BIM IMPLEMENTATION AND PROJECT COORDINATION IN DESIGN-BUILD PROCUREMENT

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Various procurement methods have been proposed as being more appropriate for implementing BIM. Simultaneously, BIM implementation affects the project coordination. Whereas many approaches to BIM implementation have considered integrated procurement, not all are applicable to various local markets. Particularly in the Netherlands, BIM implementation is characterized by 'ground-up' and self-regulated initiatives. This paper aims to explore and identify the relationship between design-build procurement and the emerging coordination structures from BIM. Exploratory case study research has been undertaken. The findings included two main coordination structures: centralized and decentralized. These two structures subsequently carry implications for various construction firms and their respective business models, as well as BIM implementation in general.

Keywords: Building Information Modelling, coordination, management, procurement

INTRODUCTION

The supply chain of the Architecture, Engineering and Construction (AEC) sector is highly fragmented. A building is usually designed by numerous domain experts with different disciplinary inputs and afterwards, a builder is engaged to execute this design on site. Winch (2002) defines the AEC project team as a temporary project network, a coalition of small firms and specialties that are assembled for a project-specific goal. Poor performance in AEC is attributed to this temporary network. The design process is clearly separated from construction and the project information generated and shared across phases is often unreliable and difficult to access due to lack of team and process integration. The overall management of design and construction is achieved via the emergent function of the project manager. Forgues and Lejeune (2015) argue that traditional project management is ineffective, as the project manager has little control over the various actors' tasks' interdependences. Despite the many years of criticism over this separation of design and construction, and many national initiatives proposed, e.g. Egan's Report in the United Kingdom (UK), fragmentation and poor project coordination continue to be a challenge that hampers productivity in AEC.

In the past decade, Building Information Modeling (BIM) has been considered a solution to fragmentation, poor project coordination and information management problems (Eastman *et al*., 2008). The promise is that BIM and its associated processes and

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technologies, facilitate simultaneous work by multiple design disciplines. It provides a platform for integrated information exchange through model federation. BIM challenges the traditional configuration of the supply chain. BIM requires new roles and new workflows. On one hand, many BIM-specialized companies emerge. Some offer all-inclusive BIM-related services to AEC firms and on projects. The services sometimes encapsulate the traditional project management services as well as technology and information management-related services. On the other hand, various in-house roles pertinent to BIM have emerged within existing firms. New project organization, project coordination structures and processes, distribution of responsibilities, tasks and risk allocations emerge, due to advancements in BIM.

The AEC sector needs more insights into emerging structures from BIM. Will BIM lead to the demise of the traditional project network or will the traditional project network align with the features of BIM and re-invent their workflow and interactions? This paper aims to present and discuss lessons-learned from BIM implementation in two cases in the Netherlands. It would examine and compare the project coordination structures that emerged from BIM implementation in Design-Build projects, and the actors' roles. It will also attempt to shed light on the impact that the various structures had on the cases, i.e. challenges and outcomes. The findings would inform and assist AEC firms to improve their BIM adoption processes to reap its acclaimed benefits.

THEORETICAL FRAMEWORK

The concept of BIM

Eastman *et al*., (2008) define Building Information Modelling (BIM) as ‘a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital, machine-readable, documentation about a building, its performance, its planning, its construction, and later its operation.’ The adoption of those tools, processes and technologies is a 'building information model'. With BIM a building can be represented in a digital, computable and intelligent 3D form, where all information pertinent to realization can be stored. The input from the various design disciplines, contractor, suppliers and subcontractors can be sought early in the design process; and potential problems, e.g. clashes and constructability issues, can be resolved digitally.

The design stages can be overlaid by the BIM Level of Development (LOD). LOD describes the dimensional, spatial, quantitative, qualitative, and other data included in a design model (AIA, 2013). The LOD can help designers define and manage information richness of the design over the design stages. Thus, BIM could eliminate waste in project delivery if applied appropriately (Eastman *et al*., 2008). BIM is seen as a radical innovation that will change how building information is represented, manipulated, and shared (Eastman *et al*., 2008). The changes in the sharing of building information would further induce changes in project organization and coordination. However, the maturity of BIM tools, technologies, processes, knowledge and skills could play a significant role in the success of BIM implementation. On its way to maturity, BIM implementation would continue to stimulate new coordination structures and would carry implications for project collaboration, procurement and how production in AEC is organised in general.

