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Actors’ Freedom Of Enactment In A Loosely Coupled System: The Use Of Building Information Modelling In Construction Projects

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ACTORS’ FREEDOM OF ENACTMENT IN A LOOSELY COUPLED SYSTEM: THE USE OF BUILDING INFORMATION MODELLING IN CONSTRUCTION PROJECTS

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Abstract

Construction design is typically a collaborative effort involving multiple design professionals covering different areas of expertise. These professionals typically form ‘loosely coupled’ temporary project organisations for the duration it takes to accomplish their work. Even though construction designers operate in loosely coupled systems, their work tasks are highly interdependent. Additionally, the designers are interdependent in their use of technology and need to fuse and integrate their information systems (e.g. Building Information Modelling [BIM] systems) for the project’s duration.

The controversial situation of being highly interdependent in conjunction with having to operate in a loosely coupled system is discussed in this paper. These two characteristics of project-based work along with the notion of the actors’ position in the process chain, are then conceptualized to have an impact on the actors’ freedom of enactment in using a certain technology. Instead, improvised practices emerge or actors simply decide not to constitute the possible enactment. We develop a conceptual framework to capture the interplay of the aforementioned concepts. As an initial validation, we test the plausibility of the framework using data from two construction projects that involve the use of BIM systems.

Keywords: Building Information Modelling, BIM, construction project, freedom of enactment, loosely coupled system.

1 Introduction

Today’s construction projects could not be run at the necessary speed without using advanced information systems (IS) such as Building Information Modelling (BIM). In this study, BIM is defined as 3D digital representations of all physical and functional characteristics of a facility (NIBS, 2007). Anticipated benefits of the BIM systems include improved clarity in design information sharing and the potential to streamline the construction design process ranging from early design negotiation and generation to execution. BIM systems are intended to provide a shared digital infrastructure to link heterogeneous, previously unconnected actors in a collaborative environment (Yoo et al., 2010). BIM technologies have the potential to serve as catalyst for innovation and improved inter-organisational processes (Berente et al., 2010; Boland et al., 2007).

Despite the increasing uptake of BIM systems, scholars report that design professionals still miss out on many of the crucial advantages the technology has to offer (Ahmad & Sein, 2008). There is a tendency for designers to use the new technology predominantly to automate old design processes rather than to substantially transform the way in which they communicate (Merschbrock, 2012). Not all actors are able to partake in BIM collaboration (Merschbrock, 2012) and especially those working at the ‘periphery of a digital innovation networks’ are frequently excluded from innovative practices.
Tales from the field support this claim and the following two quotes by professionals having used BIM technology in a joint construction project illustrate the problem:

“We have been using BIM for some time and [...] I am happy [with the system]. [In this project] I have not been forced in a very strict routine of drawing in Revit™, collision checking, and a full BIM kind of design process from the very beginning.” (Architect)

“There is a lot of rubbish you are not able to use. So in the end, you sort of only take over the geometry.” (Timber frame manufacturer)

Basing upon the notion of enactment suggested by Weick (1988), we define the freedom of enactment as the degree of flexibility an actor possesses to perform actions in a given structure or to create new structure. For the purpose of our study we define structure as “a set of rules and resources instantiated in recurrent social practice” (Orlikowski, 2000, p. 406). BIM systems in construction projects can thus be considered a structure, as they embody social structures which presumably embedded into them by designers during their development and which are them appropriated by users when they interact with the BIM systems (Orlikowski & Iacono, 2001), and the use of BIM involves repetitive social practices carried out by various actors (Orlikowski, 2000).

The quotes above hint that the actors had different degrees of freedom when it came to technology enactment. From the first quote, we understand that the architect enjoyed his ‘freedom of enactment’ in using BIM systems. Whereas the second quote indicates that the timber frame manufacturer struggled to solve problems inflicted upon him due to prior BIM use limiting his ‘freedom of enactment’. This is partly explained by the nature of inter-organisational work in the construction industry which is characterized by high level of task interdependence (Dubois & Gadde, 2002). On the contrary, construction projects are organised as temporary organisations which are considered loosely coupled systems (Dubois & Gadde, 2002). In such a system, its elements affect each other “suddenly (rather than continuously), occasionally (rather than constantly), negligibly (rather than significantly), indirectly (rather than directly), and eventually (rather than immediately)” (Weick, 1982, p. 380) – cited in Orton and Weick (1990).

