A comparative case study of coordination mechanisms in Design and Build BIM-based projects in the Netherlands

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ABSTRACT: BIM implementation can affect the project coordination mechanisms in unexpected ways, even in widely-applied project procurement structures. Apart from the chosen procurement approach, the BIM technology and the distribution of roles in the project team influence and shape the project coordination. This paper aims to explore the emerging coordination structures and processes from BIM implementation in design-build procurement. An exploratory comparative case study has been undertaken. The findings included two main coordination mechanisms: a centralized and decentralized structure and a hierarchical ver-sus participative decision-making processes. These two patterns subsequently open a debate about the rela-tions between BIM implementation and business models in AEC and particularly the emergence of specialized all-around BIM firms versus BIM-knowledgeable engineering firms.

1 INTRODUCTION

The Architecture, Engineering and Construction (AEC) industry is usually described as highly fragmented. The conventional design and construction process of a building project involves multiple interactions among various domain experts responsible for the design as well as multiple sub-contractors and suppliers on site, arranged by a contractor on site. The project team of a construction project is usually a temporal network (Winch, 2002), which is believed to be responsible for fragmented information flows between design and construction. Accordingly, the design and construction processes are clearly separated and the project information generated and shared across these two phases is often unreliable and difficult to access due to poor k coordination among the work of the various domain experts and the those responsible for the executing the work on site. This interface between design and construction is managed by project managers. With the advent of the digital technologies in AEC, and particularly of Building Information Modeling (BIM), the chasm between design and construction is deemed to be closer to being bridged..

In past decade, BIM has been considered a solution to that fragmentation, poor project coordination and information management problems (Eastman et al., 2008). The promise is that BIM and its associated technologies and processes, can facilitate simultaneous work by multiple design disciplines. However, the BIM collaboration process is often asynchronous under most circumstances (Cerovsek, 2011). Also, despite the popular and utopic belief that BIM could enable a centrally controlled flow of information – and thus centralized collaboration – this is not possible due to computational limitations (Miettinen and Paavola, 2014). Howard and Björk (2008) claim that “the single BIM (model) has been a holy grail but it is doubtful whether there is the will to achieve it” and thus directly defying the claims for centrally controlled BIM. However, BIM sufficiently supports a centrally performed federation of multi-disciplinary information from the various actors (Berlo et al., 2012). Accordingly, BIM challenges the traditional coordination mechanisms, roles and workflows in construction. On one hand, many BIM-specialized firms have emerged to offer all-inclusive BIM-related services to AEC firms and projects. These services sometimes encapsulate the traditional project management 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.

Various coordination mechanisms could be applicable for BIM implementation. To investigate the emerging BIM coordination mechanisms, this paper focuses on Design-Build (DB) procurement, within which according to Eastman et al. (2008) “the use of BIM (…) is clearly advisable”. This paper aims to showcase coordination structures from BIM implementation in two cases in the Netherlands. It would examine and compare the emerging project coordination from BIM implementation in DB projects, and the various actor's roles. It will also attempt to shed light on the impact that these mechanisms had and the challenges and the outcomes of the cases. Thereafter, the findings would attempt to inform and assist AEC practitioners to improve their BIM adoption processes and reap its acclaimed benefits.

2 BACKGROUND, RELATED PREVIOUS WORK AND GAP

2.1 *The interactions of project procurement and project coordination with BIM*

Building Information Modelling (BIM) has been defined as 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' (Eastman et al., 2008). BIM entails the use of many tools, processes and technologies to produce a building information model. In a BIM-based project delivery process, input from the various design disciplines, contractor, suppliers and subcontractors can be sought early in the design process, be visualized and the potential disciplinary coordination problems could be detected and resolved. This process requires close and ongoing collaboration among the project team members. Eastman et al. (2008) advice that DB procurement "may provide an excellent opportunity to exploit BIM technology, because a single entity is responsible for design and construction", as it is more cost-efficient and shorter than the Design-Bid-Build (DBB) approach.