Project procurement and BIM implementation

Procurement can be defined as ‘the organisational structure adopted by the client for the management of the design and construction of a building project” (Masterman 1992). Uher and Davenport (2009) describe it as ‘the process by which the client seeks to satisfy his [or her] building requirement, characterised by a particular organisational form, distribution of responsibility, tasks and risk allocation'. Turner (1997) identified two essential decisions in procurement (1) the organisation for the overall project management, and (2) the organisation for design and construction.

The organisation for the overall management of project involves client's decisions for either using an in-house project manager or an external project management or a combination of the two. The role of the project manager is to oversee the organisation of the different work parts, define project scope, plan and control project deliverables, (Forgues and Lejeune 2015). The organisation for design and construction involves decisions about how those two would be brought together, either in a fragmented or integrated way. It also entails the allocation of design responsibility and the timing of the contractor's involvement – either early in the design or after design for the purpose of construction only. This has given rise to various procurement methods before BIM.

Turner (1997) classify the procurement routes into (1) design-led (2) designer-led, and (3) management-led. Other procurement routes have also emerged to address the need for creating value and increasing performance, namely the Public Private Partnerships (PPP), alliancing, and Integrated Project Delivery (IPD). The use of project partnering has also been developed. It is a management approach that two or more organisation can use to achieve predefined mutual business objectives including agreement on method of resolving problems and continuous improvement (Lahdenperä 2012).

Generally, the procurement structure supports the coordination activities, by creating a setting that fosters concurrent interactions among team members, throughout the project. From life cycle BIM perspective, Holzer (2015) conducted an analysis of the opportunities and challenges of BIM under procurement methods applied in Australia and deduced that IPD is the closest fit, contractually speaking, for full BIM implementation. The potential opportunities for BIM use and its challenges in Design and Build procurement include: it facilitates increased transparency in setting up and tender pricing, models can be set up with construction in mind, it increases the potential for interfacing information between consultants and trade contractors, and it requires a contractor who understand BIM (Holzer, 2015). Loke (2012) argued that the Design-Bid-Build (DBB) procurement is not an arena for realizing the full benefit of BIM, whereas isolated actors may reap some productivity benefit.

The collaborative benefits of BIM could be leveraged through the use of Integrated Project Delivery (IPD). Unlike DBB procurement that encourages project team to work in disciplinary silos (Loke, 2012) IPD is a contractual agreement between a minimum of the owner, design professional and builder, where risk and reward are shared and stakeholder success is dependent on project success thereby encouraging collaboration and some elements of partnering relationships (Lahdenperä 2012). It involves mutual benefits and reward, early involvement of key project actors, and early definition of project goals. Thus, IPD could facilitate interaction among project actors in a BIM-based project. For the AIA (2007) the use of BIM and IPD is called 'Virtual Design and Construction' (VDC). VDC has been pioneered by the Centre for Integrated Facility Engineering (CIFE) at Stanford University and supports the description, explanation, evaluation, prediction, alternative formulation, negotiation and decisions about a project's scope, organization and schedule with virtual methods (Khanzode *et al*., 2006).

Despite the significance of IPD to BIM, it is unrealistic to implement IPD, entirely and globally (Holzer 2015), due to transaction cost issues, market maturity, client experience, and contextual differences across projects. Holzer (2015) observed that the excitement about the combination of IPD and BIM is fading because IPD in its pure form does not suit current market dynamics. Whereas the most procurement methods do not support smooth flow of BIM process, practitioners are now turning to exploring the role that BIM can play within existing procurement routes. Sebastian (2011) presented two hospital project cases in the Netherlands where the clients opted for traditional DBB procurement while at the same time developed clear vision for BIM to achieve specific project ambitions. The implication is that new coordination structures emerge within the existing project procurement methods. This study would contribute to the discourse on BIM and its implementation in practice by exploring the BIM implementation process in two Dutch Design-Build (DB) projects and it would highlight the project coordination structures that emerged from BIM.

