BI Norwegian Business School - campus Oslo

GRA 19703

Master Thesis

Thesis Master of Science

Building Information Modeling in the Norwegian Construction Industry: A Comparison of Different Contractual Models

Navn: Anne Marthe Magnussen, Linda Paulsen

Start: 15.01.2019 09.00

Finish: 01.07.2019 12.00

Anne Marthe Bøttinger Magnussen
Linda Paulsen

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A Comparison of Different Contractual Models

Programme:
Master of Science in Business Major Strategy

Supervisor:
Ragnhild Kvålshaugen

Date of Submission:
30.06.2019

ACKNOWLEDGMENTS

First of all, we would like to express our gratitude towards our supervisor Ragnhild Kvålshaugen for her invaluable guidance throughout the process of writing this thesis. Ragnhild has continuously provided us with constructive and insightful feedback. Additionally, she introduced us to the Centre for Construction Industry, which further deepened our understanding of the topic of relevance. We would also like to thank the employees at the Centre for Construction Industry who have provided us with useful insights. Lastly, we would also direct a special thank you to all of the interview objects for being so open when sharing their insights.

Oslo, June 30th 2019

Anne Marthe Magnussen   Linda Paulsen

Anne Marthe Bøttinger Magnussen   Linda Paulsen

ABSTRACT

The adoption of building information modeling (BIM) among construction firms, can contribute to resolving many of the issues inherent in today's construction industry. However, despite a proliferation in BIM adoption across the Norwegian construction industry, these issues remain. We suggest that this can partly be explained by the delivery models that govern construction projects. This master thesis builds on transaction cost economics, and aims to extend previous literature on how contractual models can act as boundary conditions for effective use of BIM. Seven propositions were developed on the basis of case study evidence from eight construction projects in Norway. Findings suggest a relationship between different contractual models and effective use of BIM. The strength of this relationship was also found to depend on a set of conditional factors. Novel contributions are: first, to identify characteristics of BIM exchange; second, to offer some insights on the contextual appropriateness of different delivery models in governing BIM exchange; and third, to explain how different contractual models can play a complementary role in governing the exchange of information in BIM. The study offers practical implications for project owners seeking effective use of BIM. Most notably, project owners should be aware of the opportunities and challenges of the different contractual models with regards to BIM. They should also pay attention to the contextual factors that may influence the relative effectiveness of the different contractual models.

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CHAPTER 1: INTRODUCTION

The fundamental characteristics of the architecture, engineering, and construction (AEC) industry are uncertainty, complexity and a lack of coordination between project phases and disciplines. These characteristics are considered the source of poor productivity development, cost-overruns, and conflicts commonly observed in construction projects today (Eikeland, 1998; Briscoe & Dainty, 2005; Papadonikolaki & Wamelink, 2017). Increased integration, referring to a more extensive exchange of knowledge and information, is considered to counterbalance the effects of complexity and uncertainty (Fergusson, 1993; Bråthen et al., 2016). The need for integration has resulted in a proliferation in the adoption of Building Information Modeling (BIM) throughout the industry (Bryde et al., 2013). BIM can be defined as a "shared digital representation of physical and functional characteristics of any built object [...] which forms a reliable basis for decisions" (ISO, 2010). The potential of BIM lies in its ability to integrate all relevant information in one single model, and thus encourage coordination across project phases and disciplines (Fischer et al., 2017). Indeed, previous research has shown that this integration can positively influence project costs, schedule, and quality (Azhar et al., 2011; Bryde et al., 2013).

Nevertheless, the industry as a whole has not yet been able to achieve the full benefits highlighted in the literature. This has been attributed to technological, social, cost-related and legal factors surrounding the process of modeling and information exchange (Sun et al., 2017; Alreshidi et al., 2018). The contractual environment is an example of a legal factor that may significantly influence BIM use. Particularly, the project delivery models in the construction industry determine roles and responsibilities, risk sharing, project organization, information flow, and the collaborative model. Together these factors act as boundary conditions for coordination between project participants (Lædre, 2009; OSCAR, 2016). The current delivery models in the Norwegian AEC-industry differs in two key areas when it comes to integrating the different disciplines. That is, whom to include in the different project stages and the timing of involvement (El Asmar et al., 2013). Researchers have found that the choice of project delivery model can influence the degree of integration between disciplines and phases and thus the effectiveness of

BIM (Hardin & McCool, 2015; Liu et al., 2017; Ahmad et al., 2018). Delivery models may also indirectly influence BIM use through its effect on other factors surrounding the process of modeling and information exchange. Thus, understanding the influence of delivery models on the use of BIM is important in order to be able to realize the positive effects of BIM.

While there is a growing body of research investigating the relationship between delivery models and BIM, the vast majority of studies have been set outside of the Norwegian context (Lloyd-Walker & Walker, 2015). The SamBIM report is the only study set in the Norwegian context that has identified a possible relationship between delivery models and BIM (Bråthen et al., 2016). Still, delivery methods was not a topic given significant attention in this study. Due to slight variations in delivery models across jurisdictions, the available international studies are not generalizable to the Norwegian context. Another concern with previous research is that it tends to assume that certain delivery models are more suitable with regards to BIM, without empirically investigating this relationship. Thus, researchers call for studies focusing on empirical analyses based on interviews and surveys of various project participants across jurisdictions (Sebastian, 2011; Papadonikolaki & Wamelink, 2017). Sebastian (2011) further emphasizes the need for cross-case comparisons of different project delivery methods in relation to BIM.

The present paper responds to the call for advancing research on the relationship between BIM and delivery models in the construction industry. Particularly, this study will investigate this relationship through the lens of transaction cost economics (TCE), which is the principal framework for determining the suitability of contractual models under various contextual conditions (Carson et al., 2006). MacNeil (1973) studied historical forms of contracting and found that contracting models range over a spectrum that lies between fully transactional and fully relational. The different contractual models in the Norwegian construction industry can be placed within this spectrum, while some mainly follow transaction based principles, others are thought to be relation-based (Reve & Levitt, 1984). Transactional contracting emphasize legal rules, formal documents, and self-liquidating transactions (Williamson; 1979; Jobidon et al., 2019). Relational contracting is based on informal agreements and norms, which influence the behavior of individuals (Baker et al., 2002). The TCE perspective recognizes that transactional contracting effectively govern exchange under low to medium levels of uncertainty, complexity, and specialized asset investments (Williamson, 1975). Conversely, when uncertainty, complexity, and specialized asset investments are significant, relational contracting is predicted to be an appropriate governance form (Granovetter, 1985; Gulati, 1995). Although a significant amount of empirical evidence show that contextual factors influence the selection of governance form, there is little support for the relative effectiveness of this choice (David & Han, 2004). In addition, the interrelation between transactional and relational contracting remains a puzzle. Whereas some scholars argue that they are complements, others view them substitutes (Poppo & Zenger, 2002).

The construction industry is characterized by complexity, uncertainty and medium levels of asset specific investments, which indicate that relational contracting is the most suitable contractual model (Matthews & Howell, 2005). The characteristics of transactions in construction projects contextualize exchange in BIM. Further, we aim to identify the more specific characteristics of BIM exchange and explore the suitability of the different contractual models under these conditions. Thus, we hope to contribute to theory by offering empirical insights on the effectiveness of different contractual forms in governing BIM exchange. Further, we aim to improve our understanding of the relationship between transactional and relational contracting. We also believe this study can be useful for construction practitioners, in that it offers guidance on how to facilitate effective use of BIM. Given that the industry is still not realizing the full positive effects from BIM, this contribution appears both important and timely. This leads us to the following research question:

How do contractual models act as boundary conditions for effective BIM use?

To approach this topic, we used a multiple case study design, where several transaction- and relation-based delivery methods were included in the sample. The main data source was interviews with key project participants. The interviews were supplemented with project specific and publicly available documentation and information. This method allowed us to compare different delivery models and identify patterns across cases.