In addition, previous studies (e.g., Gal et al., 2008; Merschbrock, 2012) in the context of construction projects find that the potentials of BIM are not fully exploited, partly because of lack of a shared organizing vision and ‘automation islands’. In order to get its full potentials, these inter-organizational problems should be eliminated (Lyytinen & Damsgaard, 2011). But hitherto, these unsolved problems and their roots in collaborative work involving various actors and interdependent technologies, like BIM systems, are not properly understood. Instead of examining the phenomenon from a macro level (i.e., strategic/industry level) (see e.g., Lyytinen & Damsgaard, 2011), in this study we are particularly interested in understanding it from a micro level perspective (i.e., operational/project level). We expect that this effort will complement the stock of previous studies. Hence, the question addressed by this study is: How does this contradicting situation in construction projects influence the actors’ freedom of enactment in using BIM systems?

To answer this question, we attempt to develop a conceptual framework and plausible arguments derived from extant literature. In doing so, we use data from two construction projects to provide illustrations and to undertake an initial validation of the framework.

This study is important for three reasons. First, the conceptualization of construction projects as both highly interdependent and loosely coupled seems to be taken for granted and unproblematic in literature (Dubois & Gadde, 2002; Gidado, 1996). However, when it comes to the use of BIM systems, understanding this contradicting situation may help addressing some challenges experienced by professionals in the field. Second, the actors’ freedom of enactment in the context of information technology use in construction projects, both generally and concerning BIM use in particular, has received little attention. This notion is useful to explain various problems emerging in the collaborative work between the actors involved. Third, scholars have argued that BIM and its exciting potential for transforming a major industry such as building construction is an interesting artefact in need for further IS research (Merschbrock & Munkvold, 2012).
The remainder of the paper will be structured as follows. Section 2 presents the conceptual premises of this paper, followed by an attempt to develop a conceptual framework in Section 3. Section 4 presents brief tales from two construction projects. The findings with practical and theoretical implications are discussed in Section 5.

2 Conceptual Premises

2.1 Characteristics of construction projects

Construction projects are very complex in their nature rooted in their uncertainty and interdependence (Gidado, 1996). The high degree of uncertainty stems from incomplete activity specification, unfamiliarity with local resources and environment, and the diversity of materials and people involved. Meanwhile, the high degree of interdependence results from the number of interdependent technologies, the sequential nature of processes, and the high division of labour typical for the construction industry with design professionals covering different areas of expertise (Gidado, 1996).

However, scholars argue that the construction industry can be seen as a loosely coupled system (Dubois & Gadde, 2002). Several causes leading to loose coupling are highlighted in the literature, namely causal indeterminacy, fragmented external environment, and fragmented internal environment (Orton & Weick, 1990). The construction industry is characterized to be highly fragmented in its nature and it is argued that IS may help to reduce this problem (Howard et al., 1989).

In addition, Orton and Weick (1990) unveil several direct effects of loose coupling, namely modularity, requisite variety, behavioural discretion. This is to some extent the case in the construction industry (Voordijk et al., 2006). Further, loose coupling may happen between individuals, organizations, activities, intentions, and/or actions. Loose coupling is not always regarded as negative and in many cases it is the preferred way of organising. Opting for a loosely coupled system can increase satisfaction, effectiveness, and adaptability (Orton & Weick, 1990). To sum up, construction projects are complex due to their high degree of uncertainty and interdependence, but at the same time, they are loosely coupled. This leads to a contradicting situation which will be elaborated next.

2.2 Enactment

We have defined freedom of enactment as the degree of flexibility an actor possesses to perform actions in a given structure or to create new structure. The structure can be used, misused, or not used by the actors in various contexts (Orlikowski, 2000). In the context of this study, by adopting an ensemble view of IT artefact (Orlikowski & Iacono, 2001), BIM systems can be considered as a structure, where actors to some extent have freedom to use BIM in a way they perceive contextually appropriate. Moreover, enactment can also represent an actor’s response to emerging changes in structure. Thus, the action is shaped and being shaped by structure (Gioia, 2006).