Project coordination structure and BIM implementation

Project coordination structure is regarded as the pattern of decision-making and communication among a set of actors (Malone and Smith 1988). Underlying abstract decision-making patterns characterize every project procurement method and are needed for managing the tasks dependencies. Dabbish *et al*., (2010) distinguish between formal and informal coordination. For early organisational theorists, formal coordination is needed where uncertainties are low, e.g. where tasks are clear and based on routine and involving ‘a priori definition of organizational structures and processes for managing dependencies including supervision, rules, routines, standardization, scheduling, pre-planning, and division of labour into minimally dependent units’ (March and Simon 1958). Informal coordination is interpersonal coordination, better suited for managing highly interdependent and complex tasks where actors interact directly to exchange task information and negotiate task dependences (Malone and Crowston 1994). In the context of product development in organisations, Olson *et al*., (1995) classified formal coordination structure into seven structures ranging from the most mechanistic, e.g. bureaucracy, to the most organic and participative structure, e.g. design centres. These are characterised by varying degrees of complexity (simple to complex), distribution of authority (centralised to decentralised), formalization (formal to less formal), and autonomy (low to high).

Such structures are also characterised by features that affect decision-making/conflict resolution (hierarchical to participative) and information flow (formal to informal). Martin *et al*., (2014) concluded in their study that the better structure for communication is the decentralised because it reduces communication resistance in teams. According to Olson, Walker Jr and Ruekert (1995), in decentralised organisation, rules and operating procedures are less formalized and less rigidly enforced, and individual units tend to have more autonomy to develop their own methods and make their own decisions. The success of a BIM-based project may exhibit a different response between centralised and decentralised coordination structure.

Project design in AEC is highly dynamic with complex interdependent tasks often targeting new solutions and involving frequent changes. Using design artefacts, such as models and web platforms, to connect the actors and integrate design work is then crucial. It can facilitate information exchange and help the actors to understand each other’s view, negotiate and resolve conflicts in an ongoing basis. The advent of BIM in a common data environment (CDE) (level 3 BIM in the UK) is making consistent information exchange possible. These new developments challenge the role of the traditional project manager. Koskela and Howell (2002) argue that the traditional project management tools only optimise efficiency at task levels; they do not address task interdependences. BIM is set to address the gap in task interdependencies, as it entails a shift from fragmented workflow to concurrent engineering and engages the various firms in dynamic and frequent interactions. Thus, in the BIM era, a project manager would need both the skills of the traditional project manager and additionally BIM-related technical skills for the technical coordination of the design.

Certainly, BIM has also led the emergence of new roles, e.g. BIM manager, BIM co-ordinator. In BIM projects, the use of the traditional project manager together with the BIM manager can result in conflict and duplications (Forgues and Lejeune 2015). The project manager is typically responsible for managing project scope and deliverables, whereas the BIM manager is responsible for the BIM models and the information exchange for the models. The paradox is that the BIM manager is more familiar with the status of the BIM, and thus project schedule. Forgues and Lejeune (2015) suggested that to transform the traditional project network into a BIM workflow, an ‘organisation architect’ is needed to guide the translation of a project vision to a flexible, integrated platform by devising the right combination of BIM processes, capabilities and technologies. Based on the above theorisations, it would be useful to explore the emerging coordination structures arising from BIM as well as disturbances in the traditional project phases and roles dictated by BIM implementation.

METHODOLOGY

Two BIM-based projects were analysed as to their BIM implementation and namely the, (a) BIM management structure, i.e. distribution of roles, responsibilities and tasks, (b) BIM-related activities and processes. Two cases in the Netherlands were analysed, cases A and B. The Dutch AEC was selected for the study, given that BIM adoption in this market presents a balanced mix between policy-driven BIM roadmaps and emerging BIM practices (Kassem, Succar and Dawood 2015). Whereas BIM policies are not very advanced in the Netherlands, the construction firms are quite proactive in BIM adoption using various strategies. The two cases were antithetical, because although both had DB procurement method, opposite approaches were used for managing and coordinating the BIM process. Case A used a specialist BIM consulting company, while case B involved BIM functions undertaken by in-house BIM-knowledgeable employees from the various firms involved. Case A was studied during early 2013 and case B during late 2015.