CHAPTER 2: LITERATURE REVIEW

In the second chapter of this paper we will review literature and shed light on how contractual models can act as boundary conditions for effective BIM use. The chapter is structured as follows. We start with defining BIM, examining its effect on construction projects and the factors influencing BIM adoption. This is followed by a presentation of the commonly used delivery models in Norway, and their possible influence on BIM use. Thereafter we review and discuss transaction cost economics in construction. This perspective is the theoretical underpinning of how we study delivery models in relation to BIM.

2.1 Building Information Modelling

BIM is considered the leading technology used in construction projects and is thus central in the digitization of the AEC-industry (GhaffarianHoseini et al., 2017). Despite its widespread use in construction projects, the term BIM is ambiguous and has no universal definition (Guillermo et al., 2009). A building information model can be defined as a “shared digital representation of physical and functional characteristics of any built object [...] which forms a reliable basis for decisions” (ISO, 2010). However, existing literature tend to define BIM as a process, supported by a 3D model. One example of this is, Succar et al. (2007:357) which define BIM as “a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle”. For the purpose of this paper we will refer to a building information model as a digital representation of the physical and functional characteristics of a project, and building information modeling (BIM) as a process of modeling, collaboration and integration (Sun et al., 2017).

2.1.1 Effective use of BIM

The benefits realization of BIM requires that the technology is implemented and used effectively on an intra- and interorganizational level. In order to use the model for decision making and as a plan for construction, sufficient and correct information must be added to the building information model. The original 3D model can be enriched with additional information and abilities, referred to as dimensions. Utilizing several dimensions increases the effectiveness of the model, as it entails additional information sharing between stakeholders (Fu et al., 2007). The 4D model enriches the model with construction scheduling information, the 5D model adds a cost calculation element, the 6D model includes environmental information, and the 7D model attaches information to support facilities management (GhaffarianHoseini et al., 2017; Volk et al., 2014). It is believed that the 3D model can potentially be enriched with unlimited dimensions. Aouad et al. (2006) referred to this multidimensionality as “nD- modeling”.

A prerequisite for the benefits realization of BIM is interorganizational collaboration (Miettinen & Paavola, 2014; Liu et al., 2017). Lack of coordination between stakeholders can result in an incorrect information foundation in the model, which undermines the model as a plan for construction (BuildingSMART, 2019). Crucial factors for effective use of BIM therefore includes that the model is shared beyond the boundaries of the individual firm, and that all relevant project participants can view and add information to the model. The Bew-Richards model (Bew & Richard, 2008) classifies the BIM use spectrum as time and competences which evolve into four different levels of maturity. BIM maturity can be defined as the supply chain’s ability to exchange information digitally. Thus, the higher the level of BIM maturity, the more effective the use of BIM. The four classifications can be described as follows:

(I) Level 0: There is no collaboration across the supply chain. 2D drafting is still used with output via paper or electronic prints. *(II) Level 1:* 3D is used for conceptual work, while 2D is the method of choice for drafting product information and approval documentation. *(III) Level 2:* Characterized by the movement from the two classifications established by RIBA (2013) from “lonely” towards a “social” application of BIM. Instead of an isolated usage, key project participants work collaboratively. Project participants work through their own 3D models and share the model with others, using open file formats such as industry foundation classes (IFC). This enables a combination of the different models

(BuildingSMART, 2019). *(IV) Level 3:* All the project participants work collectively in one model on the highest level of BIM, minimizing the risk of conflicting information. Consequently, for the purpose of this paper effective use of BIM will be defined as the exchange of information between all project participants, where this information is continually updated and free from defaults and conflicts.

Previous reports on BIM usage across the AEC-industry have found that, although most industry-players has moved past level 0, the current usage of BIM is still at a relatively early stage and can be described as rather simple. Yet, it varies across the industry (CIB, 2015). This is reflective of the Norwegian AEC-industry, which is characterized by an all-over low level of digital competence, which has implications for the extent of integration and information flow in BIM (Bygg21, 2015).

2.1.2 The Effect of BIM on Construction Projects

Existing literature has found that an effective use of BIM can result in benefit realizations throughout projects' life-cycles (Azhar et al., 2011; Azhar et al., 2012; Bryde et al., 2013). Project owners can use the model to recognize project needs, and thus benefit from early assessment of design, to make sure that project-requirements are fulfilled. Designers can utilize BIM in design and analysis. Potential benefits for those building the model are increased quality of design with input from project owners, more environmentally friendly designs, early assessment of inaccuracies, and speedy production of technical drawings. Furthermore, BIM can be a tool for contractors when managing construction projects. The accompanying potential benefits to contractors are increased profitability, cost- and time-savings, increased customer service, production quality, and improved security planning and management. Finally, BIM ensures that all relevant information for operations and maintenance are available in one single model, and can thus be utilized by facility managers throughout the lifetime of a building (Grilo & Jardim-Gonclaves, 2010; Azhar et al., 2011; Azhar et al., 2012).

Furthermore, previous research has found an all over positive effect of BIM on the cost, time, and quality of construction projects. Conducting multiple case studies, Azhar (2011) found that the average return on investment for BIM was 634%. Moreover, studying secondary data of 35 case studies, Bryde and colleagues (2013) found that BIM resulted in cost reductions in 60% of the cases, time reductions in 34% of the cases and improved quality, due to more sustainable and accurate design. Although studies have found a positive relationship between project efficiency and BIM use, Miettinen & Paavola (2014) argue that empirical evidence of the effectiveness of BIM is often anecdotal and based on descriptions of case studies. They further raise concerns regarding the credibility of measurements, due to difficulties in separating the effects of BIM on a project from other factors that might have an influence on project outcomes. Moreover, existing literature on BIM emphasize that in order to realize its full potential, other technological, cost-related, socio-organizational, and legal factors must be considered.

2.1.3 Factors Affecting BIM Adoption

Regardless of the multiple potential benefits associated with the application of BIM across the AEC value chain, many firms are failing to implement BIM properly. Consequently, the industry as a whole have not yet been able to achieve the full benefits highlighted in the literature. Previous research has identified several factors influencing the use of BIM in construction projects. These factors can be divided into four categories, namely technology, costs, socio-organizational and legal factors (Alreshidi et al., 2018; Sun et al., 2017).

Technology. Former research has found that technological factors can significantly influence the use of BIM in construction projects. As such, Porwal & Hewage (2003) argued that interoperability of BIM software packages is one of the main barriers to successful BIM adoption. They emphasize the need for standards and protocols with a shared language, so that software packages are able to communicate with each other. An example of such a language is IFC. Similarly, a UK-based study found that one of the main technological barriers to BIM adoption was the absence of interoperability (Alreshidi et al., 2018). This study also pointed to lack of technical training and data integration between stakeholders during the life-cycle of a project as major technological barriers to adoption.

Cost. Studies have also found that costs in terms of training and software and hardware setup may limit the effective use of BIM in the AEC-industry, which is characterized by small budgets and low margins (Porwal & Hewage, 2013; Alreshidi et al., 2018).

Socio-Organizational. A number of socio-organizational factors have been identified as barriers and enablers of efficient BIM adoption. The socio-organizational barriers identified are manifold, including resistance to change among project participants, variety in BIM skills, cultural differences, undefined roles, responsibilities and BIM scope, underdeveloped strategies and standards, and lack of cooperation among industry partners (Gu & London, 2010; Alreshidi et al., 2018; Sun et al., 2017). Nevertheless, researchers have also identified factors that could positively influence BIM application. Amongst them are Gu & London (2010), who suggest that mapping out the BIM maturity of project participants and creating awareness around BIM application and its value for the different activities in a construction project can improve BIM adoption. Khosrowshahi & Arayici (2012) further suggest that having an implementation strategy and professional guidelines on how to achieve value from BIM, could enable its adoption. Finally, establishment of trust among project participants (Papadonikolaki & Wamelink, 2017), clarity of BIM scope, roles and responsibilities (Papadonikolaki & Wamelink, 2017; Sun et al., 2017), and the existence of a BIM coordinator is thought to facilitate benefits realization for BIM (Jacobsson & Merschbrock, 2018).

