A BIM-centred big data platform to support digital transformation of the AEC industry

Abstract—This paper reports on a case study that has been performed at a medium-sized Dutch construction company. We propose a reference architecture and data platform to help overcome the barriers of BIM (Building Information Modeling) adoption by the Architecture, Engineering, and Construction (AEC) industry and to support digital transformation and transition to smart industry.

1. Background

Traditionally, the Architecture, Engineering, and Construction (AEC) industry relies heavily on the use of paper-based communication. This is a major source of errors resulting in extra costs, delay, friction and even lawsuits in the construction process, since AEC projects typically involve complex communication-intensive processes across multiple organizations. For example, Hendrickson and Au (2008) describe a large scale project ($10M+) comprising 420 companies, 50 different types of documents, spanning 56.000 pages. It is therefore no surprise that the AEC industry has long searched for techniques to decrease communication errors, project costs, increase productivity and quality, and reduce project delivery time (Shalman, 2011). The concept of Building Information Modelling (BIM) has the potential to help achieving these goals (Azhar et al., 2008).

In the first version of the National BIM Standard-United States (NIBS, 2007, p.21), BIM is characterized as "a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about the facility forming a reliable basis for decisions during its life cycle from inception onward. A basic premise of BIM is the contribution of different stakeholders at different phases of the facility's lifecycle to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder."

2. Problem

Many construction and civil engineering companies already use BIM in their building projects. However, there are mixed perceptions and opinions of the benefits of BIM, leading to a general misunderstanding of its expected outcomes (Barlish and Sullivan, 2012). Yan and Demian (2008) found that the most important barrier to BIM adoption is the effort and costs of BIM training. This seems in line with a more recent study of BIM adoption in the Dutch construction industry (BouwKennis, 2015). This study also concluded that the required training for and knowledge of BIM is the number one concern regarding BIM adoption. A close second is 'difference in BIM usage between parties'. One of the major benefits of BIM is the potential it offers for facilitating digital collaboration between the many stakeholders in a construction project. This benefit is however complicated by both technical (lack of interoperability between BIM software vendors) and organizational factors (fear of collaborating with competitors, ownership of data, cost sharing, etc.). In the AEC industry, the level of detail denotes how detailed a model is in describing a construction project. The LOD ranges from 100 (sketch) to 500 (as-built with the real specifications for all elements). Song et al. (2017) discovered that only a low percentage of daily work orders from the construction site had corresponding elements in BIM with a medium level of detail, and that higher levels of detail (which are supported by BIM) are therefore critical.

3. Goal

As mentioned above, the most notable technical reason AEC companies are not yet reaping the full benefits of adopting BIM is the lack of interoperability between BIM implementations, organizational barriers for collaboration, and different maturity levels of using BIM across but also within organizations. In view of this, we argue that a *reference architecture* and a *data platform* are useful artifacts to help overcome these barriers. A reference architecture could embed generic AEC processes and link them to BIM elements, and a data platform could support the flexible delivery of data from BIM compliant applications to business processes. AEC companies can assess their maturity level by referring to this reference architecture. The reference architecture may be complemented with a roadmap that provides guidelines on how to migrate from their current level to a higher level, while mentioning the relative benefits of the higher maturity levels. AEC companies can use the data platform to overcome the technical interoperability problems, but also as a means to achieve more 'intelligent' delivery of data or data-driven services. The goal of this paper is therefore to support the digital transformation and transition to smart AEC industry by using a BIM-centered reference architecture and data platform.

4. Approach

After having conducted a literature study on the state-of-art of BIM adoption by the AEC industry, we investigated the use of BIM in a medium sized Dutch construction company. We have explored typical intra- and inter-organizational processes and identified the input/output data requirements of these processes. Our idea is to compare the data requirements with the elements of the BIM standard, and analyze whether the current use of BIM can be improved. More precisely, we want to focus on three points: i) understand the extent to which BIM elements are correctly and consistently used for the data requirements of processes, ii) identify processes that cannot be linked to BIM elements and their data requirements, and iii) find opportunities to adapt processes (and their data requirements) such that they can become more effective/efficient in making better use of available BIM data. In this way we obtain insights in the shortcomings of current processes and how they can be improved. We propose a roadmap for the AEC industry (especially medium-sized companies) to improve BIM integration (BIM maturity status). The road map is supported by a reference architecture, which models processes and their relation to BIM. The road map and the reference architecture can be seen as a conceptual support tool for the digital transformation of medium-sized construction companies.