The study used exploratory case study. The cases exploration involved interviews with the project actors, analysis of project documents, and live observations of BIM clash and design sessions. The interviews were semi-structured, addressed to various actors, e.g. contractor, client, engineers and the BIM consultancy firm (only in case A). The first questions were about the firms’ BIM adoption history, challenges and outcome. The next questions were about BIM implementation at a project level, e.g. motivation for BIM, BIM workflow, contractual strategies, BIM roles and responsibilities and technical challenges from BIM. The case description as to type, scale, location and dates, and the responses to questions about BIM adoption, motivation and strategy are shown as text using thematic analysis, whereas the responses to questions about BIM implementation activities and roles are presented in tables, to aid the case analysis.

CASES ANALYSIS

Case description

Case A (2013) is a housing project of 40 rental apartments with five apartments per floor for single and two-person households, using industrialized building systems. The client is a housing association in partnership with a property developer. For the project, BIM was not a contractual requirement. The use of BIM was part of the contractor’s tender proposal to the client with the goal of using BIM to achieve 'a better building delivered at the lowest possible cost'. It was envisioned that BIM and VDC methodology will be used for reducing design errors and clashes and deliver the project faster (time), cheaper (cost) and better (quality).

In case B (2015) whereas, the client did not require BIM, the contractor and his partners decided to adopt BIM to increase project quality. It involved a housing tower with 12 stories and 83 housing units of two to four bedroom apartments, to buy or rent. BIM was used because the project had technical challenges in the site logistics. It was a tower in a small plot, adjacent to a shopping centre, whose operation could not be disturbed. This project also used industrialized building systems and dry construction, which is very common in the Netherlands. The Architect stated that they did not dare to do this project in a non-BIM way. The motives for using BIM in case B was also strategic, because the contractor and their partners wished to deliver "as-built" drawings and potentially master the use of BIM for their future projects.

Project procurement structure

Figure 1 illustrates the project procurement structures of the two cases. In case A, the project delivery method was DB procurement. The designers were engaged by the owners to define the scope of the project whereby the design was developed from conceptual design (Level of Development (LOD100) to schematic design (LOD200). Based on the LOD200, the project was tendered for, then the contractor was selected and thereafter the architect was novated to the contractor. The contractor thereafter engaged the BIM managers while the designers worked under the BIM manager's leadership. Various suppliers and subcontractors were also selected by the BIM managers (with contractors input) on the basis of their experience with BIM.

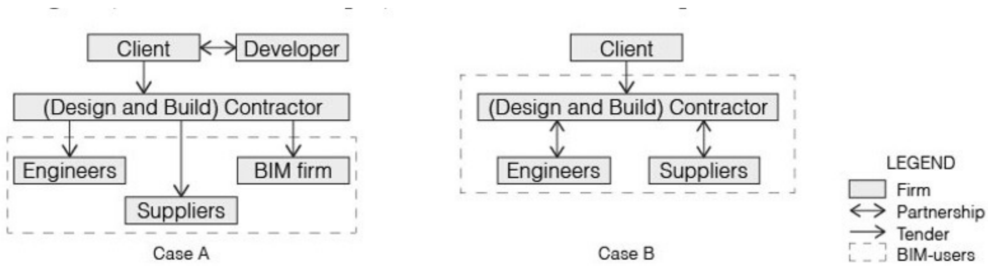

Figure 1. Project procurement structures of cases A and B.

The procurement of case B was simpler than that of case A. The client hired the contractor to deliver the design and construction and gave them complete power over the next decisions. The contractor had long-term partnerships with the Architects and the Structural engineer (Str. Eng.), who were responsible for the architectural and structural design respectively. Also the contractor had long-term partnerships, or 'chain contracts', with a MEP firm and some sub-contractors and suppliers. Other suppliers were selected from a list of 'preferred partners' of the contractor.