Legal. Previous studies have shown that there are significant legal barriers to BIM adoption. As such, Alreshidi et al. (2015) found that a lack of property rights, collaboration standards and fair-practice standards for digital information and documentation, may negatively impact BIM adoption. Their research further highlights that having undefined liabilities for adding incorrect information to the model may act as a potential barrier. Sun et al. (2017) similarly bring forward stakeholder responsibilities, data ownership and contractual environment as factors affecting BIM adoption. The latter will be elaborated on in the consecutive section.

2.2 Project Organization

Every construction consists of multiple systems, such as the structure and foundation and no one actor can ensure the completion of all the systems by themselves (Fischer et al., 2017). Consequently, multiple firms are involved in a construction project. To regulate the relationship between the project participants, and thus the legal environment surrounding them, the industry operates with different project delivery methods. These can further be categorized into transactional and relational contractual models. The choice of delivery method decides which participating parties will have contractual ties, the project organization, and the allocation of responsibility (Lædre, 2009). The project delivery methods are operationalized through the Norwegian Standard contracts. NS8401/8402 represents the contracts used between the owner and the design and engineering team (Standard Norge, 2019a). While NS8405/8406/8407 governs the relationship between the owner and the contractor (Difi, 2018a; Difi, 2018b). Due to a changing construction environment and the introduction of new delivery models, a consultative committee has recently started investigating the need for revising the available contracts and whether new standards are needed (Standard Norge, 2019b). Furthermore, the SamBIM report found that the choice of project delivery method was an important factor, affecting the use of BIM (Bråthen et al., 2016). More specifically, the contractual models can act as boundary conditions for effective BIM use as they either restrain or impose requirements on the projects' BIM use and thus its effectiveness (Magnussen, 2019). Figure 1 illustrates the contractual environment in the Norwegian construction setting.

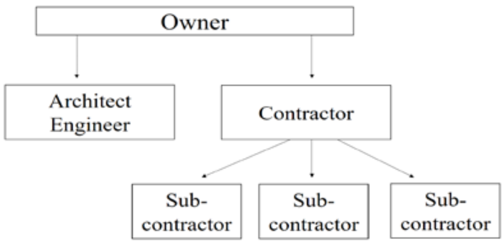
Figure 1: Contractual Models in the Construction Industry

Source: own analysis

2.2.1. Design-Bid-Build (DBB)

Historically, Design-Bid-Build (DBB) has been the dominant project delivery method in most countries (Lloyd-Walker & Walker, 2015). DBB is a traditional delivery form that tends to separate design and delivery (El Asmar et al., 2013). First, the owner contracts with architects and engineers. After the design and engineering phase is completed, the contractor will be involved. The DBB way of contracting is illustrated in figure 2. The strengths of the DBB delivery model are that the method is well-known and commonly implemented with established legal precedents. Additionally, the owner retains a high level of control over the project's cost estimation (Pierce et al., 2003; Harper, 2014). On the other hand, DBB is considered to have a negative impact on project costs, schedule, and quality (Latham, 1994; Egan, 2002). Prior research suggests that DBB is the least suitable delivery model for effective use of BIM , due to the sequentiality inherent in this delivery model (Liu et al., 2017)

Figure 2: Design-Bid-Build

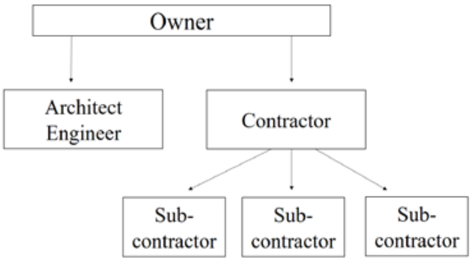


Adapted from: Legislative analyst's office (2003)

2.2.2. Design-Build (DB)

Although Design-Build is not seen as the historically dominant project delivery method, it is actually the oldest type of delivery system (Gransberg et al. 2006). In the recent years, DB has increased in popularity in the Norwegian AEC-industry (Nye Veier, 2016). The basic concept behind Design-Build is that a project owner enters into a contract with a single party, who is to be responsible for the project both in the design and construction phase (Espelien & Reve, 2007). In DB, the owner will normally engage a general contractor after 20% of the design and engineering is completed (El Asmar et al., 2013). The ties between actors in DB is illustrated in figure 3. DB has been found to yield several benefits. Studies comparing the performance of DBB and DB projects, have argued that the latter might be of preference as it yields the most positive outcomes related to costs, quality and schedule (Roth, 1995; Konchar & Sanvido, 1998; CII, 2012). Hardin & McCool (2015) propose that DB leads to more effective BIM use compared to DBB. DB offers a higher degree of integration as the contractor is involved in both the design and construction phase (Eastman et al., 2008). Integration is believed to increase the effectiveness of BIM.

Figure 3: Design-Build



Adapted from: Legislative analyst's office (2003)

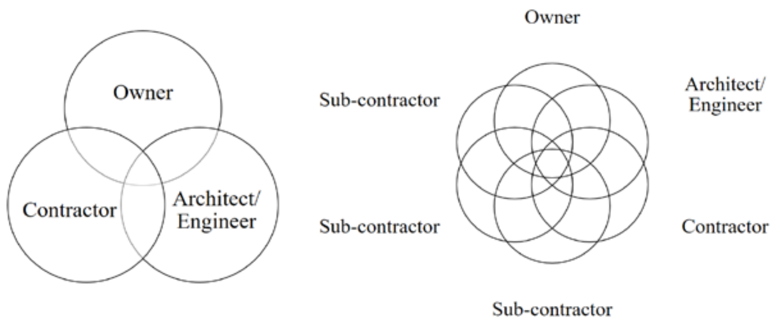
2.2.3. Partnering

The roots of partnering in the AEC-industry started in the early '90s (CII, 1991). Key participants of the project, including the owner, users, engineers, architects, and contractor, are involved in the early stages of the design phase (Difi, 2018c). There are three ways in which partnering is executed in Norway; I) Partnering to DB II) Partnering with incentive, and III) Public-Private Partnership (PPP). The first phase of the project is similar for Partnering to DB and Partnering with incentive. In the initial phase of the project, the owner of the project, its users, contractors and the planning team work collaboratively to develop the project. However, as the name suggests, the contract on to a design-build contract in the first option. In the next phase for partnering with incentives, the contractor is paid for necessary costs related to the completion of the work with a markup for indirect costs (Entrepriserettsadvokater, 2019). PPP involves the contractor from the early stages of a project to the operational phase (Difi, 2018c). A study comparing 280 construction projects with differing delivery models found that partnering had the most positive impact on project costs and quality (Larson, 1995). The novelty of partnering represents a limitation in that implementation barriers need to be broken down to reach the outlined benefits (Chan et al., 2003; Eriksson et al., 2008; Bygballe et al., 2010). Partnering is also believed to be more appropriate than DBB and DB to govern BIM as it, to a larger extent, integrates the project participants and facilitates collaboration (Liu et al., 2017).