In general, the procurement methods, BIM technology and the distribution of responsibilities have a major impact on the coordination process and project success. Whilst the procurement governs 'design, construction and commissioning of projects' (Holzer, 2015), the coordination is the underlying abstract pattern of decision-making and communication among the project team. The coordination plays a crucial role in every project procurement method and is needed for managing the tasks interdependences (Malone and Smith, 1988). Thus, the project procurement method would interact with project coordination structure and thereafter influence the success of BIM implementation. The DB procurement approach could support BIM coordination, by creating an environment that fosters concurrent interactions among team members, and especially in the interface of design and construction.

2.2 *Project procurement and BIM*

Procurement can be defined as 'the organizational 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, characterized by a particular organizational form, distribution of responsibility, tasks and risk allocation'. Turner (1997) identified two essential decisions in procurement (a) the organization for the overall project management, and (b) the organization for design and construction. The organization 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.

In the AEC industry, various procurement methods have been used before BIM. Turner (1997) classify them into (a) design-led (b) designer-led, and (c) management-led. Others include Public Private Partnerships (PPP), alliancing, and Integrated Project Delivery (IPD). There is agreement in the literature that the Design-led procurement is not an arena for realizing the full benefit of BIM (Loke, 2012, Sebastian, 2011a). Holzer (2015) conducted an analysis of the opportunities and challenges of BIM under the contract procurement methods as applied in Australia and deduced that IPD is the closest fit, contractually speaking, for full BIM implementation, although it is not applicable to all local markets (Sebastian, 2011b, Holzer, 2015). In DB procurement, some potential opportunities for BIM use and issues identified by Holzer's (2015) analysis are:

- BIM facilitates increased transparency in setting up and pricing tender packages,
- The stakeholders can set up their models up with Construction BIM requirement in mind,
- BIM increases the potential for interfacing information between consultants and trade-contractors in construction documentation,
- The risk lies with the contractor to maximize BIM knowledge transfer,
- It requires skilled contractors who understand BIM workflows and
- The input from client to help define operational requirements is not automatically guaranteed.

Holzer's (2015) work is theoretical. Sebastian (2011a) reaches to comparable conclusions as to the fit of DB for BIM when he compared various procurement approaches using a single case study. Whereas, all procurement routes could support BIM, the DBB would add to the fragmentation of information between design and construction, and on the other hand, the DB discourage a potential involvement of the client in design and construction phases (Sebastian, 2011a). Therefore, there is always a trade-off between the project scope and the extent of the client's involvement and the coordination of the information flow from design to construction.

2.3 *Project coordination structure and BIM*

The coordination structure is regarded as the pattern of decision-making and communication among a set of actors who complete tasks to achieve project goals (Malone and Smith, 1988). It is the underlying abstract decision-making that characterizes every project procurement method and is needed for managing the tasks dependences. The task interdependences in a construction project require that: for each party to complete their task, they must receive information needed from another party. In order to fulfil the client's needs, there is need for coordinated teams, dynamic information flow, and efficient communication and interaction among actors and tasks. The success of coordination would depend on interactions among parties and the communication paths that could enabled by digital technologies. Thus, coordination in BIM-based projects involves technology and human interactions. Dabbish et al. (2010) distinguish between formal and informal coordination. For early organizational theorists, formal coordination is needed where uncertainties are low, e.g. where the tasks are clear and based on routine and involving 'a priori definition of organizational structures and processes for managing dependences including supervision, rules, routines, standardization, scheduling, pre-planning, and division of labor into minimally dependent units' (March and Simon, 1958). Informal coordination is interpersonal coordination, better suited for managing highly interdependent and complex tasks where the actors interact directly to exchange task information and negotiate the tasks' dependences (Malone and Crowston, 1994).

In the context of product development in organizations, 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 centers. These are characterized by varying degrees of complexity (simple to complex), distribution of authority (centralized to decentralized), formalization (formal to less formal), autonomy (low to high). Such mechanisms are also characterized by processes that affect decision-making/conflict resolution (hierarchical to participative) and information flow (formal to informal). Figure 1 illustrates Olson et al's (1995) types of coordination mechanisms.

