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A Building Information Model-centered Big Data Platform to Support Digital Transformation in the Construction Industry

This chapter 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 building information modeling (BIM) adoption by the architecture, engineering, and construction (AEC) industry and to support digital transformation and transition to smart industry.

26.1. 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 [HEN 08] describe a large-scale project ($10M+) comprising 420 companies, 50 different types of documents, spanning 56,000 pages. It is therefore not surprising that the AEC industry has long searched for techniques to decrease communication errors, project costs, increase productivity and quality, and reduce project delivery time [AZH 11]. The concept of building information modeling (BIM) has the potential to help achieve these goals [AZH 08].

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In the first version of the National BIM Standard – United States ([NIB 07], 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".

26.2. 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 [BAR 12]. Yan and Demian [YAN 08] 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 [BOU 15]. 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 (LOD) 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.* [SON 17] 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.

26.3. Goal

As mentioned, 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.

26.4. Approach

After completing 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 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 (1) understand the extent to which BIM elements are correctly and consistently used for the data requirements of processes, (2) identify processes that cannot be linked to BIM elements and their data requirements, and (3) find opportunities to adapt processes such that they can become more effective/efficient in making use of available BIM data. 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. The roadmap is supported by a reference architecture, which models processes and their relation to BIM. The roadmap and the architecture can be seen as conceptual support tools for the digital transformation of medium-sized companies. An important component in the reference architecture is a data platform for BIM integration. We consider this to be a *big data* platform because of the volume and variety of BIM data elements. The ultimate goal of our research is to validate the platform with a prototype. In this paper, we discuss its main functional features and we give an account of the current prototype status. 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. The platform can be extended with a knowledge layer that interprets data events as a representation of the status of a project in progress, compares the status with the expected or desired status, and takes appropriate actions (send reminders, etc.) in case of threshold-exceeding deviations.

26.5. Solution design

While investigating the 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 an industry standard file format called Industrial Foundation Classes (IFC), and subsequently finalized through collaboration with subcontractors. However, it seems that the BIM model and data are rarely used later during the construction process, despite the benefits of BIM claimed in existing literature. Data from the model is sometimes used in further processes, but always manually and in an ad hoc fashion. Our findings are corroborated by earlier research at another medium sized construction company in the Netherlands [BER 15]. 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 extra work and possible data inconsistencies. 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 26.1). 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 of the need to fully learn BIM tooling, which is one of the major impediments of BIM adoption.

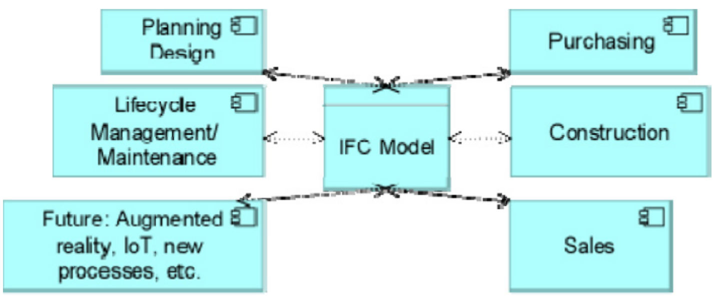

Figure 26.1. *Desired BIM-centric situation. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

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 storage solution, we use BIMServer. BIMServer is an open source model server allowing stakeholders to collaborate on central repositories of BIM models [BEE 10].

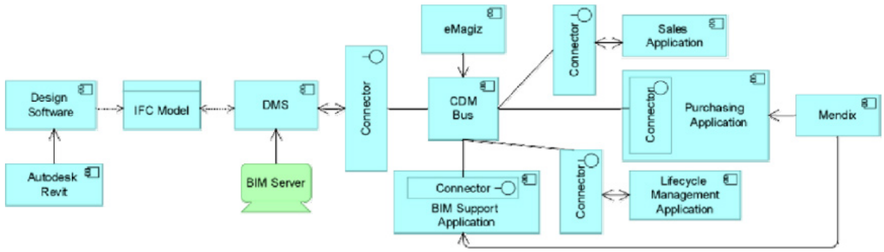

Figure 26.2. *BIM-centered solution architecture. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

We hope to ease the shift towards an inter-organizational collaborative platform, by providing an example of successfully integrated intra-organizational processes and developing a Common Data Model (CDM). 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)[1]. For the Purchasing Portal a simple demo application developed in Mendix is sufficient. This leads to the architecture shown in Figure 26.2.

An extra Mendix application, referenced in Figure 26.2 as BIMSupport, is used to store the IFC data required to enrich IFC data in the external applications. It enables the purchasing application to use its own terminology rather than having to store IFC terminology in all connected applications. See Table 26.1 for an example.

	BIMServer/ BIMSupport Object	Related Purchasing Object
Type	IfcDoor	Door
GUID	22erBPISX01uqcwczID30V	
ObjectID	600492430	
ArticleNr		
Name	swedex_draaideur_SL01	swedex_draaideur_SL01

Table 26.1. *Purchasing data object in relation to BIMSupport object*

Figure 26.3 shows the eMagiz architecture of the bus component of the architecture. The bus, using the CDM, is used as common ground between the

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

connectors used to connect the BIMServer with the purchasing portal (and other similar applications).

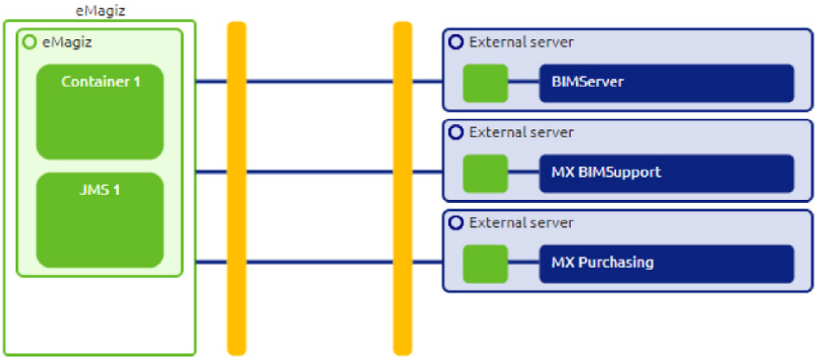

Figure 26.3. *eMagiz architecture. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

eMagiz translates all incoming and outgoing messages to the CDM. The internal transformations are handled in the main container, while a JMS server takes care of all messaging operations. All messaging services on both sides of the bus use the SOAP protocol and are in XML format. This architecture allows other applications and subcontractors to easily connect to the existing system in the future. The prototype is capable of retrieving all IfcTypes from the model, selecting the ones relevant for the purchasing application, and translating object information to the correct purchasing terms. These objects can then be enriched in the purchasing application with manufacturer information, which is then stored back into the original model.

26.6. Conclusion

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-centered platform, which we prototyped for the purchasing process of a medium-sized Dutch construction company. We believe this platform provides a good foundation for BIM-centered integration. The prototype provides AEC companies with a clear example of how BIM data can be used and integrated into their processes. It is extendable for further process integration, as well as inter-organizational integration. The goal is to further validate and improve this prototype, extending the scope to other processes and opportunities for integration.

26.7 References

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