2.2.4. Integrated Project Delivery (IPD)

The early publications regarding IPD emerged in the mid-2000s (e.g. Matthews & Howell, 2005; Lichtig, 2005; AIA, 2007). The fundamental characteristics of IPD can be summarized as follows : I) multi-party contracts at least including the owner, designer, and builder, II) continuous involvement of key project participants, III) collaboratively developed project goals, IV) collaborative decision-making process and control and V) shared risk and reward based on project outcome (Ghassemi & Becerik-Gerber, 2011; Lahdenperä, 2012; AIA, 2007, 2010,2014; Fischer et al, 2017). The main benefits of IPD are its positive effect on the quality of the construction and time spent (Matthews & Howell, 2005; Lichtig, 2005; El Asmar et al., 2013; Franz & Leicht, 2016). Its limitations lie in the novelty of the approach as there is still a lack of an appropriate legal structure and financial incentives (Ghassemi & Becerik-Gerber, 2011; Jayasena & Senerivathna, 2012; Roy et al, 2018). Furthermore, co-location of teams and frequent meetings are considered highly desirable for IPD (AIA, 2010). IPD seems to be the project delivery method which leads to the most effective use of BIM, as there is a mutually reinforcing relationship between the two. IPD principles might be fostered through applying BIM, and IPD principles can provide opportunities for increased BIM use (Kim & Dossick, 2011; Wong & Fan, 2013; Holzer, 2015; Ahmad et al., 2018).

Figure 4: Tri-party and Multi-party agreements



Adapted from: Lean IPD (2019)

Although, IPD principles can foster effective use of BIM, a limited number of studies have empirically investigated the relationship between delivery models and effective use of BIM. The available studies are not generalizable on a global level, due to slight variations in delivery models across jurisdictions. Thus, researchers call for cross-case empirical analyses based on interviews and surveys of various project participants in various national settings (Sebastian, 2011; Papadonikolaki & Wamelink, 2017). Particularly, in the Norwegian context, research on contractual conditions` enabling or inhibiting effects on BIM integration is very limited. The SamBIM report, however, identified that the project delivery method was an important factor influencing BIM use. Still, delivery methods were not a topic given significant attention in this study, and the report does not compare transactional and relational delivery methods. Thus, there is a need for cross-case comparisons of various project delivery methods with regards to BIM integration in the Norwegian construction industry. The next sections will review the effectiveness of transactional and relational contracting models from a transaction cost economics perspective.

2.3 Transaction Cost Economics (TCE)

Transaction cost economics (TCE) is considered to be a principal framework for explaining organizations' boundary decisions (Geyskens et al., 2006). Thus, the transaction cost perspective can provide invaluable insights into the appropriateness of different delivery models in governing BIM transactions in the construction industry. Coase (1937) first introduced the concept of transaction costs' influence on the choice of governance structure. Later, Williamson (1975) operationalized these concepts, by showing that the theory could be tested. Williamson (1981:552) explain that “a transaction occurs when a good or service is transferred across a technologically separable interface”. Transaction costs refer to the cost of carrying out an exchange, whether at the inter- or intra-organizational level, when a market is classified as imperfect (Williamson, 1985; 1991). Williamson’s work spurred great interest among researchers, and has been the basis for numerous empirical tests and studies (Geyskens et al., 2006).

The main assumptions and ideas behind the transaction cost economics perspective will be described in more detail below. We will also outline the characteristics of transactions in construction projects, which contextualize BIM exchange. Thereafter we assess the concepts of transactional and relational contracting in construction organizations and the conditions under which the different contractual models are deemed appropriate governing structures.

Behavioural Assumptions

Transaction cost economics makes two principal behavioral assumptions. The first is the assumption that humans are subject to bounded rationality (Williamson, 1985; 1987). This implies that, despite intentions to act rationally, people are limited by their capacity to evaluate all possible alternatives (Hobbs, 1996). As a result, people will not be able to include all relevant eventualities in a contract. Williamson (1987) thus contends that all complex contracts are inevitably incomplete. The AEC-industry consist of many small, interdependent and multidisciplinary firms and is, thus, highly fragmented (Briscoe & Dainty, 2005; Dainty et al., 2001). A construction project requires a unique set of material inputs and labor specialities, including architects, contractors and numerous subcontractors. This interdependency is a source of complexity and bounded rationality in construction projects. Consequently, it may be challenging to develop complete contracts to govern these relations (Winch, 1989). However, BIM might assist in overcoming the issue of bounded rationality and complexity, as information from different actors are integrated in one single model.

The second behavioral assumption made in transaction cost economics is opportunism. Williamson (1975:6) defined opportunism, in general terms as “self-interest seeking with guile”, guile meaning "lying, stealing, cheating, and calculated efforts to mislead, distort, disguise, obfuscate, or otherwise confuse" (Williamson, 1985:47). In construction projects, informational asymmetries between the many participating parties may create opportunities for parties to act opportunistically. The temporal nature of projects may additionally provide incentives for the parties to gain benefits at the expense of other project participants (Lu et al., 2015). Furthermore, the risk of opportunism is expected to increase with a high level of asset specificity and uncertainty (Gulati, 1995).

Dimensions of Transactions

Williamson (1979) points to three key characteristics of transactions, namely, asset specificity, uncertainty, and frequency in which transactions between the parties occur. Among these, asset specificity is argued to be the most critical characteristic for describing a transaction. The notion of asset specificity refers to investments that are specialized to a certain transaction. That is, investments that cannot be redeployed to other exchanges, without carrying cost-bearing consequences. According to Williamson (1979, 1981) asset specificity can take several forms, including site specificity, where facilities are located in relation to each other; physical asset specificity, items such as specialized tools or equipment, human asset specificity, where skills and knowledge specific to the transaction is acquired; and temporal asset specificity, referring to the degree of which timely performance by one party is critical (Masten et al., 1991; Artz & Brush, 2000) . While asset specific investments tend to be made intentionally, they may also occur unintentionally, as for example the knowledge and skills gained through interactions with an exchange partner (Tadelis & Williamson, 2012).

Winch (1989) asserts that, because of the existence of many alternative suppliers in the construction industry, the risk of opportunism as a result of asset specificity is only significant post contracting. Changes in project specifications allows contractors or subcontractors to opportunistically price extra for additional services, because the owner is tied to the original contractors. Employing another contractor to carry out additional work will have cost bearing consequences. Moreover, according to Eccles (1981) the physical asset specificity of transactions in construction projects is insignificant. The levels of human asset specificity and temporal asset specificity are more noteworthy. As projects require actors to coordinate and work simultaneously, skills and knowledge on how to collaborate is required. It can be assumed that human asset specificity increases with BIM, as it entails increased collaboration between parties. What is more, the work of one discipline is oftentimes contingent on the progress of the work carried out by other disciplines, which imply a degree of temporal asset specificity.

Moreover, uncertainty is an important factor in describing transactions. According to Carson et al. (2006), uncertainty consists of two concepts, volatility and ambiguity. Volatility is defined as “the rate and unpredictability of change in an environment over time, which create uncertainty about future conditions” (Carson et al., 2006:1059). Ambiguity, on the other hand, is defined as uncertainty in how the environment is perceived, regardless of how it changes over time. The term ambiguity again consist of several dimensions, such as, the absence of clear information and uncertainty related to the importance and cause-effect relationships of environmental variables, and about possible actions and their effects (Carson et al., 2006).

Construction projects have a relatively high degree of uncertainty attached to them. First of all, site conditions, such as weather, are a source of uncertainty (Eccles, 1981). Especially, there is a level of uncertainty attached to the difficulty of obtaining complete geological information (Winch, 1989). Yet, BIM applied to geotechnics offers the possibility to reduce this uncertainty (Morin, 2017). Second, a coalition of a large number of actors carries with it a variance of resource requirements over time and possibly differing environmental perceptions (Eccles, 1981). Third, because every project is unique, novel designs are required and new issues arise for each project. Reusing information and modules from a building information model might, however, reduce this uncertainty as it enables learning across projects. Fourth, the contracting system itself entails a degree of uncertainty, due to the difficulty of estimating cost during competitive tendering (Winch, 1989).

