lack of information through the internal value stream is assumed to materialise during the assembly, hence the special attention on surveying and assembly. The case study also consists of semistructured interviews with key personnel from the departments responsible for sales, production preprocessing, manufacturing, logistics and assembly. The interviews focused on how the organization relates to the surrounding actors. On-site observations were performed during surveying, during manufacturing in the production facilities and extensively during assembly and have been documented through notes, photographs and audio recordings. To improve the productivity for joinery-products companies, ways to improve the internal process through modelling of information and coordination have been explored. Potential improvements in efficiency resulting from the application of new technology such as 3-D measuring and modelling and principles of information management are discussed.

3 RESULTS AND DISCUSSION

Here the current process for the joinery-products supplier is described and ways to improve the process are discussed. Figure 1 shows the value stream of the current process.

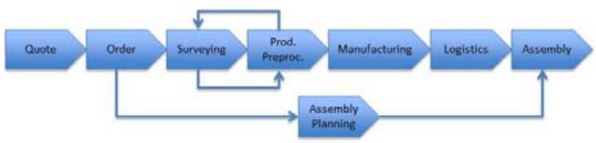

Figure 1*: The value stream from quote to assembly.*

3.1 QUOTE/ORDER

Generally, sales process quotes are made in two steps, a preliminary quote for construction contractors making a quote to a client and a final quote to the construction contractor who received the client order. This procurement process normally involves supplier competition. Sales base their quote on the architectural drawings. By using a BIM, the joinery-products supplier could have a better basis for pricing their product.

3.2 SURVEYING

The production preprocessor determined important dimensions from the architectural drawing. Those dimensions where later measured at the construction site by a surveyor. The current process relies on manual measurement techniques done with folding rulers and tape measures, with 2-D information written directly on a printout of the architectural drawing (Figure 2). The printed drawing acts as the main carrier of information. Faults in drawings can be difficult to detect until on-site assembly has begun. The geometrical information is needed to complete the production preprocessing, and complementary measurements were needed to get all important dimensions. By using 3-D digitizing equipment, the surveying would provide the production preprocessor a complete and accurate depiction of the site. The 3-D data depict the whole on-site environment and negate the need for eventual secondary on-site measurements. For capturing the correct construction site data, coordination between surveyor and construction contractor is necessary.

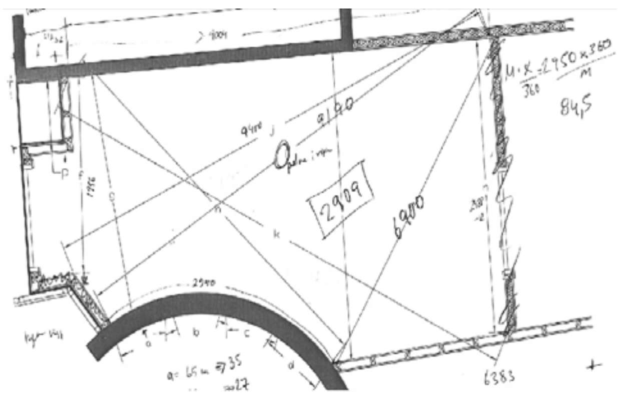

Figure 2*: A simplified drawing that the surveyor used at the construction site to insert all important dimensions.*

3.3 PRODUCTION PREPROCESSING

The surveyors' geometrical verification in 2-D is the basis for defining the joinery products' dimensions. The production preprocessor defines a product from the given dimensional information, develops production methods and schedules the production start. Since joinery production requires tighter tolerances than construction in general, there is a need to verify the geometrical shape of the environment and compare it to the construction drawings. The geometrical verification leads to dimensional uncertainties. The dimensional uncertainties make it necessary to produce products to be adjusted to fit during the on-site assembly. With an accurate 3-D depiction of the adjacent environment, joinery products could be produced to fit without adjustments.

3.4 MANUFACTURING

Manufacturing of the products is performed on the basis of information from preprocessing. This information is mediated mainly on 2-D CAD drawings and a manufacturing bill. A production plan is used to show the time demand for the manufacturing. Errors in the joinery product are hard to discover from the 2-D model. A 3-D CAD model gives the opportunity to inspect the joinery product before manufacturing and can minimize time-consuming design errors (Figure 3). 3-D CAD also gives the opportunity to automatically generate tool paths in CAM software.

***Figure 3.** Design error, the laminate is missed on the top of the lower shelf.*

3.5 LOGISTICS

After manufacturing, the products are packed to fit on the pallet, rather than grouped to facilitate assembly. A product declaration of content is supplied with the parcel; however, observations show that this is an area of frequent failure. Lack of complete information caused delays in assembly when the personnel had to open several parcels to find the related components. There was no concern of the internal logistics on the construction site when the parcels were put together. The parcels did not fit the in-transport routes of the site, forcing the assembly personnel to open the parcels and carry the components to the right floor (Figure 4). This is not only time consuming, but also involves the risk of damaging the joinery products and causing injuries to personnel due to bad lifting positions. The shipping of parcels should be coordinated with the needs of assembly, rather than the time of manufacturing. Visualization of in-transport routes and the final product could eliminate these problems.