According to Malone (1987), the costs of coordination structures include production cost, coordination cost and vulnerability cost. Production cost include the cost of delays in finishing tasks; coordination cost are the cost of the maintaining the communication links among the parties as well as cost of exchanging 'messages', e.g. information, whereas the vulnerability cost is the cost of failure of parties to perform their tasks or failure to make decisions. Drawing on Williamson's (1975) transaction cost economics concept, there are two means of coordination for tasks: (a) internal coordination for tasks using in-house capacity and (b) market coordination for the same task, based on outsourcing. According to Williamson (1975), the choice between in-house and market coordination is that of differences in transaction costs of the two means of coordination. Coordination of production in construction is often achieved by the use of the market. The overall cost of market coordination structure can vary according to two types of coordination namely – centralized and decentralized (Malone (1987). In centralized coordination, there is a centralized manager who coordinates the activities of the various actors. The manager has a communication link to each actor and is responsible for ensuring that all the tasks are performed appropriately and on time and are brought together with other tasks to fulfil the goals (client needs), whereas, in decentralized coordination, the actors interact with each other and there are communication links among all actors. Thus, the communication links is denser than in centralized structure. According to Malone (1987) the coordination cost is proportional to the number of connections between the actors. In centralized coordination, the failure of the manager to act, make decision or perform can delay the overall production. However, in decentralized coordination, the failure of an actor to perform could result into termination of the con-

Types of Coordination Mechanisms

Bureaucratic Control — Individual Liaisons — Temporary Task Forces — Integrating Managers — Matrix Structures — Design Teams — Design Centers

Structural and process variables	Bureaucratic Control …		… Design Centers
Structural Attributes			
Complexity	Simple structures	⟷	Complex structures
Distribution of Authority	Centralized	⟷	Decentralized
Formalization	High; More Rules	⟷	Low; Fewer Rules
Unit Autonomy	Low	⟷	High
Processes			
Decision Making	Hierarchical	⟷	Participative; Democratic
Confict Resolution	Hierarchical	⟷	Participative; Consensual
Information Flow	Vertical; Formal	⟷	Horizontal; Informal
Work Flow, Job scheduling	Sequential	⟷	Concurrent
Evaluation and Rewards	Based on Functional or Company outcomes	⟷	Based on Project or Unit outcomes
Motivational Focus	Functional	⟷	Customer/Project

Figure 1:A Continuum of Interfunctional Coordination Mechanisms: Attributes and Processes (Adapted from Olson et al. 1995).

tract of the actor and selection of another actor of similar expertise. Thus, vulnerability cost is lower in decentralized structure than in centralized structure whereas coordination cost is higher in decentralized than centralized structures. Nevertheless, Stank et al. (1994) anticipated that the centralized firms would have better information support than decentralized firms, whereas there was no significant differences between the level of information support for the two structures. They also hypothesized that the sophisticated information systems would handle information requirements regardless of the organizational structure." (Stank et al., 1994).

Project coordination in AEC is highly dynamic and entails complex interdependent tasks often targeting new solutions and involving frequent changes. Using design artefacts, such as BIM models and web platforms, such as Common Data Environment (CDE) to connect the actors and integrate design work is then crucial to support information exchange, and coordination. It can help the actors to understand each other's view, negotiate and resolve conflicts in an ongoing basis. Based on the above theorizations, it would be useful to explore the emerging coordination mechanisms arising from BIM and the disturbances in the traditional project phases and roles dictated by BIM implementation. This study will highlight how these opportunities and issues play out in real world Design-Build (DB) projects. It will contribute to the discourse on BIM and its practical implementation by showcasing lessons learned from BIM implementation in two DB cases in the Netherlands by examining the project coordination mechanisms that emerged from BIM.

3 RESEARCH APPROACH

The paper used a case study methodology. The BIM-based projects were analyzed as to the, (a) BIM management structure, i.e. distribution of roles, responsibilities and tasks, (b) BIM-related activities and processes, (c) outcomes. Two cases in the Netherlands, cases A and B, were analyzed and compared. The Dutch AEC was selected for this study, because BIM adoption in the Netherlands presents a balanced mix between policy-driven BIM roadmaps and emerging BIM practices (Kassem et al., 2015). Whereas, the BIM-related policies are not very advanced in the Netherlands, the construction firms have been quite proactive in adopting BIM technologies. Both cases had a DB procurement method, but used opposite approaches for managing and coordinating the BIM implementation process. In case A, a specialist BIM consulting company was hired for BIM implementation, whereas in case B the various relevant BIM functions were performed by inhouse BIM-knowledgeable employees from the various firms. Case A was studied during early 2013 and case B during late 2015.

