MANAGING BUILDING INFORMATION AND CLIENT REQUIREMENTS IN CONSTRUCTION SUPPLY CHAIN – CONSTRUCTOR'S VIEW

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ABSTRACT

Supply chain management (SCM) has been undervalued subject in the construction process. Effectiveness of the supply chain and information interaction, are fundamental requirements of the industrialised construction having immediate influence on construction productivity. Information management methodologies in the construction are not at the same level as in some other industries mainly due the fragmented project based business models. In the last 10 years, the building information model (BIM) technologies have become common in design phase and gained critical mass for credible usage as a platform for construction planning and management, and for product data management in supply chains. However, the participants in the process interpret the project information from design documents differently. Interpretation actualises in several phases of project without systematic data management. The use of intellectual information on virtual model is unsystematic and users of models exploit the data manually. The current construction process sets also restrictions to the implementation of BIM technologies, but the BIM based building design itself will improve the construction process and reduce the errors with real 3D design work, and better compatibility of design disciplines. Now the accomplishment of all these benefits is not necessarily possible.

The main objective in on-going research is to develop a comprehensive BIM based product data management procedure for the supply chains in industrialised construction process. This requires the definition of the process and needed methodologies that the stakeholders in networked construction branch can apply to get product and production information in an electronically interpretable format, and update their subset of this information. In this paper, we will define the key challenges and possibilities for BIM based supply chain management between main contractor and product suppliers. This paper rests on the observations made in product group specific workshops, interviews and meetings related to three different kinds of product groups.

Keywords: supply chain management, BIM, construction

1 INTRODUCTION

1.1 Supply chain management in construction

As an output, buildings are unique, immobile and have high amount of variety. This has led to extensive use of subcontractors and caused fragmented nature of the whole construction industry (Morledge, Knight and Grada 2009). Considering this and current business environment, the supply chain management (SCM) is an undervalued subject in the construction process. The focus has been heavily in the client's perspective bypassing the role of the main contractor (Pryke 2009). Morledge, Knight and Grada (2009 p. 39) suggested that supply networks would better describe supply chain management in construction due to the "less permanent or secure relationship".

SCM influences directly on the effectiveness of construction (Winch 2010). Fundamental requirements of the industrialised construction have immediate influence on construction productivity.

However, due to the lack of standardisation in the construction industry, same levels of productivity and quality control have not been achieved than for example in the manufacturing industry, which has successfully applied SCM techniques (Morledge, Knight and Grada 2009).

Information interaction is the key process to be handled in SCM. Information processing systems are in core of the organisations and projects; however, huge amount of uncertainty is always attached in the management of information (Winch 2010). Lots of information needs to be changed during the construction project between different parties in the supply chain. There have been attempts to control material flows on site based on just-in-time (JIT) approach, however, there has been challenges to apply this in the construction sector (Ng, Fang and Shi 2009).

1.2 Information management methodologies in the construction

There exist more advanced information management methodologies in other industries than in construction. This is likely a result of the fact that the business models in construction industry are very fragmented and the business is heavily project oriented (e.g. O'Brien et al. 2002; Rezgui, Zarli and Hopfe 2009). BIM technologies have become more common in design only during the last 10 years, but large number of challenges still exists. Identified challenges relate to interoperability, interfaces with other systems, ownership of BIM, integration of wired and wireless sensor networks to enhance the real-time data collection and processing on site, change management during the construction phase, and controlling the access to project information and ensuring the information security and privacy (e.g. Winch 2010; Shen et al. 2010). BIM technologies have nowadays gained critical mass for credible usage as a platform for other construction information management systems (Cutting-Decelle et al. 2007). ICT applications in tendering phase can be divided into two different groups, collaborative and integrative i.e. web-collaborative extranets and project integrated databases (Ajam, Alshawi and Mezher 2010). Some examples of key challenges of current applications identified by Ajam, Alshawi and Mezher (2010) are:

- Hierarchical complicated routes of communication
- Primarily a manual driven process that utilises exclusively hard copy-based format
- Lack of proper quality control procedures
- Lack, inconsistency or incompatibility of tracking and control systems
- Obsoleteness of information utilised
- Inability to efficiently and effectively incorporate changes
- Lack of an entity responsible for the coordination, synchronisation and management of the whole process
- Cultural resistance to any introduced change
- No clear delineation of scope of works
- A large portion of risks were transferred to the contractor and tenderers

1.3 Current use of project information

The participants interpret the project information from design documents and BIM files, contractual documents etc. for they own needs (Koch and Firmenich 2011). Same activities, e.g. data collection and interpretation, are repeated in several phases. In ideal case, each piece of information is entered only once (Cutting-Decelle et al. 2007). Activities also often overlap with each other and same information is entered multiple times into different systems.