Most firms involved in case B adopted BIM as a means to control the information flows in the project and to increase project quality. The adoption of BIM was triggered from either internal or external reasons. On one hand, for the architect, the structural engineer and the contractor, BIM adoption was a natural decision to improve their businesses. For example, the architects were already designing in 3D before BIM. The structural engineering firm was also using 3D since 2007 and fairly rigorously made the transition to BIM. For the contractor the information sharing with their partners would become more efficient because of BIM. On the other hand, the concrete sub-contractor, the steel supplier and the MEP engineering firm adopted BIM to comply with 'customer demand' and because 'this was requested from the market'.

Case analysis: BIM implementation and coordination

Overall management structure

In case A, after the project award to the contractor, the BIM consulting firm i.e. BIM managers, was hired by the contractor. The BIM managers were responsible for not only the overall management of the project, as project managers, but also for the generation of the BIM models based on models produced by the designers and several subcontractors, as coordinators. To ensure the success of BIM implementation, an initial project workshop was conducted i.e. a BIM "kick-off" meeting. The purpose was to ensure that all the parties understood the project and agreed to the way of working and BIM use. All parties had to sign the BIM execution document as a part of their contract. The BIM process was supported by BIM protocols and management plan from the early stage of the workshop and the project.

In case B, BIM was applied from various roles within the involved firms. The architect, structural engineer and MEP firms had at least one BIM-savvy engineer, alongside the project engineer. The main project management function was held by the contractor. A "kick-off" session and a BIM protocol took place from the start, to coordinate the BIM scope. The BIM process was supported also from frequent collocations. The architect was the BIM coordinator until the pre-construction phase. Thereafter, a site engineer from the contractor's firm became the BIM coordinator. Figure 2 illustrates these two BIM coordination structures.

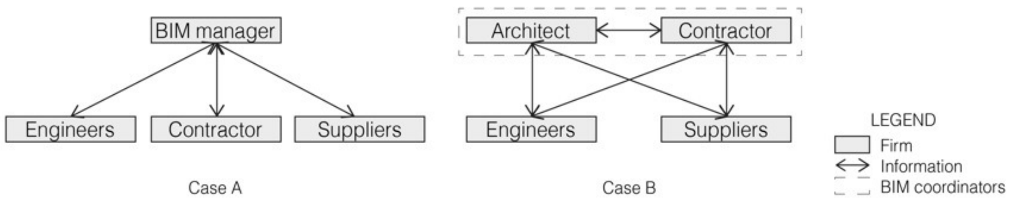

Figure 2. BIM coordination structure of cases A and B.

Processes and activities

In case A, BIM was used from Definitive Design, with LOD200 until the Construction Preparation phase with LOD400. BIM was used for the following activities: design coordination, clash detection, design visualization, quantities take-off, cost estimation, preparation of working (shop) drawings and information exchange. The project schedule was prepared in different software and was not linked to BIM tools. The BIM manager was responsible for modelling, cost calculation and clash detection. The federated model formed a basis for the subcontractors. There were a lot of formal and informal coordination activities with the various subcontractors to produce jointly a working model for construction. Interestingly some of the suppliers were co-located in the same office building with the BIM managers. According the BIM managers, this greatly influenced the team collaboration. A project website hosted on the servers of the BIM managers was used as a Common Data Environment (CDE) to share project information using Industry Foundation Classes (IFC).

In case B, BIM was used from the Initiation phase, i.e. LOD100 until the Hand-over (as-built BIM). It was used for design exploration, visualization, design coordination, cost estimation, clash detection, quantity take-off, information exchange and site resource management. Similar to case A, the information exchange took place in a CDE, where all parties uploaded their IFC files. Afterwards, the various references models were federated to perform clash detections as described in Berlo *et al*., (2012). The contractor used preliminary input from the architectural and structural models to perform the budget estimation, and early informal discussions with some preferred suppliers. The suppliers were involved early in the process after the LOD300 phase and provided preliminary input.