An important component in the reference architecture is a data platform for BIM integration. We consider this to be a large data platform because of the volume and variety of BIM data elements and the multitude of concurrent users. The ultimate goal of our research is to develop a prototype of this data platform. In this paper we discuss its main features and architecture and we give an account of the current development status of the prototype. The platform supports the interaction between a BIM-compliant storage layer and a data-dependent process layer. The platform separates the process layer from the various existing BIM software packages/vendors, and makes the storage layer independent of specific input/output data formats of process implementations. Moreover, the platform enables processes to subscribe to certain events that result in BIM data updates, and be informed about such events when they occur. Building on this functionality, the platform can be extended with a knowledge layer that interprets data events as a representation of the current status of a project in progress, compares the status with an expected or desired status, and takes appropriate actions (makes recommendations, send reminders, etc.) in case of threshold-exceeding deviations.

5. Solution Design

While investigating a medium sized Dutch construction company, it became clear that a gap exists between the possibilities of BIM described in the extant literature, and the actual usage of so-called BIM models in practice. We found that BIM is currently used extensively in the planning and design phase of a construction project; mainly for collision testing and collaboration with subcontractors. An initial design is shared with subcontractors using a standard file format called Industrial Foundation Classes (IFC)[1], after which it is finalized through collaboration with subcontractors. However, it seems that the BIM model and data are rarely used later during the construction process, despite the identified benefits of BIM in existing literature. Data from the model is sometimes used in further processes, but always manually and in a very ad hoc fashion (see figure 1). Our findings are corroborated with earlier research at a another medium sized construction company in the Netherlands (van Berlo et al., 2015).

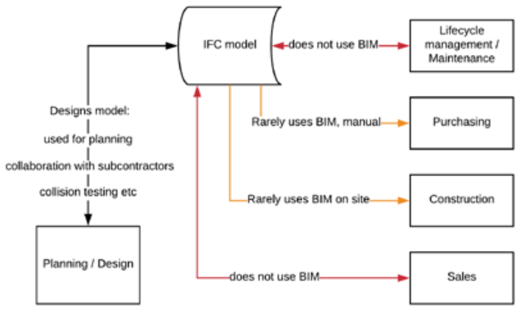

Figure 1. Current situation regarding BIM usage

The same data is stored in multiple locations, requiring manual actions to extract and use, despite being available in the BIM model as well. This leads to possible data inconsistencies and a lot of extra work. The ideal situation would be to have BIM as a single data source, allowing each of the processes/departments to interact with it, and enrich the same source data (see figure 2). To achieve this BIM-centric approach, it is imperative to have integrations between applications used by these processes, and the BIM platform. This also relieves users to fully learn BIM tooling, which is one of the major impediments of BIM adoption.

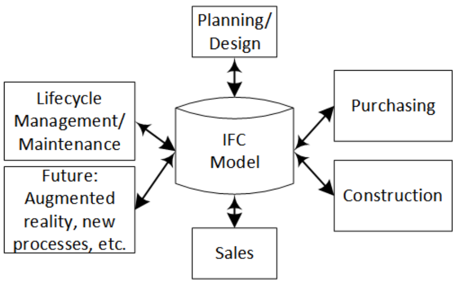

Figure 2. Desired BIM-centric situation

For the prototype we connect one process, namely the purchasing process, with a central BIM storage solution, which makes use of the IFC standard for the models. As

[1] IFC is considered the industry standard for BIM models.

storage solution, we use the BIMServer. BIMServer is an open source model server allowing stakeholders to collaborate on central repositories of BIM models (Beetz, Jakob, et al., 2010). The first step is to provide an example of successfully integrated intra-organizational processes first and to develop a useable Common Data Model (CDM). This in turn hopefully leads to less impediments in the future, when shifting towards an inter-organizational collaborative platform. For the integration, we use a message bus architecture, implemented in the eMagiz Integration Platform as a Service (IPaaS). The CDM will be based on the messages in the BIM Service interface exchange (BIMSie)[2]. For the Purchasing Portal a simple demo application developed in Mendix is sufficient. This all leads to the architecture shown in figure 3.