The version-oriented models are commonly used in construction industry compared to change-oriented models; however, this causes several limitations in relation to the exchanging, comparing and merging different versions of models (Koch and Firmenich 2011). For example, current systems have limitations to store the histories of documents in a linear fashion and even if the models are capable to store huge amount of information, using them as native application models is expedient. Koch and Firmenich (2011) have proposed two-dimensional approach to building modelling, building state and building behaviour, which they call *processing-oriented* modelling. This approach is expected to overcome the current limitations by:

- Supporting both revisions and variants
- Preventing information loss due to model change interpretation
- Determining and visualising changes in model
- Ensuring model consistency

When the virtual model exists, the intellectual information included in the model is used unsystematically and often the data have to be interpreted mainly manually. Before the use of BIM can be realised in wider scale in the industry, standardisation and changes in legal frameworks need to be conducted as well (Olatunji 2011). A decade ago solutions for integrating document management were developed (Hajjar and AbouRizk 2000). Current solutions are based on integrating object models with document management systems (Ajam, Alshawi and Mezher 2010).

In the following sections, we will present the key challenges and possibilities for BIM based supply chain management between a main contractor and product suppliers based on 3 workshops and 20 interviews. A specific feature of this project is that the participating companies are doing research in cooperation, but administratively they all have their own company-specific project, of which they are responsible for the financier. The work has been started in active cooperation between the participating companies by identifying and evaluating important product groups and key phases of a whole building project, and the research efforts has been focused to concrete issues. Through these cases, a wider perspective will be taken in research and covered in the future proceeding as a so-called bottom-up principle. The project involves one contractor and three product suppliers representing steel frames, precast concrete elements and standard construction products.

2 RESEARCH METHODOLOGY

2.1 Interviews, workshops and working meetings

The objective in the interviews was to identify the initial situation of utilisation of BIM and product information management in the participating companies, and to define their individual objectives and expectations for the research. The interviews were conducted in Finland as a part of wider BIM-related research programme called Built Environment Process Re-engineering (PRE). After the first set of interviews, each of the three product suppliers joined a workshop with the main contractor. At first in the each workshop and work meetings, the contractor and the supplier gave a presentation introducing the use of BIM in the company and expectations for the research, or researchers gave a presentation about product specific possibilities that modelling can offer in projects. In addition, question lists were used to lead the discussion to such issues as the product information exchange between the main contractor and the supplier, and related current problems, as well as the most important products and project phases from viewpoint of a specific product group. The presentation was followed by a discussion about needs and possibilities of current procedures. In those three workshops, specific products from each supplier were chosen as a target for the analysis in order to be able to achieve profound knowledge about the related procurement and supply processes, as well as the possibilities related to use of BIM in these cases.

After the first three main workshops, about 10 work meetings with fewer participants has been conducted in order to study more closely the separately identified subjects. For example, separate work meetings were held for standard products in relation to two phases of a building project: 1) design phase and 2) planning and construction. The results will be generalised at the later stages of the research to cover different types of products, so that the exploitation of the results is possible among the whole industry.

2.2 Methods for analysis

Management of product data, information content and modelling method of the chosen products have been introduced and analysed gradually in the workshops and work meetings. Participants from each company have included business developers and people working with the information in each phase. This enables combining of practical experiences of information requirements and current problems with research objectives. This method was considered also the best approach when choosing the relevant direction for research and preliminary committing operative bodies to exploit the research results in the future.

3 FINDINGS

3.1 Design management

We could identify seven key areas related to challenges and possibilities for BIM based supply chain management between a main contractor and product suppliers. First of the areas is design management, where it is important to clarify how the model based design provided by a product supplier is connected to the architectural and structural design of the building project. There are also possibilities to develop controlling and management of design status information with help of BIM so that delays in design could be identified early enough to avoid disturbances on construction work at site.

In order to improve the constructability of the design, there is also a need to clarify possibilities for the product suppliers to have an earlier access to a project so that they can influence on the design solutions or offer their own solutions. For example, in Finland, in residential construction, the main contractor orders the precast concrete elements typically based on the designs made beforehand by an external structural engineer, not based on the dialogue with the supplier. However, the same product suppliers are usually involved earlier in projects relating to commercial building projects, and may develop the optimal structural solutions in cooperation with the main contractor. In that case, the product supplier is usually responsible for the design, manufacturing and installation of the products. This same approach could be applied in residential construction, at least in relation to steel frames and precast concrete elements.