The case studies were exploratory cases. The exploration involved interviews with the project actors, analysis of project documentation, and live observations of BIM clash and engineering sessions. The interviews were semi-structured and addressed to various actors, e.g. contractor, client, engineers and the BIM consultancy firm (only in case A). The first set of questions was about the firms' BIM adoption history, challenges and outcome. The next set of 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 is presented in text, and the responses to the questions about BIM activities and roles are presented in tables, to facilitate the case comparison.

4 COMPARATIVE CASE ANALYSIS

4.1 *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 use BIM to increase project quality. The project was a housing tower with 12 stories and 83 housing units of two to four bedroom apartments, to buy or rent. BIM also supported the technical challenges in the site logistics. It was a tower in a small plot, adjacent to a shopping center, 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 without BIM. 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.

4.2 *Project procurement*

Figure 2a illustrates the project procurement structures of the two DB projects. In case A, the designers were engaged by the client to define the client's requirement and the scope of the project via development of conceptual design (Level of Development (LOD100) to schematic design (LOD200). The contractors tender was based on the LOD200 documents and model, then the contractor was selected and thereafter the architect was novated to the contractor. The contractor afterwards hired the BIM firm, whereas the designers worked under the BIM manager's leadership. Various suppliers and subcontractors were also selected by the BIM managers, after consulting with the contractor, on the basis of their experience with BIM.

The procurement of case B was a less complex DB than that of case A. The client hired the contractor to deliver design and construction and gave them complete power over next actions. The contractor had long-term partnerships with the architects and the structural engineer (Str. Eng.). Also, the contractor had long-term partnerships with a MEP firm, sub-contractors and suppliers. Most firms involved in case B adopted BIM as a means to control the information flows in the project. 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. On the other hand, the concrete sub-contractor, the suppliers and the MEP engineering firm adopted BIM to comply with customer demand and because it was requested from the market.

4.3 *BIM implementation and coordination*

4.3.1 *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 about 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 main project management function was held by the contractor. The architect, structural engineer and MEP firms had at least one BIM-savvy engineer, alongside the project engineer. 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 coordinated the BIM process. Figure 2b illustrates the BIM coordination structures in case A and B.

4.3.2 *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 (Table 1). The project schedule was prepared in different software and was not linked to BIM tools. The authoring tools employed include: Revit Architecture, Revit MEP, Navisworks, ArchiCAD, HiCAD , Tekla, and BIM-ID (for cost calculation). The BIM manager was responsible for modelling, cost calculation and clash detection.