Our notion of enactment is closely related to the notion of technology-in-practice proposed by Orlikowski (2000). She defines it as “sets of rules and resources that are (re)constituted in people’s recurrent engagement with the technologies at hand” (Orlikowski, 2000, p. 407). In her study, technology is enacted in three possible ways dependent on the response of the actors: inertia, application, and change. Enactment in the form of inertia happens when the technology is used to reinforce and preserve status quo, by limited use of it. In this case, the actors may either avoid using the technology or engage in but a cursory manner (Boudreau & Robey, 2005). In the application enactment, the actors may use the technology in collaboration, individual productivity, collective problem solving, or process support. All these are intended to reinforce and enhance the status quo (Orlikowski, 2000). The enactment in the form of change is chosen to transform the status quo by making improvisations in technology use. The last type relates to the notion of improvised learning by Boudreau and Robey (2005). They defined it as “learning situated in practice, initiated by users, and implemented without any predetermined structure” (Boudreau & Robey, 2005, p. 9). Another type of
enactment is introduced by Boudreau and Robey (2005), which is reinvention. It is defined as “unintended uses of technology in which users compensate for their limited knowledge of the system and perceived system deficiencies by developing ‘tweaks’ and ‘workarounds’” (Boudreau & Robey, 2005, p. 9). Here, the invention or the technology is changed by its adopters after its original development (Johnson & Rice (1987) – cited by Boudreau and Robey (2005)). To sum up, actors’ flexibility to decide what types of enactment they could choose under certain circumstances reflects the freedom of enactment. The enactment could manifest in various forms: inertia, application, change, and reinvention.

3 Conceptualizing the Freedom of Enactment

This chapter is concerned with advancing our conceptualisation of the freedom of enactment. We develop our conceptualisation stepwise beginning by discussing the contradiction between loose coupling and interdependence in systems. In doing so, we bring in the notions of interdependent and loosely coupled system and conceptualize their possible impact on the freedom of enactment. We argue that these notions are important to understand the context in which BIM systems are used. This is followed by a brief discussion of how an actor’s position in the process chain relates to freedom of enactment. This discussion is important to understand the process at the micro level (i.e., operational/project level). Finally, we put forward a framework linking the aforementioned concepts, by introducing the notions of conversion factors that transform the freedom of enactment into constituted enactment.

3.1 Impact of interdependent and loosely coupled system on the freedom of enactment

In general, one would expect that actors’ freedom of enactment is influenced by the degree of interdependence between elements constituting a system. The element could be a task, a technology or a person. In a highly interdependent system, actors’ freedom to enact technology is low (see Figure 1(a)). In addition, we argue that the degree of system coupling may determine the actors’ freedom of enactment. In a loosely coupled system the actors’ freedom is expected to be high. Conversely, when the system is tightly coupled, the actors’ freedom is limited (see Figure 1(b)). In a loosely coupled system, the types of enactment may be considered as the system’s outcomes (Orton & Weick, 1990).

Figure 1 illustrates how both the degree of interdependence and the degree of coupling correlate negatively with the freedom of enactment. But, this is not always the case in the context of construction projects. Construction projects have been conceptualized as interdependent systems on one hand (Gidado, 1996), and as loosely coupled systems on the other (Dubois & Gadde, 2002; Howard et al., 1989). This leads to a contradicting situation.