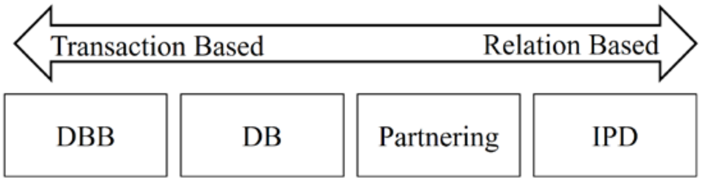
The aforementioned factors, as well as complexity, contractual incompleteness and court limitations, contribute to exchange hazards. When such hazards are present, firms might wish to safeguard against opportunism. Thus, according to TCE the characteristics of the transaction will influence the choice of governance form (Tadelis & Williamson, 2012), where governance form refer to the "interunit or interfirm framework within which exchange takes place" (Zaheer & Venkatraman, 1995:375). Governance structure can be viewed as a continuum, with markets (no vertical integration) at the one end and hierarchical control (full vertical integration) at the other. Between the two ends of the continuum numerous ways of organizing exist, including alliances, joint ventures and formal written contracts (Hobbs, 1996).

Essentially, when there is a high level of transaction costs it should be cheaper to transact within a hierarchical structure (Winch, 1989). According to TCE, the characteristics of exchange in construction might favor hierarchical governance. It is suggested that hierarchical governance in construction projects leads to more learning across projects, feedback loops between phases, less opportunism, and reduced costs of contracting (Winch, 1989). Additionally, hierarchical governance is arguably more efficient in successfully implementing technologies, such as BIM, because it requires a higher degree of integration. Nevertheless, construction projects are characterized by the need for specialized design and construction. It can, thus, be more efficient for firms to specialize and work simultaneously across several projects, than to engage in all activities and investments within one single firm (Reve & Levitt, 1984). Consequently, Reve & Levitt (1984) argue that hierarchy is not as efficient as suggested by TCE in the construction context. Winch (1989) further argues that construction firms does not resort to vertical integration because this might result in blurring the boundaries of the professional expertise, where the final outcome can be loss of economic and social power for certain groups of professionals. Thus, construction firms tend to organize themselves in a hybrid between market and hierarchies, with the assistance of construction contracts.

Following Macneil (1977), Williamson (1979) suggests that contract law can be categorized into three groups: Classical contracting, neoclassical contracting and, relational contracting, and that these contracting methods are suitable for different types of transactions. For the purpose of this paper, the contracting modes will be grouped into two categories: transaction-based, referring to classical and neoclassical contracting, and relation-based, referring to relational contracting. The different contracting modes and the conditions under which they are considered appropriate are further assessed in the sections below. This may inform our research question in terms of the conditions under which the different contractual models can facilitate effective use of BIM.

Figure 5 is based on an analysis of some of the project delivery methods currently available in the Norwegian AEC-industry, and categorizes these models according to transactional and relational contracting.

Figure 5: Transaction and relation based contracts



Source: Own Analysis

2.3.1 Transactional Contracting

Market governance: Classical contracting

Classical contracting is considered purely transactional in nature (Macneil, 1977). A distinguishing attribute of classical contracting is that it relies extensively on legal provisions and formal documents. In addition, the contracts are agreements between two parties only and the identities of the parties are treated as irrelevant. Third party involvement in the transaction is discouraged. Furthermore, it is distinguished from the other contractual models in that it has fixed boundaries, with predictable consequences for failure to fulfil a promise or condition (Macneil, 1977; Williamson, 1979; Jobidon et al., 2019). The transactions carried out under such contractual boundaries generally have low levels of stakeholder involvement and minimal social exchange (Macneil, 1977).

According to the transaction cost perspective this type of contracting is suitable for standardized transactions, where alternative trading partners are easily available (Williamson, 1979). Yet, it is argued that classical contracting models offer inappropriate safeguarding mechanisms when uncertainty and asset specificity exists and when the projects are long term. In these cases, all future contingencies and appropriate adaptations cannot be anticipated at the initiation of the project. Because construction projects are characterized as being longer term and needing specialized labour and planning, the purely transactional contracting is not considered to be appropriate. The contractual relations in the construction industry tend to require more flexibility. This is offered by neoclassical contract law, which is based on the same overall system as classical contract law, but with some essential adjustments (Jobidon et al., 2019).

Trilateral governance: Neoclassical contracting

In essence, neoclassical contract law recognizes that it is not possible to include every eventuality in a contract, and thus allows for greater flexibility than classical contracting. In case of conflict, this contractual model relies on third party assistance, rather than litigation (Macneil, 1977). The need for third party assistance is especially important in the presence of complex technology (Reve & Levitt, 1984), which implies that neoclassical contracting is more effective than classical contracting in governing exchange in BIM. Neoclassical contracting also puts greater emphasis on the preservation of relationships than classical contracting, and is thus considered to be more relational. However, both contracting methods views exchange as involving only two parties.

Neoclassical contracting can be related to the contracting modes traditionally used for construction projects. Of the aforementioned delivery methods, DBB, is considered the most transactional. The contract has many resemblances to what is described as neoclassical contracting. First, with DBB the owner enters into two-party contracts with a general contractor, an architect and an engineer. All contracts are based on terms and conditions developed by the owner, with third party assistance from architects or consulting engineers (Reve & Levitt, 1984). The general contractor thereafter enters into two-party contracts with the subcontractors.

The contracts are based mainly on a fixed price for a project or on hourly compensation with fixed timelines (Eccles, 1981; Winch, 1989).

The DB contracts are relatively similar to DBB, with two main differences. The first is that the general contractor is involved at an earlier stage. The second is that the contracts are not as detailed. The owner here defines the final outcome of the project, yet not the details of how this result should be achieved (Codex Advokat og Entrepriserettsadvokater, 2018). As such, DB contracts are considered to be relatively more vertically integrated and flexible. Although DB contains certain relational elements it is still considered a transactional contract type, as there are only two parties involved and the incentives of one party are oftentimes in conflict with those of the other party.

Williamson (1979) contends that when uncertainty is present, exchange happens occasionally and requires a medium or high level of asset specificity, neoclassical contracting can be applied. He further argues that the cost related to establishing full vertical integration and relational contracting are higher, hence neoclassical contracting is preferable for occasional transactions. Still, neoclassical contracting has shown to display shortcomings in dealing with relational issues (Macneil, 1977). Ghasemi and Becerik-Gerber (2011) argues that transactional contracts in the AEC-industry does not focus on the overall project goals, but foster sequentiality, silo thinking and a focus on individual goals. So far as BIM is concerned, integration and collaboration between players are crucial factors, which might suggest that transactional contracting is limited in effectiveness when it comes to governing BIM exchanges in construction projects.

2.3.2 Relational Contracting

Transactional contracting has been criticized for downplaying the relational and social aspects of the exchange. Relational contracting acknowledges that exchange involves a significant social aspect reflected in the social relationship and behavior of the parties to the exchange (Macaulay, 1963; MacNeil, 1973; 1977; 1982; 1985). Egan (2002), described the construction industry as being contested, fragmented and highly adverse with inherent problems. The inherent problems include inadequate information exchanges between actors and inappropriate contracting methods. To overcome these inherent problems, the industry has responded with project delivery methods which are based on integration and collaboration between project participants (Matthews & Howell, 2005; Lichtig, 2005).

Within relational contracting, the social relationships between the parties to an exchange are oftentimes characterized as being collaborative, trusting, and long-term (Ring & Van de Ven, 1992; Mohr & Spekman, 1994). Extensive communication and cooperation are among the behavioral aspects which facilitate such relationships (Mohr & Spekman, 1994). Effective use of BIM has been found to depend on high levels of trust fostered through communication, and trust has been found to be more likely to occur in long-term relationships (Liu et al., 2017; Lee et al., 2018). The delivery method with the most evident emphasis on achieving such relationship is IPD, as trust among project parties and open communication is encouraged under this contractual model (AIA, 2007; 2010; 2014). The expectation of a long-term relationship between the parties is reflected in the principle of early involvement of key participants (AIA, 2007; 2010;2014; Fischer et al. 2017). Focus on early involvement is also present in the partnering model where the owner, users, contractors and planning team work together from the design and engineering stage of the project (Difi, 2018c).