***Figure 4**: Parcel opened and carried into elevator due to parcel design not fitting in-transport route.*

3.6 ASSEMBLY

The planning of the assembly is performed concurrently with production. Since projects are geographically spread, the strategy applied is to contract assembly contractors close to the construction site. The main tasks of the assembly planning are to contract assembly and coordinate with production. The product assembly is performed on site and requires time to develop understanding of the product to be assembled. During assembly, there are no instructions provided, and the information from the 2-D drawings is used as support, sometimes with additional sketches from the preprocessor. Having a 3-D model of the site would be of help for the construction personnel to visualize the joinery product and the environment where it will be assembled. Assembly instructions or exploded views were not supplied to the assembly contractor. The planning of the assembly has a start date and a stop date, but there is no daily or weekly planning. Coordination between the manufacturer and assembly personnel is needed as well as with other actors performing work on the construction site. The assembly contractor needs to communicate with the production preprocessor in order to develop an understanding of how to assemble the product. Communication was done by phone, but could have been avoided if good assembly instructions had been provided. Because of the lack of spatial information about the construction site, products are manufactured to be adjusted to fit. This process requires lot of craftsmanship instead of assembly work. Assembly problems are solved *ad hoc* and the root of the problems is not investigated. Having complete spatial dimensions of the site would increase the level of prefabrication of the joinery products, thus making assembly rely less on craftsmanship and more on installation work.

3.7 MODEL BASED PRODUCTION

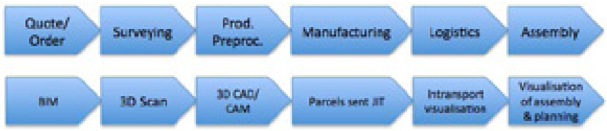

Figure 5*. Value stream map of the improved process and how information should be built.*

To enhance the process and keep the information updated and accessible for the suppliers in the whole value stream, we propose a 3-D model-based process as seen in Figure 5. Information is created through the whole value stream and information dissemination between the actors is improved. In order to improve the quality of joinery products for construction, more of the as-built spatial information needs to be known and to be more accurate than in the current process. The 3-D information must be based on as-built dimensions rather than as-planned spatial dimensions of BIMs [6]. To facilitate dissemination of project information to the different actors in the internal value stream, it is suggested that all information be retained in digital format. When sales receive the order, a visualization of the site provides a better basis for estimating the quote. Surveying with a 3-D digitizer enables acquisition of the spatial information needed for creating products with good fit and provides a tool for visualizing and planning of assembly. By using 3-D CAD, the fit of the model can be assured virtually in the 3-D scan or in a surface/solid model created from the scan data (Figure 6).

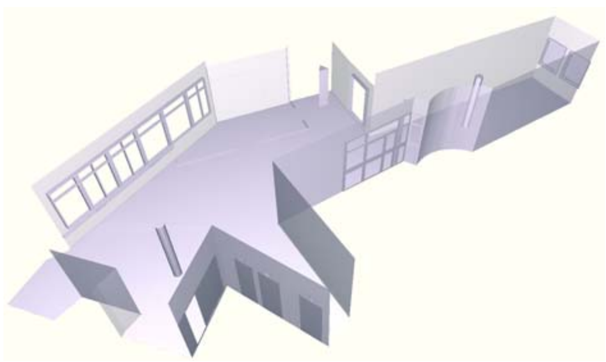

Figure 6*: 3-D model of construction site.*

The model consists of a wide range of information such as dimensions, surface finish, tolerances and URLs. In this stage, the model can also be prepared for machining (CAM). If the manufacturer has a better understanding of the final product, it is easier to send parcels with the right components at the right time. The manufactured parts can be sent correctly packed, in parcels that fit in-transport routes at the construction site. The visualization of the site is used to make sure that parcels will fit in-transport routes, eliminating the need for repacking of the parcels. During the assembly, the 3-D scan together with the CAD models can be used with various planning tools [3, 4] to make assembly more efficient by visualizing where a product should be placed and when.

4 CONCLUSIONS

In the current process, the main information carrier is printouts of architectural drawings with added information. This information can be difficult to interpret and needs to be further processed in order to create CAD models for production. The information in the drawings offers little support for the assembly. A higher degree of utilization of ICT and planning tools is suggested in order to create accurate and accessible information for all actors in the internal value stream. When information is available to all involved actors early in the process, a more concurrent approach is possible, which means that several tasks can be done in parallel. Providing better spatial measures results in joinery products with higher quality and better fit, which will make assembly less time consuming. The knowledge gained from different projects could be accumulated and used to facilitate future projects.

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