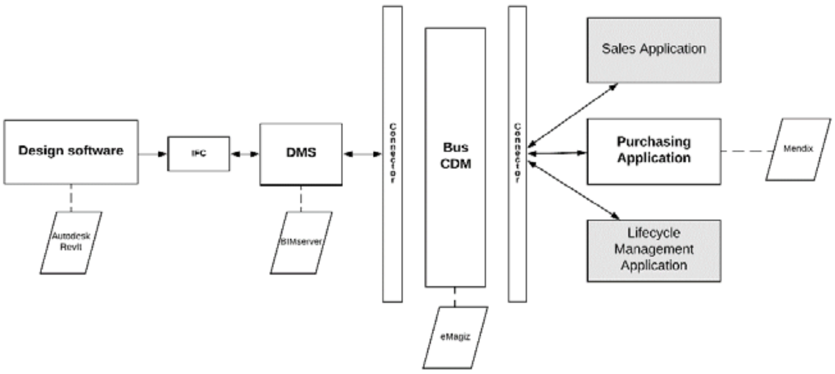

Figure 3: BIM-centred solution architecture

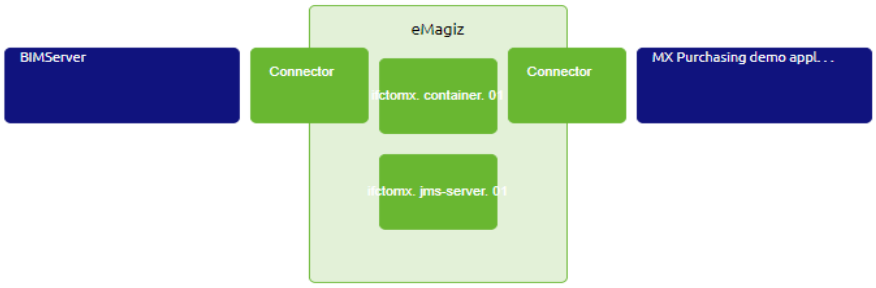

Figure 4: eMagiz Architecture & first iteration of Common Data Model

Figure 4 shows the eMagiz architecture of the Bus CDM component of the architecture. The CDM is used as common ground between the connectors used to connect the BIMServer with the purchasing portal (and similar applications). eMagiz is in charge of translating all the incoming and outgoing messages to this CDM. All internal transformations are handled in the main container, while a JMS server takes

2 https://www.nibs.org/?page=bsa_bimsie.

care of all messaging operations. This architecture allows other applications and even other subcontractors to easily connect to the existing system in the future.

6. Conclusion

Building Information Modelling (BIM) is the future for the construction industry. While existing research has determined it to be useful for many different tasks and processes, in practice we found extensive use during planning and design, but limited use during other steps of the construction process. In order to allow other processes to also profit from the data stored in BIM, we propose a BIM-centred platform, which is currently prototyped and validated for a purchasing process of a medium-sized Dutch construction company. The goal is to further develop and improve this prototype, extending the scope to other processes and opportunities for integration.

References

S. Azhar, A. Nadeem, J. Mok, and B. Leung. *Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects.* First International Conference on Construction in Developing Countries, 2008, pp. 435–446.

K. Barlish and K. Sullivan. *How to measure the benefits of BIM — A case study approach.* Autom. Constr., vol. 24, pp. 149–159, Jul. 2012.

BouwKennis. *BIM & Ketensamenwerking in Kaart.* July 2015.

C. Hendrickson and T. Au. *Project management for construction: Fundamental concepts for owners, engineers, architects, and builders.* Version 2.2, 2008. Online: http://pmbook.ce.cmu.edu/

National Institute of Building Sciences. *NBIMS version 1.0.* 2007. Online: 5http://www.1stpricing.com/pdf/NBIMSv1_ConsolidatedBody_Mar07.pdf

A. Salman. *Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry*. Leadership and Management in Engineering, vol. 11, no. 3, pp. 241–252, Jul. 2011.

M. H. Song, M. Fischer, and P. Theis. *Field Study on the Connection between BIM and Daily Work Orders.* J. Constr. Eng. Manag., vol. 143, no. 5, May 2017.

H. Yan and P. Demian. *Benefits and barriers of building information modelling.* Twelfth International Conference on Computing in Civil and Building Engineering, Beijing 2008.

L. van Berlo, G. Derks, C. Pennavaire, P. Bos, P. *Collaborative Engineering with IFC: common practice in the Netherlands.* In Proc. 32nd CIB W78 Conference, 2015.

J. Beetz, J., L. van Berlo, R. de Laat, P. van den Helm. *BIMserver.org–An open source IFC model server.* In Proc. 27th CIB W78 Conference, 2010.