In the case of incidents of benefits and burdens, relational contracting suggests an undivided sharing of such (Macneil, 1977). In contracts, these elements are present through formal safeguards that ensure that the parties' financial incentives are aligned and work as a mechanism to control opportunism (Klein, 1980, Williamson, 1983). The relational contracting scheme also differs from the transactional in terms of dispute resolution - in transactional contracting an external party will usually be engaged to determine whether a breach has taken place, whereas relational contracts are self-enforcing (Telser, 1980). Lastly, the number of participants in a relational contract may be as few as two, but is likely to be more than two and often large masses (Macneil, 1977). Both partnering with incentives and IPD seek to align the financial incentives for the participants (AIA, 2007;2010;2014; Fischer et al, 2017). Fischer et al. (2017) argue that when the financial incentives are aligned, the project participants are more likely to cooperate towards a common goal. Further, cooperative behavior has been found to positively impact BIM use (Lee et al., 2018). The IPD model is self-enforcing as one of its principles includes the concept of limited liability among contracting parties (AIA,2007;2010;2014). Multi-party contracts are also present in IPD and is the factor which most clearly distinguishes this approach from other relation based contracts such as partnering (Lahdenpäre, 2012).

The construction industry is complex, with a certain degree of asset specificity (Eccles, 1981; Winch, 1989). In such contexts, relevant literature regards relational safeguarding mechanisms as substitutes to complex, explicit contracts (Granovetter, 1985; Gulati; 1995). Relational governance is favored in addressing the safeguarding problem posed by asset specificity (Geyskens et al., 2006). Trust and asset specificity are also a self-reinforcing process, as commitment in assets generates trust between partners, and trust, in turn, encourages a firm to invest more in specific assets (Narayandas and Rangan, 2004).

Additionally, construction projects are characterized by a relatively high level of volatility (Eccles, 1981). One of the main consequences of volatility is an adaptation problem (Geyskens et al., 2006). The adaptation problem, refers to difficulties in adjusting agreements which in turn increases the transaction costs. Relational governance promotes flexibility through the enforcement of obligations, promises, and expectations that arise through social processes (Poppo & Zenger, 2002). This flexibility is highly needed in uncertain environments, as it helps to facilitate the adaptation to unforeseeable events which occurs through uncertainty. These arguments were supported by Carson et al. (2006: 1073) who found that if volatility increases, relational contracts are best suited to govern exchange, due to the flexibility they offer compared to formal contracts and because they carry significantly lower cost than hierarchy. Relational delivery methods, such as IPD, are relatively flexible in that they foresee multiple possible outcomes (Matthews & Howell, 2005). However, the findings of Carson et al. (2006) suggest that relational contracting is a less suitable tool for managing ambiguity. In fact, the authors found that ambiguity and opportunism arises when using relational contracts.

The development and maintenance of relational governance may involve considerable time and resource allocation (Larson, 1992). This reasoning suggests that firms should only apply relational contracts when significant exchange hazards are present (Poppo & Zenger, 2002). The absence of hazards, may not justify the additional costs incurred by utilizing relational contracts. The presence of a hazardous exchange environment has shown to be an important factor in determining the suitability of relational project delivery methods. Singleton & Hamzeh (2011) investigated this relationship and evaluated the suitability of different projects to apply different IPD techniques. They found that projects that were highly complex, large in size and highly unique was suitable candidates for the application of this approach. Furthermore, the exchange in BIM might entail additional transaction characteristics, thus an evaluation of these and the contracting methods appropriate to govern them are necessary.

2.3.3 Transactional and Relational Contracting - substitutes or complements?

There is no clear consensus across relevant literature with regard to the effect of the combination of transactional and relational contracts. Some research has shown that the presence of one contract obviates the need for another (Larson, 1992; Gulati, 1995; Dyer & Singh, 1998). In contrast, other articles present a positivist view of the relationship between the two, suggesting that they act as complements rather than substitutes (Lorenz, 1999; Poppo & Zenger, 2002; Cao & Lumineau, 2015). So far as effective BIM is concerned, Lee et al. (2018) found that transactional and relational delivery methods are complements as they together foster an optimal level of trust. Transactional contracting by itself did not encourage trust-building. Relational contracting alone, was argued to foster blind faith, which may open for opportunistic behaviour.

2.4 Discussion of Literature

In the preceding sections we have reviewed existing literature on BIM, project organization and transaction cost economics. The concepts and findings from these studies provide a background for our research and offer assistance in addressing our research question: *how do contractual models act as boundary conditions for effective BIM use?* So far, we have established the relationship between the AEC-industry and the appropriateness of contract schemes under the presence of different transaction costs. The transaction of relevance in this study is the exchange of information through the use of a building information model. Consequently, in order to answer our research question, the relationship between BIM, project organization and transaction cost economics must be investigated. In order to achieve this, we have identified three sub-questions for further investigation.

Literature suggests that the general BIM maturity in the Norwegian AEC-industry has exceeded level 0, yet is still at a relatively early stage (CIB, 2015; Bygg24, 2017). Effective BIM use in construction projects have previously been defined as the exchange of information between all project participants, where this information is continually updated and free from defaults and conflicts. To reach effective BIM use, the industry as a whole needs to move towards level 3 of BIM maturity, where all project participants work in the same building information model (Bew & Richard, 2008). Moreover, the model needs to be of high quality and thus reliable. In order to answer our research question we need to identify how BIM is currently used for each of the studied projects, and whether there is any variance between them. Moreover, it is necessary to identify not only the overall use of BIM, but to investigate any variance in BIM levels between the parties to a construction project.

How is BIM currently used in construction projects?

Throughout the literature review, it has been established that transactional and relational contracting are two different alternatives to govern exchanges. Transactional contracting may further be distinguished into classical and neoclassical contracting. Classical contracting is purely transactional in nature and relies extensively on legal rules and formal documents (Macneil, 1977). According to TCE, this type of contract is ideal to govern standardized transactions, where trading partners are easily available (Williamson, 1979). Neoclassical contracts allow for greater flexibility in adjusting to change than classical contracting since it recognizes that it is not possible to include every eventuality in the contract (Macneil, 1977). Relational contracts are the most flexible of the three. This flexibility emerges from the enforcement of obligations, promises, and expectations that occurs through social processes (Poppo & Zenger, 2002).

In the literature review, we gave an overview of the contractual models currently available in the Norwegian AEC-industry. Based on their characteristics, these were placed within the spectrum ranging from transactional to relational. Throughout this process, we discovered that the different contractual models currently used in the Norwegian AEC-industry might not fully fall under any of the main categories identified. Consequently, their suitability to govern the exchange might be difficult to assess based purely on the existing literature. Additionally, the literature review revealed that there is a lack of research applicable to the Norwegian AEC-industry, because although project delivery methods have the same name in different countries, they might not be similar in their content. E.g. Lloyd-Walker & Walker (2015) defines alliances within the Australian AEC-industry as an IPD method, whereas Lahdenperä (2012) makes a distinction between the two. Moreover, many articles are vague in defining all of the elements included in the contract, thus generalizability may not be applicable to the Norwegian AEC-industry. We would therefore need to investigate the elements of the different contractual models available in Norway that could influence the use of BIM.

How do the elements of the different contractual models influence the use of BIM?