The product suppliers could comment feasibility and safety viewpoints of the designs made by architects and structural engineers, who often do not have enough knowledge about how the chosen solutions influence on manufacturing production and installation work at site. For example, hollow core slabs may be designed by an inexperienced structural engineer causing extra work for element supplier in form of corrections and design changes. The product suppliers could also provide alternative solutions, for example for structural frame, to be evaluated and compared with the beforehand made designs. As far as a supplier gets a possibility and responsibility for design of a product or building parts, the same company will be responsible for modelling of his own products as well.

3.2 Identification of construction products and building parts digitally in various systems

Second challenge relates to the identification of materials and building parts in separate systems utilized by different project parties (product identifiers and nomenclatures). Product identifiers and nomenclatures are needed in BIMs so that the content of the model and requirements of the building elements can be interpreted efficiently and unambiguously during the different phases of the supply chain. Identification information is also needed during the maintenance phase of the building.

In this context, product identifiers and nomenclatures are attached especially to mass-produced articles, while analysing product group specific procedures and use of type or unique identifiers of building parts are related especially to project specific products like concrete elements and steel frame. In design phase, BIM includes generic product definitions, which will be revised as specific product brands during the procurement. Some information about product brands is needed into BIM, but it is not clear yet, for which parts, in which phase and by whom that data should be stored into BIM.

Alternatives as product identifiers when managing supply chain can be found in both national and international codes and nomenclatures. In practice, the companies that are participating in the research project are multinational corporations, which makes the international options interesting for them, and raises also the question whether IFD (International Framework for Dictionaries) will develop to serve as international solution or not. The goal is that modelling libraries and identification codes used are such that the building components and materials can be identified regardless of the designer. In addition to uniform use of the nomenclatures, this requires that the modelling and naming of building parts in models are made by following the same principles in different design offices. Considering standard products, it should be possible to collect product requirements efficiently from the model so that the requirements can be compared with the available products in the market.

3.3 Utilisation of BIM in cost estimation and tendering process

Thirdly there are challenges related to the use of BIM as a source of quantities for cost estimation and tendering process. The product and quantity information obtained out of BIM should be reliable and identical when generated and used by different parties (contractor and product supplier). For example, when costs of all specific products can be calculated based on the information acquired from the model, this increases the accuracy of the calculations made by the supplier and confirms the accuracy of the overall costs relating to the whole project from the contractor point of view as well. The goal is that the main contractor will get well-established and controlled BIM based tender from e.g. precast element supplier. However, the measurement methods related to BIM based calculations differ from established and traditional calculation principles.

On the other hand, if product suppliers will have accurate quantities from BIM, they could use time more valuably to analyse the solutions or the tendering period could be shorter. Nevertheless, the contractor and product supplier should define together the content of the tendering material as a whole, including BIM, because now there is a lot of variation in the material used. The exploitation of BIM in the calculations requires disciplined modelling and product information recording practices affecting on the content requirements of the model, modelling practices, and identification information needed in the model. In addition, the principles of BIM based and traditional quantity calculations need to be revised and compared.

3.4 Providing accurate product and quantity information to site staff

Providing accurate product and quantity information to the site personnel at the right time, correctly itemised and grouped is a challenge related to the use of BIM during the construction phase. For example, the quantities are often recalculated on site because the plans have become more accurate, they have changed after the cost estimation phase, or the quantities need to be defined more accurately for all installed parts and products on site.

The product, location and quantity information is needed during the building frame construction, for example about the single elements, cast-units or several parts in specific area to be cast at one time. Additionally, accurate product and quantity information is needed for lifting the interior work materials, gypsum boards for light partition walls and ceramic plates for internal surfaces, on vault of a specific story and section of the building already when setting up the frame. Quantity information from interior building elements is also needed when scheduling the works.

Today, use of BIM during the interior work phase is very limited on site . Reasons effecting on this are for example the inability to use several different BIM-based software on-site to view models, models from different disciplines (HVAC, structural and electrical engineering) cannot be combined as one model keeping all essential information from each model as well as visual appearance of the original model. Additionally, all information (e.g. all building parts and surfaces) needed on-site are not modelled. In practice, the product information is collected during interior works mainly from traditionally used documents like specifications created by the architect in the project.