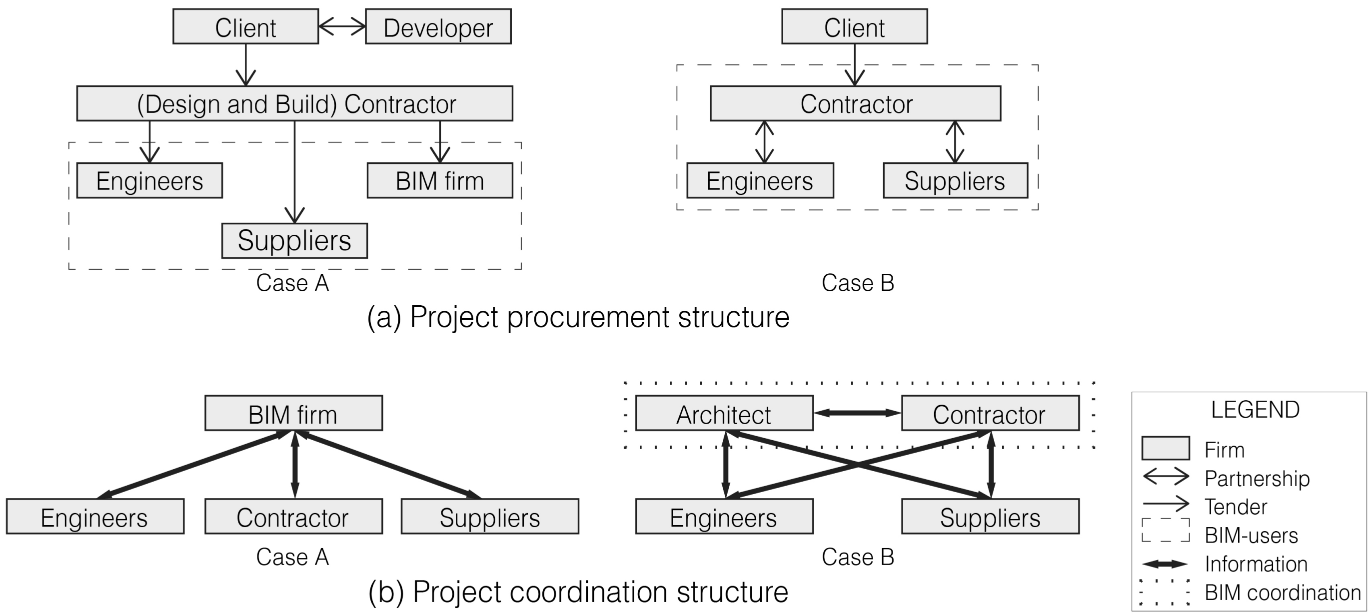

Figure 2: Project procurement structure (a) and project coordination structure (b) in cases A and B

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 collocated 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. The authoring BIM tools used were primarily Revit and Tekla Structures and the BIM checking tool used was Solibri Model checker. Similar to case A, the information exchange took place in a CDE, where all parties uploaded their IFC files. Afterwards, the various reference 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 the suppliers. The suppliers were involved early in the process after the LOD300 phase and provided preliminary input.

4.3.3 *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 some 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 to meet 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. Table 1 contains the case comparison across the processes and roles of BIM implementation.

Table 1. BIM implementation, coordination structure and BIM roles in cases A and B.

Phase	Activity	Responsible party Case A	Case B
BIM "Kick-off"	Transfer of documents to all parties	All parties	Contractor
	Presentation of BIM methodology	BIM firm	Architect
	Preparation of the online platform (CDE)	BIM firm	Contractor
	Providing the BIM execution plan to all parties	BIM firm	Architect
	Verifying & agreeing on the execution plan	All parties above	All parties above
BIM drafting until LOD300	Set-up of the architectural model	BIM firm	Architect
	Set-up of the structural model	BIM firm	Str. Eng.
	Clash detection: architectural and structural model	BIM firm, Contractor	Architect
	Revising the previous models	BIM firm	Architect, Str.Eng
	Transferring the revised models to MEP engineers	BIM firm	Architect
	Preparation of MEP models	MEP engineers	MEP engineers
	Clash detection: architectural, structural and MEP model	BIM firm	Architect
	Revising the models	BIM firm, MEP engineers	Architect, and engineers
	Sharing working model with the subcontractors/suppliers	N/A	Architect
	Verifying & agreeing on models	All parties above	All parties above
BIM drafting until LOD400	Sharing LOD300 model with the subcontractors/suppliers	BIM firm	Architect
	Identifying key constraints based on subcontractors/suppliers input	Subcontractors/suppliers	Contractor
	Preparation of subcontractors/suppliers models	Subcontractors/suppliers	Suppliers
	Clash detection of the models	BIM firm, Contractor	Architect
	Revising the models	Subcontractors/suppliers	Suppliers, engineers
	Verifying & agreeing on models	Contractor and all parties above	All parties above
BIM until Pre-construction phase	Identifying required information for working drawings	Contractor	Architect
	The list of required working drawings	Contractor	Contractor
	Clash detection and Processing design changes of models from the suppliers to	BIM firm	Contractor

	LOD400 model		
	Preparation working drawings out of LOD400 model	BIM firm	Suppliers, engineers
	Control of the working drawings	Contractor, Architect	Contractor
	Adjusting/revising the working drawings	BIM firm	Engineers, suppliers
	Verifying & agreeing on technical drawings	All parties above	All parties above
General activities in all phases	Consultation with the contractor	All parties	N/A
	Consultation with the client	Contractor	Contractor
	Process management	BIM firm	Contractor
	Consultation with other parties e.g. authorities	Contractor	Architect
	Specific explanation of methodologies	BIM firm	Architect
	Collocations	N/A	All parties
	Maintenance of the CDE	BIM firm	Contractor
	Evaluation of the project	All parties	All parties