We have identified that the multiplicity of different actors act as a source of uncertainty and complexity in construction projects. Nevertheless, it has been suggested that BIM can assist in overcoming the issue of bounded rationality and complexity, as information from different actors are integrated in a single model. This may, in turn, enable actors to make decisions for the benefit of the project as a whole, as opposed to more narrowly (Fisher et al., 2017). Furthermore, literature points to the existence of human and temporal asset specificity as factors contributing to contractual hazards in construction projects (Eccles, 1981). As effective use of BIM requires the different parties to a project to collaborate to a greater extent, one can assume that the need for human asset specificity will increase. Additionally, the investment in BIM-related software and hardware can be considered transaction specific physical asset investments.

The literature also reveals that the effectiveness of relational and transactional contracts depend on the transaction characteristics. The appropriateness of the different contractual models can be summarized as follows; I) transactional contracts are effective under the presence of medium levels of ambiguity, II) transactional contracts are not effective under the presence of high asset specificity, complexity and volatility, III) relational contracts are effective with the presence of high levels of complexity, volatility and asset specificity (Granovetter, 1985; Gulati, 1995; Poppo & Zenger, 2002), and IV) relational contracts are ineffective in the presence of high levels of ambiguity (Carson et al, 2006).

Hence, in order to identify which contractual modes are best suited to govern BIM transactions, we must first recognize the factors that contribute to or reduce exchange hazards in relation to this transaction. Research has found that the factors influencing effective BIM use are related to technology, cost, organization and legal matters. These can be viewed as sources of exchange hazards or factors reducing them. In this study we would like to map out these factors in the Norwegian construction setting and investigate if these factors can mediate or moderate the influence of contractual models on effective BIM use.

What are the factors mediating and moderating the influence of contractual models on effective BIM use?

The three sub-questions are highly interrelated, and will be examined in the light of our findings. By investigating the three identified sub-questions, we hope to contribute to existing literature by shedding light on how contractual relations can act as a boundary condition for effective use of BIM.

CHAPTER 3: RESEARCH METHODOLOGY

This chapter is structured as follows. We start with a description of the research design. This is followed by a description of the theoretical sampling of cases and interview participants. A brief description of the case studies follow. We then outline the data sources. Thereafter, we describe our data analysis. We finish by discussing the scientific quality of our research.

3.1. Research Design

The topic of investigation in this study is how contractual models act as boundary conditions for effective use of BIM. Effective use is defined as the sharing of information between all project participants in a building information model, where this information is continually updated and free from defaults and conflicts. The purpose of this paper is to describe how BIM is currently used in construction projects and to establish a causal relationship between contractual models in the construction industry and effective use of BIM. As such, the study is descriptive and explanatory and aims to generate theory (Saunders et al., 2009).

A qualitative research method has been chosen to approach this topic. The power of qualitative research lies in its "capacity to capture temporally evolving phenomena in rich detail, something that is hard to do with methodologies based on quantitative surveys or archival databases that are coarse-grained and tend to skim the surfaces of processes rather than plunging into them directly" (Langley & Abdallah, 2011:202). Particularly, qualitative research has been argued to be the preferred method when wanting to gain an in-depth understanding of relations among parties (Thagaard, 2009). As we want to study the process of exchanging information through a building information model and the collaborative relations between parties to this exchange, a qualitative approach is deemed appropriate. This approach is characterized by closeness to research objects, text analysis, small samples and a focus directed toward processes and meanings. The role of the researcher in qualitative research is to gain a holistic overview of the context being studied (Miles & Huberman, 1994).

Furthermore, this research employed a multiple case study design strategy. The choice of a case study design was guided by the research question, as case studies are considered the most suitable strategy for addressing “how” questions (Saunders et al., 2009). Moreover, case studies are generally the preferred strategy when the unit of analysis is a contemporary phenomenon in a real life context (Yin, 2003). In order to answer our research question, we needed to look at contrasting contractual models and compare these in relation to effective use of BIM. Following, a multiple case study approach was chosen. Multiple cases can be holistic (single unit of analysis) or embedded (multiple units of analysis), distinguished by the number of units studied within each case (Yin, 2003). This study have taken the holistic approach, where the unit of analysis is the project as a whole (Saunders et al., 2009).

Overall, our research design is based on what is commonly referred to as the “Eisenhardt method”, which is an inductive method where propositions are developed on the basis of case study evidence. The method draws on multiple case studies to verify and elaborate relationships found in each case (Eisenhardt, 1989; Langley & Abdallah, 2011). This research design is reckoned to be applicable when there is a lack of previous research on a phenomenon, as with the relationship between contractual models and effective use of BIM in construction projects (Langley & Abdallah, 2011). Furthermore, several cases using the same delivery models were included, when possible. This was possible for the more common project delivery methods, that is DB and DBB. Yet not possible for the more novel project delivery methods such as partnering and IPD. Due to the limited number of these projects, we were only able to include one of each. Although, according to the categorization of transactional and relational contracting, we were able to conduct case studies of several transactional and relational contract models.

3.2. Theoretical Sampling

3.2.1 Sampling of Cases

This purpose of this study is to generate theory from case study research, therefore the study relies on a theoretical sampling of cases (Glaser & Strauss, 1967). That is, cases were chosen on the basis of their suitability in regards to illustrating and advancing relationships between constructs (Eisenhardt & Graebner, 2007). Hence, the cases in our research were chosen on the basis of whether they could answer questions regarding our theoretical categories, namely transactional and relational contracting. As such, we chose eight cases, fulfilling both our contracting categories. This allowed for a comparison between transactional and relational contractual models, with respect to their influence on the effectiveness of BIM use. Within each category, multiple cases were chosen, which allows the findings within each category to be replicated. Furthermore, both polar types of transactional (DBB) and relational contracting (IPD) in the construction industry was included in our sample. Including polar types of contracting models increases the possibility of observing the process of interest (Eisenhardt, 1989). Moreover, we aimed to choose cases that showed a varying degree of the dependent variable. That is, effective use of BIM. This turned out to be challenging, because information on how BIM was used in construction projects were oftentimes not publicly available. In addition, the potential interview objects approached had different interpretations of what effective BIM use entailed. Nevertheless, cases with varying degrees of BIM effectiveness are present in our study, for both relational and transactional contracting.

Except for the variety in delivery methods and effectiveness of BIM use, we sought to keep other variations to a minimum. In terms of project size, we included smaller and larger projects of both transactional and relational contracting methods, to control for size variations in the results. We also aimed to study cases that were in similar project phases. All projects studied was either in the later phases or completed. This focus was based on the desire to understand the use of BIM throughout the life-cycle of a project. Additionally, all cases were similar with regard to their ambition to achieve a high level of BIM proficiency. Industry participants were consulted and publicly available reports and online publications were reviewed to identify cases with high BIM ambitions.

3.2.2 Sampling of Interview Objects

As for the individuals interviewed, they should optimally have reflections on a quite specific area, namely, the different project delivery methods available in Norway and their relationship with BIM. The need to access individuals with appropriate knowledge and projects with certain types of delivery models, raised the need for theoretical sampling. In theoretical sampling, individuals are included based on the likelihood that they will offer theoretical insights (Eisenhardt & Graebner, 2007). Further, to avoid one-sided reflections, all the main actors participating in a construction project had to be represented in the sample. The following actors typically take part in a project and will thus be a part of the sample; I) project owner, II) engineer and architect, III) contractor and IV) subcontractor.

Notably for the majority of the cases, only one representant were interviewed. We contacted multiple persons within the projects of relevance who directed us to an individual whose competence was considered appropriate to answer our questions, and thus were most likely to offer useful theoretical insights. To reflect around the topic of interest, the interview objects need a broad experience of working under different delivery models. Following, we included one subcontractor with significant experience from different project delivery methods, although he was currently not involved in a project. At the most, two project participants working within the same project considered their knowledge base as relevant and decided to take part of the study. Table 1 summarizes key characteristics of the interviewees including the project they were part of, what kind of organization they are employed by and their role within the organization. In total, our sample included 13 interview objects.