3.5 Improving logistics of incoming materials on site

Next challenges are related to identified possibilities to improve material logistics by managing and sharing product, quantity and status information in a project with the help of BIM. The use of unique entity identifiers and status information in relation to project specific products needs to be unified between the different project parties. This enables the sharing of the real time status information related to design, manufacturing, construction and installation on the site so that the information can be exploited for example when planning deliveries or defining the building parts needed at the construction site on some given moment. Deliveries should also follow the shipment and delivery plan agreed between the site and product supplier.

Combined material deliveries that are just on time (JOT) enable the lifting of products directly to a specific position on vault without the need to intermediate storing and additional transfers on site. In this case, BIM enables the access to more accurate information about quantities than traditionally used when planning the deliveries. However, this demands product identifiers that are accurate enough to be used in model-based quantity take-off. In more general, the deliveries arriving to the site should be planned so that unnecessary intermediate storing can be avoided (i.e. not to deliver all products and materials to site at one time or full loads of specific items). Status information concerning e.g. building elements, materials and lots coming to the site should be managed in the same way as 4D scheduling and construction status information is carried out.

3.6 Recording and saving as-built-data into BIM or database

Maintenance information of products installed into building during the construction phase should be available for facilities management. Possibilities and expectations exist to improve the storing and management of that information with the help of BIM. Relevant questions then are what product data is collected to BIM for maintenance phase, whether the data is handed over to the client in BIM or as a list generated out from the model, and how the instructions and maintenance manuals of used products needed for maintenance are linked to the model. Detailed product data of used products might be needed to be tracked also as a demand from authorities, or users can be interested afterwards about the used materials.

3.7 Legal status of BIM-based information in construction projects

Finally, the lack of legal status relating to BIM in design and construction contracts restrains the generalisation of BIM-based and automated data exchange. 2D drawings are official documents and the model is still provided as additional information. As a result, today, designers do not take responsibility about the quality of models and the contractors cannot then trust the content of models and exploit them at full scale for example as a source of quantity information or when reviewing design details. BIM-based plans are not used as a basis for tenders from product suppliers or as a basis of contracts.

4 CONCLUSIONS

The research project seeks to find answers to three main questions: how product information is collected from BIMs to supply chain, how this information is exploited during the design and construction process, and how the as-built data is collected from the site back to the models to serve maintenance activities. Ideas collected from the interviews and workshops have been analysed to clarify following issues in the cooperation between the contractor and the suppliers:

- Usage of BIM in managing product information and supply chain in specific product groups
- Define effects of project type (e.g. residential or commercial properties) on BIM-process
- Describe tasks, information flows and use of BIM-based tools in renewed construction process
- Define the role and tasks of a company that is producing mainly standard products and bulk materials in BIM-based construction process and product data management procedure
- Define alternative logistics control procedures and variations on data management
- Evaluate BIM-based design, especially functionality of the modelling objects
- New tendering and procurement methods

In this paper, we have defined the key challenges and possibilities for BIM based supply chain management between main contractor and product suppliers. Together with existing literature in the field, this paper concludes a holistic approach to the issue. Following Table 1 summarises the identified theoretical frameworks based on the challenges presented in empirical part of this paper.

Table 1: Summary of findings and related theoretical frameworks

Finding	Identified theoretical frameworks
1. Management of design and planning	Processing-oriented modelling approach (Koch and Firmenich 2011)
2. Identification of construction products and building parts in various systems of parties in construction project	Interoperability (Winch 2010), the development and potential of international classification systems
3. Utilisation of BIM in cost estimation and tendering process	Integrating object models with document management systems (Ajam, Alshawi and Mezher 2010)
4. Providing accurate product and quantity information to site staff	Systems integration and collaboration (Shen et al. 2010)
5. Managing logistics of incoming materials on site	Just-in-time (JIT) and activity-based simulation (Ng, Fang and Shi 2009)
6. Recording and saving as-built-data into BIM-database	Processing-oriented modelling approach (Koch and Firmenich 2011)
7. Legal status of BIM-based information in construction projects	Legal frameworks, contracts (Olatunji 2011)

This research will continue by aligning the above presented issues according to the later agreed order of importance among project participants. After the product group based results are documented, the new procedures, modelling and data management practices will be tested in pilots i.e. existing construction projects, and best practices will be described, analysed and collected as a vision of industrialised construction. The designers' role was not included in this study as a separate entity even if design phase is one of the key areas and such being important separate research topic.

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