Figure 1. The relationship of (a) the actors’ degree of interdependence; (b) their degree of coupling; and their freedom of enactment

We have argued in the Introduction section, that it is important to understand this contradicting situation. In doing so, at least two explanations can be provided.
First, in the context of BIM use, one possible way of explaining the contradicting situation is by distinguishing between task interdependence and technology interdependence (Bailey et al., 2011). The former deals with the interrelationship of what the actors do in a broader sense (such as making a building design, an electricity installation plan), while the latter concerns with the interrelationship of the technologies used to perform tasks. Bailey and colleagues (2011) found that these different types of interdependence require different degrees of coordination. They concluded that high levels of task interdependence may call for high coordination, but high levels of technology interdependence may not necessarily do so. They also revealed that managers’ policies around technology interdependence are not directed at managing the use of technology more efficient, but to manage the work accomplished by the technology. This finding seems to assume that there is a clear-cut separation between technology and work. In the context of collaborated work in construction projects involving a set of interdependent technologies along the way, the finding needs to be rethought. Could the absence of a focussed managerial response to technology interdependence explain why the actors working in ‘the periphery of digital innovation networks’ are frequently excluded from innovative work? A systematic study is required to answer this question.

Second, another way to understand this contradicting situation is by contrasting project and industry level of analysis. Dubois and Gadde (2002) argue that complexity of construction projects is managed through tight couplings among the firms, by relational exchange and inter-firm adaptations. But, this is not the case in the construction industry. Further, they assert that in the construction industry, there are few inter-firm adaptations beyond the scope of individual projects, and the involved firms tend to rely on short-term market-based exchange (Howard et al., 1989). Here, it is expected that there is a tight coupling among the firms. But in a larger context of permanent firms network, at industry level and beyond short-term construction projects, the coupling is loosened (Dubois & Gadde, 2002).

### 3.2 Impact of the actors’ position in the process chain on their freedom of enactment

Effects of loose coupling may be functional or dysfunctional (Weick, 1976). The question is then functional or dysfunctional for whom? One way to address this issue is by making a distinction between recurrent and sequential systems, and considering the actors’ position in the process chain.

In a recurrent system, where a process may go back and forth several times between the actors, the degree of interdependence between them is high along the way. At the same time, the system can be assumed to be tightly coupled. Hence, the actors’ freedom of enactment is managed and constrained from the very beginning. Although it is still possible that the degree of freedom of the actors at the early stage of the process chain is somehow higher than that one of the late actors, it will not be significantly different.

The sequential nature of the supply chain in construction projects, where (1) architects explore aesthetical solutions; (2) consultants explore technical solutions; and (3) contractors build the specified product, is seen as a root cause for poor communication resulting in costly rework and unproductive downtime (Love & Li, 2000). In a sequential system (such as a construction project) with limited recurrent processes between the actors, the degree of interdependence varies along the process.

The actors in the early stage of the process depend less on the actors in the subsequent stages, while the actors in the late process chain depend greatly on the previous ones. This degree of dependence affects the actors’ freedom of enactment.

To sum up, a loosely coupled system may be functional for the early actors, but dysfunctional for the later ones. The relationship between the position of the actors in the process chain and their freedom of enactment is depicted in Figure 2(a). In either case, the freedom of enactment is tunnelled as the project progresses (Figure 2(b)).
3.3 Freedom of enactment and constituted enactment

This part is inspired by the notion of capabilities and functionings in the capability approach by Sen (1999). We argue that this notion provides insights how the actors’ freedom of enactment is transformed into constituted enactment. A capability reflects a person’s ability to achieve a given functioning (‘doing’ or ‘being’), while functioning is an achievement of a person: what she or he manages to do or be. Not all capabilities can be transformed into functionings.

This transformation is facilitated by a set of conversion factors, which can be personal, social, or environmental conversion factors (Robeyns, 2005). Personal conversion factors are factors internal to the persons using information systems. The personal conversion factors suggested by Robeyns (2005) include physical condition, skill, knowledge, and education. The social conversion factors are inherent in the society in which a person lives. Examples of social conversion factors include public policies, social norms, societal hierarchies, and power relations. Environmental factors emerging from the physical or built environment, in which a person lives, include geographical location, climate, the availability of tools, and the presence of infrastructure.