Outcomes of the cases

Case A was delivered ahead of schedule. The client was satisfied with the quality. All parties had better understanding of the BIM process but challenges included time pressure because of the contractual obligations and late completion of tasks by some parties. The contractor's expectations were too high because it was their first BIM project, which also put work and time pressure on the other parties. The BIM managers had to work overtime for the BIM management function. Case B is an ongoing project and so far no time delays have been reported. Time pressure was reported by various project actors, but according to them it was not due to the BIM implementation, but rather due to the strategic decisions of the contractor's commercial managers. However, some coordination issues surfaced regarding the role of the BIM coordinator. In the beginning, the architect performed this function, but later, after request from the partners, a site engineer was trained to become a BIM coordinator, so as to combine technical expertise from the site to technical BIM expertise. Also, frequent collocations of the partners increased the understanding and knowledge about BIM process.

DISCUSSION AND IMPLICATIONS

In Case A, BIM coordination and project management were highly centralized. The BIM managers were responsible for BIM modelling and coordination, project and cost management. They also exerted control over the MEP, sub-contractors' and suppliers' models. The BIM managers send their staff to support the other BIM users whenever issues arose. Surprisingly, whereas the control was centralised, the decision-making was not strictly hierarchical. This was possible because the CDE ensured participative structure and a quasi-concurrent workflow. Most of the interactions were between the BIM managers and the suppliers and subcontractors, and were facilitated by the CDE. There were also a lot of informal interactions. The BIM managers performed an 'integrating manager' role (Olson, Walker Jr and Ruekert 1995). They also exerted informal influence from their central position (see Figure 2). The CDE was critical for the interaction of the BIM users. Case A also shows that the designer's and contractor's roles were less visible due to the power of the BIM management firm.

Whereas Case B was also DB procurement, had opposite BIM coordination structure, because of the multiple partnering relations among the firms. The contractor executed the project management activities. All engineers and suppliers were then responsible for their BIM input to the federated model. The paradox in case B was that although the project management was centralized, BIM coordination was decentralized. Both the contractor and the architect were BIM coordinators and this lead to a decentralized BIM structure (see Figure 2), concurring with the participative, consensual, horizontal and informal coordination structures from Olson *et al*., (1995). The engineers and suppliers were empowered to apply BIM and exert distributed control via their input. Given that not all actors had the same BIM capabilities, frequent collocations, informal communication and shared learning took place.

Case A carries implications for business models in AEC firms. The BIM management firm was originally cost managers that reinvented into a firm that provided all-round BIM services and information management, together with cost and project management services. Their services might be attractive to clients looking for cheap, good and fast projects, especially in repetitive and less complex buildings. This could lead to mergers rise of consortiums, and acquisitions of firms that previously provided auxiliary services. From case B, the analysis indicates that the contractors would become information managers. Also, in case B, there was an increase in the engineers' and supplier's empowerment and responsibilities to provide their services using BIM standards and agreements. This could be a sign that the future AEC business models AEC would offer integrated BIM and discipline-related services. Accordingly, it would be interesting to explore the clients' preferred approach for reducing the risks of BIM adoption, i.e. choosing between specialized or integrated BIM and engineering firms.

CONCLUSIONS

Due to the increasing adoption of BIM, the various firms would gain experience from BIM-projects and become increasingly aware of its benefits. The two cases with DB procurement presented two contradictory routes to BIM implementation. The cases used either specialized BIM consulting firms or solutions within their firms, e.g. hiring BIM-savvy engineers or training their in-house personnel, to reduce the cost of outsourcing BIM implementation. This produced two models of BIM coordination: centralized and decentralized. There are lessons to be learned from both cases, given that the centralized and inclusive approach towards BIM, from the BIM consulting company, sets high-quality standards that challenge the ad-hoc or decentralized BIM approaches. The engagement of organizations in both 'centralized and 'decentralized BIM coordination could potentially contribute to effective diffusion and development of BIM knowledge and higher BIM maturity among AEC professionals.

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