5 DISCUSSION AND IMPLICATIONS

5.1 *Structural attributes of coordination*

In Case A, the BIM coordination structure and the project management were highly centralized. The BIM managers were responsible for BIM modelling and coordination, project and cost management. This made the coordination structure more simple according to Olson et al (1995), and more cost-efficient according to Malone (1987). The BIM managers 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. The BIM managers performed an 'integrating manager' role (Olson et al., 1995). They also exerted informal influence from their central position (see Figure 2b). However, this structure, whereas very controlled, would potentially have a greater vulnerability cost (Malone, 1987), as the BIM implementation would solely depend on one actor in the chain.

Whereas Case B was also DB procurement, had an opposite BIM coordination structure to case A, 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, the BIM coordination structure was decentralized and more complex. Both the contractor and the architect were BIM coordinators and this lead to a decentralized BIM structure (see Figure 2b and Table 1), providing evidence of highly autonomous and less formal coordination structures from Olson et al. (1995). According to Malone's (1987) categorization, this BIM coordination structure would induce a highly costly BIM coordination, but also less vulnerable to failure.

5.2 *Attributes of the coordination process*

Surprisingly, whereas the control in case A was centralized, 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 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.

In case B, the role of the BIM coordinator, included the tasks of distributing the information about the BIM process among the partners, assigning tasks, model federation and model checking. The design process of the engineers and the suppliers was more participative and consensus-seeking than in case A, as they were responsible for creating and revising of their own models, and also ensuring that their models were in the correct form for the federation. The engineers and suppliers were empowered to apply BIM and responsible for their work. Given that not all actors had the same BIM capabilities, frequent collocations, informal communication and shared learning took place. However, the decentralization of coordination in case B means that failure to maintain the density of communication would result in poor coordination among the engineers, and suppliers, and thus higher production cost. Future research would be useful to further investigate the vulnerability and coordination costs of various coordination structures in BIM-based projects.

5.3 *Comparison of emerging BIM business models*

The cases carry implications for the business models in AEC firms. The BIM management firm of case A was originally cost managers, who reinvented themselves into an all-round BIM firm that provided information management, cost and project management services. This could lead to rise in mergers, consortiums, and acquisitions of firms that previously provided auxiliary services. From case B, the contractor seems to have incorporated the information management services. 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.

6 CONCLUSIONS

Various procurement routes have been discussed as to their suitability to support BIM implementation. Given the promise of BIM for consistent information flows, it is considered as better combined with integrated delivery processes, e.g. IPD. However, this paper provided evidence that even simpler procurement routes, such as Design-Build could provide integrated processes for BIM implementation. To this end, it was revealed that not only the procurement, but also the selection of various involved tendered firms, affect the project coordination mechanisms and in particular the structures and processes. In particular the two cases presented two structures of BIM coordination: centralized and decentralized supported by hierarchical and participatory decision-making processes respectively. These BIM coordination mechanisms subsequently carry carious implications for future business models in AEC.

Due to the increasing adoption of BIM, the various firms would gain experience from BIM-projects and become increasingly aware of its potential. The two DB cases presented two opposite approaches to BIM implementation. The cases used either specialized BIM consulting firms or integrated BIM solutions within existing firms, e.g. hiring BIM-savvy engineers or training their in-house personnel, to reduce the cost of outsourcing BIM. There are lessons to be learned from both cases, given that a centralized and inclusive approach towards BIM (from the BIM consulting firm) sets high-quality standards that challenge any ad-hoc BIM approaches. On the other hand, a decentralized approach to BIM coordination, might soon gain more traction, given that the use of BIM technology gradually becomes an industry requirement, which could be partially or wholly supported by BIM-savvy professionals, thus making extra BIM consultants redundant. The engagement of firms in both 'centralized' and 'decentralized' BIM coordination structures could potentially contribute to greater development of BIM knowledge and higher BIM maturity across AEC firms.

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