In the context of this study, freedom of enactment can be considered as capabilities of a person or a firm. The freedom of enactment cannot always be constituted into an actual enactment. Or, the actual enactment, which can be seen as functioning, may be manifested in various forms (i.e., inertia, application, change, and reinvention). In this study, we call it constituted enactment. The forms of constituted enactment are dependent on a set of conversion factors. The relationship between the degree of interdependence, the degree of coupling, the actor’s position in the process chain, the freedom of enactment, and the constituted enactment is depicted in Figure 3. Assessment metrics such as the Software Capability Maturity Model (CMM©) by the Software Engineering Institute (SEI) could proof helpful to understand the constituted enactment in collaborative BIM use.
4 Two Tales from the Field

Norway’s wood-based building industry has witnessed heavy investments in automation and technologies such as BIM. Recent legislation in Norway such as new standards for developing low-energy and passive houses and clients pressuring for reasonable quality create a need for new technologies and innovation. We find that this part of the Architecture, Engineering and Construction (AEC) industry striving for better integrated practice makes a compelling context to test the plausibility of our conceptual framework. For this reason, we do not provide thick description of the cases that are reported in detail somewhere else (Merschbrock, 2012).

The data has been collected based on 19 semi-structured interviews with design professionals. These design professionals worked on two different construction projects, a residential and a library project and the interviews were taken over a time span from September 2011 to May 2012. We expect that the cases represent different situations in the construction industry with regards to the actors involved and actors’ digital modelling practices. Table 1 summarizes the professions of the informants interviewed. By choosing interviews as means for data collection we aim on gaining an understanding of the phenomenon by asking those experiencing it. The projects were carefully chosen based on three selection criteria: (1) the project participants should resemble a rather typical project constellation in the construction industry (e.g., client, architect, engineers and contractors); (2) the design stage had to be completed at the time of data collection; and (3) BIM technology had to be deployed in construction design. The criteria were selected, to be able to provide a holistic account of construction design activity, to understand the perspectives of the actors involved typically in such activity and, to place BIM, as technological artefact at the core of our study.

<table>
<thead>
<tr>
<th>First tale: Residential project</th>
<th>Second tale: Library project</th>
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<tr>
<td>Timber frame builders (CEO/design manager/production manager/drafter)</td>
<td>Engineering design manager</td>
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<tr>
<td>Engineering design manager (for HVAC, structural, electrical)</td>
<td>Structural engineer</td>
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<td>Geotechnical engineer</td>
<td>Electrical engineer</td>
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<td>Fire protection engineer</td>
<td>Fire-protection engineer</td>
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<tr>
<td>Client representative (CEO)</td>
<td>Massive wood builder (project manager)</td>
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<tr>
<td>Structural engineer for wooden structures</td>
<td>Glue-lime builder (project manager)</td>
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<tr>
<td>Architect</td>
<td>Client representative (municipality)</td>
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<td></td>
<td>Architect</td>
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<td>General contractor</td>
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*Table 1. The profession of the 19 informants interviewed*

4.1 First tale: Residential project

The residential project was a construction project initiated by a private property developer and encompassed the construction of three apartment buildings, which consisted of one hundred individual apartment units altogether. The architect aided the client in developing the requirements for the building at an early stage in the design process chain. The architectural work did neither depend on previously accomplished tasks nor on prior used technology. The client was indifferent which design technology was to be deployed in the project as long as the building would “look new and modern and so on” (Client, CEO). In this respect, the architect’s early position in the process chain and his task and technology independence allowed him to enjoy a high degree of freedom when it came to deciding which design technology to use and how to accomplish the design work. Moreover, the architect had modelling systems in place and he was an experienced user of this technology. Thus, he could deploy technology in the way he “liked to do it” (Architect).

The favourable combination of freedom of enactment and task and technology independence, accompanied by appropriate conversion factors resulted in the enactment of 3D Sketching Software and architectural BIM software. The architect opted for using 3D Sketching Software as it enabled him a dynamic way of communication based on “...snapshots of [his] model to show what [he] was thinking” (Architect). In addition, he decided to deploy architectural BIM software as an internal tool
to create 2D drawing sets. He decided, however, not to actively seek model based collaboration because he did not want to:

“…force everybody into a specific way of working, which would maybe be strange to them [engineers and builders], or where they would not have experience from before” (Architect)

Engineering consultants providing the structural, electrical and mechanical design came second in the design process chain. Their task included building on prior design provided by the architect, accordingly they were moderately task and technology dependent. The engineers were limited in their capacity to use their modelling technology in collaboration. This was due to the architects’ preference to use 2D drawings instead of digital models in collaboration. Thus their freedom to enact the cooperative capability of their modelling systems was limited. In consequence the engineers did not seek model based collaboration and decided to communicate with others based on 2D CAD drawings. Additionally, they were constrained in their available resources (conversion factors), hindering them to make effective use of their modelling systems:

“It’s not that difficult [to collaborate in BIM], you have to be a little more precise, and you need a little more effort. […] The clients have to be willing to pay for the extra work we do.” (Engineer, Design Manager)

The actors involved in the late stages of the process chain, such as the timber frame builders, depended on design work produced by the architects and the engineers. Thus, they were task and technology interdependent. The following quote by a timber frame builder delivers evidence for the task and technology dependency:

“I translate in fact the information from architects and civil engineers developing this building to production — to the carpenters working in our production.” (Timber frame builder, Drafter)

The timber frame contractor has been significantly constrained in his freedom to work with BIM technology, as indicated by the following statement:

“In fact the architect is not modelling in the kind of modelling which I need. The interfaces today do not deliver the kind of cubes and other volumes I need, so I have to decide in the beginning if I want to start now with a lot of information which is not usable in the same program. Or, if I try to find out what is the sense of this and start to model it new.” (Timber frame builder, Drafter)

4.2 Second tale: Library project

The library and cultural centre was a construction project initiated by a local municipality in southern Norway. The project comprises the construction of a café, meeting places and administrative areas. The building’s wooden structure consists of 27 ribs made of prefabricated glue-laminated timber elements and Computer Numerical Control (CNC) cut plywood boards. The design of the library can be considered ambitious with the ribs gradually shifting shapes resembling hybrid structures.

All architecture begins with a blank sheet of paper and architects are the first to draw a line on that blank page. Thus, the architect occupied an early position in the process chain of the library’s design. Owed to this position, the architect’s degree of task and technology interdependence towards others in early design was low to non-existing. The only task interdependencies which could be identified were loosely formulated needs, or desires voiced by the client such as to “create the new cultural heart of [the municipality]” (Architect). Thus, the architect was theoretically, at project initiation, free to use or enact whatever technology he felt was necessary to accomplish his work. Apart from having the freedom to enact technology, the architect had modelling technology and a team of co-workers possessing the skills and knowledge to operate 3D systems in place:

“…we [architectural team competent in using several types of 3D programs] are able to work closely together and we can make use of the resources we need in the projects” (Architect)

The favourable conditions encompassing a high freedom of enactment and a wide availability of conversion factors resulted in the constituted enactment of three types of Building Information Modelling technology, namely: (1) rendering software to create ‘photo realistic’ 3D geometric elements signifying the future outer shape of the building; (2) architectural Building Information
Modelling software to create detailed 3D architectural models; and (3) sketching software for creating 3D sketches.

Through the course of the library project the architects consulted with engineers to make sure that their design was structurally sound, buildable and complied to building codes. The engineers became involved about mid-way into the design process chain. Inherently, the engineers were moderately task interdependent in their work by having to extend and improve prior created architectural design work. Additionally, they were moderately technology dependent since they were required to work with modelling data created in architectural systems. At the same time they were loosely coupled to the architect as a member of the temporary project organisation. The technical interdependence resulted in interoperability challenges ultimately leading to ‘workaround’ practices. An example for improvised practice was the need to create compressed digital replicas of the architectural models to be able to use them in further work. We argue that the engineer’s freedom of enactment was moderate. Ultimately the engineers enacted all their design systems as intended, however they had to conduct some time consuming workarounds. However, the engineers had some deficiencies rooted in social conversion factors, especially with hindsight to the skills required to work with compressed replica models:

“…this was the first project where we tried to use BIM both based on IFC [the compressed files] and to change our process and I think we succeeded the first half [of the project] and then maybe not the second half.” (Engineer, Design Manager)

Several actors involved in late stages of the process chain worked with creating shop designs related to either off-site manufacturing or on-site assembly of the building’s parts. The massive-wood contractor fabricating the CNC cut plywood parts of the building serves well as an example for this group of actors. The massive wood contractor was highly task-dependent, as he had to build upon all prior executed design work ranging from architectural to engineering design. Moreover, he was highly technology-dependent, as they had to combine and make sense of modelling and drawing data created by various organisations and in significantly different design systems. This high degree of interdependence resulted in organisational and technical tensions and challenges. In the case of the library project the massive wood contractor improvised and developed workarounds to be able to make at least to some extent use of his advanced modelling systems and CNC machinery. However, they did not quite succeed gathering all prior created design data and decided for just using the structural engineering model in their design. This practice resulted in additional working hours and led to inaccuracies in the produced timber elements. We argue that the massive wood contractors had far less freedom to make efficient use of their technology than their predecessors. The following statement confirms that the massive wood contractor did not succeed in gathering the relevant data:

“If the timber structure would have been drawn in our program we could have produced all the drawings, everything that we needed.” (Massive wood builder, Project Manager)

4.3 Lessons from the tales

From the two tales presented above, we contend that the task interdependence between actors in design, planning, and construction is high. However, as a sequential system with a limited number of recurrent processes, the notion of task and technology interdependence might be interpreted in a different way. As expected our findings show that the actors in the early process chain (i.e., architects) are less dependent on the subsequent actors. Engineers who translate the design depend on the architect’s work. At the end of the process chain, the manufacturers rely heavily on the work of the architects and the engineers. We call this situation ‘backward interdependence’, to differentiate it from ‘reciprocal interdependence’ when the degrees of dependence among the actors are rather similar. This finding differed from a common understanding arguing that construction project is reciprocal interdependent, but it is not the case of BIM use in the two projects under our study. The two quotes presented in the opening part of this paper illustrate it.

We got evidence that lack of coordination in a highly technology interdependent context creates harmful effects, specifically for the actors late in the process chain (i.e., glue lime manufacturer and massive wood manufacturer). The later actors expected that the design made by the architects and the
engineers could be translated directly into the manufacturing process, but this was not the case. Inappropriate use of the BIM systems by the early actors limited the freedom of enactment of the later. To tackle with this limited freedom of enactment, we found the later actors undertook ‘workarounds’. The digital work from the early actors who used BIM systems, was only used partly by the later. In this regard, from the first tale we found that the architects adopted the inertia constituted enactment as they used 2D CAD drawing. They avoided using the BIM systems or engaged in but a cursory manner (cf. Boudreau & Robey, 2005). A different finding was spotted from the second tale, when the architects attempted to use the BIM system to a great extent. Here, they adopted the application constituted enactment (cf. Orlikowski, 2000). In addition, in general, we found that the later actors (e.g., engineers, glue lime manufacture, and massive wood manufacturer) chose the change constituted enactment by making improvisation in the technology use (Boudreau & Robey, 2005; Orlikowski, 2000). This initiative led to a costly production, due to additional working hours allocated and possible errors detected during the loosely coupled process. Without the availability of skilful workers and some degree of tolerance in various aspects (e.g. monetary resources, time and technology), these ‘workarounds’ are not possible options. We did not find any constituted enactment in the form of reinvention from these two tales.

Based on the tales, we were able to pinpoint several conversion factors leading actors to exercise their freedom of enactment and turn it into constituted enactment. We found that actors’ decisions about which technology to enact in practice were led by their perceptions about which way of working would be appropriate in a given situation.

For example, the architect in the first tale stated that he used technology in the way he ‘liked to do it’. Further, we found that objectives such as ‘creating a dynamic way to communicate’ or ‘creating an ambitiously designed building’ influenced the actors’ decisions about enacting technology in practice. We argue that the aforementioned conversion factors stem from the social environment in which the action takes place. Beyond the social conversion factors related to the way in which actors liked to do their work, we found that factors internal to the persons using the technology, such as skills, experience, and education in using BIM, translated into constituted enactment. In addition, environmental factors such as having appropriate BIM systems, monetary resources, and time flexibility resulted in constituted enactment.

5 Discussion

The findings are, on one hand, in line with the study by Bailey and colleagues (2011) as the early actors perceived that coordination in the context of technology interdependence was unnecessary. On the other hand, this study extends their work by explicating the problems of unnecessary coordination related to the freedom of enactment, especially for the actors involved in the later stages. We identified a set of antecedents and impacts of freedom of enactment. Alike, we also unearthed several conversion factors which may play a role in transforming the freedom of enactment into constituted enactment in various stages of the projects. In addition, this study also provided new insights how to understand the contradicting situation in which a construction project at the same time is both interdependent (Gidado, 1996) and loosely coupled (Dubois & Gadde, 2002). In the following, we discuss the implications of our study both for research and practice.

5.1 Implications

Implications for research. Our conceptual framework provided new insights or understanding of the antecedents and impacts of freedom of enactment, particularly in the use of BIM systems. As an initial validation, we used data from two construction projects to test the plausibility of the framework. However, our lists of both the antecedents and impacts are not exhaustive. In this regard, we also briefly introduced the notion of ‘freedom of enactment tunnelling’. We found that the actors constituted different enactment forms along the process chain. For example, the architects in two
different construction projects preferred different constituted enactment forms (in this study, inertia and application) when it came to the BIM use. However, our data did not allow us to analyze this finding further. Hence, further research, in addition to validating our findings, should seek to identify other possible antecedents for the freedom of enactment that partake in its tunnelling and the associated impacts.

Additionally, we offer new conceptualization of the notion of interdependence. Instead of seeing it as ‘reciprocal independence’, we propose to use ‘backward interdependence’. This notion then can be used to further understand the notion of loosely coupled systems in the context of construction projects. These notions (i.e., freedom of enactment tunnelling, backward interdependence, and reciprocal interdependence) could be detailed and specified further in other research. For example, further research could examine the freedom of enactment in a system with a high reciprocal interdependence. How does the process of tunnelling happen? How do the actors deal with that situation? What other factors (e.g., institutional factors) form the freedom of enactment?

One way of addressing it is by bringing in other relevant theories, such as institutional theory – specifically on the discussion of strategic response (Oliver, 1991) – or stakeholder theory (Mitchell et al., 1997) – in particular to see the power relation between the actors; and conducting systematic research in contexts with various characteristics (such as sequential vs. reciprocal systems).

Implications for practice. Our study also has some implications for practice. First, it provides insights for practitioners to understand better the issue of freedom of enactment of the actors involved in the projects. They can use our findings to determine policies how to cope with the problems. Possible recommendations include bettering coordination in terms of BIM systems use. Another practical recommendation is to increase the awareness of the actors involved in the early stages of the projects to think about possible problems they might inflict upon others by inappropriate or careless use of BIM systems, especially when the digital works are passed over to the later actors.

In addition, our study also offers insights about how to tackle the limited freedom of enactment experienced by certain actors. The tunnel of freedom of enactment can be ‘opened out’ to provide some more room for creativity enabling certain actors to constitute enactment. This can be done by performing ‘workarounds’, for example, by loosening the tolerance in terms of financial resource, man-hours, raw material, or even the (aesthetic) quality of the project.

5.2 Concluding remarks

When reading the paper’s title, one may expect at first sight that the actors’ degree of enactment in a loosely coupled system is high. But this is not the case for all actors in the context of BIM use in construction projects, due to some factors discussed above. One may ask, would the freedom of enactment be different, if the actors would use traditional, pen and paper-based tools? It could be similar, but our concern here is how to exploit the potentials of BIM systems by better understanding the actors’ freedom of enactment. Arguably, failing in managing this issue will hinder an effective inter-organizational collaboration that enables exploitation of benefits offered by BIM systems. Our hope is that our preliminary conceptualization of the freedom of enactment can be validated, fine-tuned, and extended by future research. By doing this, we expect that the notion of freedom of enactment can be used to better understand various problems emerging in collaborative work involving various actors and interdependent technologies, like BIM systems.

References