Table 1: Interviews

Project	Organization Type	Duration of Interview
A	Contractor	21:45
B	Contractor	27:39:00
C	Contractor	52:47:00
		52:47:00
D	Engineer	29:18:00
E	Construction management	31:43:00
F	Contractor	40:17:00
	Architect	46:19:00
G	Project owner	46:21:00
	Contractor	78:58:00
H	Contractor	30:55:00
		30:55:00

3.3 Case Studies

Given the comparative nature of this study, we have chosen to investigate eight different cases that follow either a transactional or relational contracting scheme. Amongst these cases, five are categorized as transactional, of which three follow a DBB contracting model and two are DB delivery models. The size of the cases in the transactional contracting category spans between 75 MNOK and 1500 MNOK and 667 sqm and 15 500 sqm. Moreover, three of the cases follow a relational contracting method. One of these cases use a DB with PPP method, another use a Partnering method and one use an IPD method. The size of these projects are in the interval of 230 MNOK and 2700 MNOK and 7581 sqm and 33 000 sqm. Each case is described in the table below.

Table 2: Case Studies

Project	Delivery Model	Contractual Model	Project phase	Size
A	Design-Bid-Build	Transactional	Construction phase	15 000 sqm 284 MNOK
B	Partnering	Relational	Construction phase	7581 sqm 230 MNOK
C	Design-Build	Transactional	Construction phase	15 500 sqm 441 MNOK
D	Mainly Design-Bid-Build, with a small number of Design-Build	Transactional	Construction phase	13 900 sqm 1500 MNOK
E	Design-Bid-Build	Transactional	Completed	8190 sqm 470 MNOK
F	Integrated Project Delivery	Relational	Construction phase	33 000 sqm 2700 MNOK
G	Design-Build	Transactional	Completed	667 sqm 75 MNOK
H	Design-Build with Public Private Partnership	Relational	Completed	11 500 sqm 500 MNOK

3.4. Data Sources

In each case, we have used two types of data sources, namely interviews and documents. The strength of using multiple sources of data lies in the opportunity to cross-check the findings (Yin, 2003; Bryman & Bell, 2015). One of the main strengths of the case study approach is exactly the opportunity it offers to use multiple sources of evidence (Yin, 2003).

3.4.1. Interviews

Interviews are considered one of the most important data sources to provide case study information (Yin, 2003). Within each case, semi-structured interviews with key personnel were carried out. In qualitative research, interviews tend to be less structured compared to quantitative with an emphasis on generality in the initial formulation of research ideas and on the interviewees' own perspective (Bryman & Bell, 2015). The qualitative way of interviewing can be conducted through either an almost unstructured or semi-structured interview. Both are considered to be relatively flexible processes. The choice of semi-structured interviews over unstructured, seemed reasonable considering the following: I) already from the beginning of the investigation, the research had a fairly clear focus rather than a very general notion of the topic, II) two persons will carry out the fieldwork. We already had a clear focus of the research and semi-structured interviews ensured that we would cover the specific topics of interest, namely BIM and its relationship with project delivery models. Because two people conducted the interviews, a semi-structured approach was chosen to ensure comparability of interviewing style.

The guide continuously changed throughout the process as new themes were raised during the interviews. The final version of the interview guide used for the majority of the interviews can be found in appendix 1. However, the main themes remained the same throughout the process such that the answers were relatively comparable. The first theme was background information of relevance. This included questions about the project participants' work experience and their current role in the industry. In addition, the interviewees were asked to provide us with background information regarding the project that they were currently a part of. The high variance in the length of the interviews had a natural explanation. For the longest interviews, the participants were eager to provide extensive information regarding their role in the firm or the project investigated. This was due to the open nature of our questions. The interviews lasted between 21:45 and 78:58 minutes. For the second theme, we included questions related to BIM. The interviewed participants were asked to draw on their experiences from previous projects and the project they were currently working on. The third theme combined the topics of BIM and contracting – both on a general and project-based level. Combined, the questions in the interview guide, informed our research question.

All of the interviews were recorded. The interview objects were informed about the recordings beforehand and how we planned to use them. They were also ensured that they remained anonymous and had the opportunity to approve the citations used in the paper. Moreover, Heritage (1984) suggests that recording interviews may assist in correcting cognitive limitations as it allows for a more thorough examination of what people say and permits repeated examinations of the answers.

For nine of the interviews, the participants and researchers met face to face. However, this was not an option for four of our interviews, due to either large physical distance or lack of available time. Following, we had one phone interview and three interviews via Skype. Before conducting the phone interviews, we were aware of the potential shortcomings of not being able to observe body language and to see how interviewees respond in a physical sense to questions (Bryman & Bell, 2015). Still, observing the body language of participants was not considered critical for this study.

3.4.2. Documents

The use of documents has been complementary to interviews in order to further deepen our understanding of BIM and how the currently available delivery models can act as boundary conditions for its use. Additionally, the documents assisted in cross-checking the information provided by the interview objects. During some of the interviews we accessed presentations with additional project information. Two of the interview objects provided us with access to the BIM manuals used for their current project. Notes from a consultative committee discussing collaborative project delivery methods and how they govern BIM use were also included. One of the interview objects has been part of this committee and many of the reflections made during the interview were elaborated in this report. Lastly, we accessed the standard contracts used by the different projects and analyzed how and if they regulate information exchange in BIM.

3.5. Data Analysis

The analysis and interpretation of the data was guided by the research question and the three sub-questions presented in section 2.4. When analyzing the data, the pattern-matching approach was applied. According to Yin (2003) this is the most favorable technique for case study analysis. Pattern-matching is used to reveal similarities, differences, frequencies and causation across the collected data. The pattern matching approach is appropriate for our study as it aims to establish the relationship between the choice of delivery models and effective BIM use. The aim of the approach is not to confirm or dispute the proposition, but rather to build explanations on whether and why the patterns are matched or not.

When the interviews provided us with sufficient input, we started the analysis process. Nvivo was used to manage the extensive amount of data collected and for the coding of this data. The interviews were organized in line with the main topics in the interview guide. Similarities, differences and patterns were identified and the answers were then revealed and categorized. We explored if there were any similarities in BIM use within projects using either relational and transactional delivery methods. Moreover, we investigated if the BIM use differed across the two contractual models. We found some overall differences and similarities of BIM use in projects using either transactional and relational delivery methods. However, some projects deviated from the overall trend, as we observed similarities in BIM use across different delivery models. These deviations led us to re-examining the relationship between project delivery methods and effective BIM use. Graebner et al. (2012) suggested that authors should be precise regarding how and when relationships emerge during the research process. Initially, we predicted that the dependent variable, namely effective BIM use, were affected by the independent variable, where the independent variable refers to the delivery method. Throughout the process, we discovered the importance of factors either influencing this relationship or explaining why there was a causality between the independent and dependent variable. These factors were later defined as mediating and moderating factors. A non-sequential process followed as we moved back and forth between the findings, theoretical background and propositions. Thus our analysis process followed an inductive approach (Eisenhardt, 1989; Bryman & Bell, 2015).

After having analyzed the interview data properly, we moved forward to the gathering and analysis of supporting data. BIM manuals and presentations about the projects were amongst others used to cross-verify the projects' BIM ambitions and realizations. While the consultative committee notes and the standard contracts were used to investigate their suitability to govern information exchange in BIM.

3.6. Quality of the Study

3.6.1 Quality Criteria

In order to assess the quality of qualitative research, two common measures are normally applied: reliability and validity (Miles & Huberman, 1994). These measures are used to assess the quality of this research.

Reliability

Reliability measures the trustworthiness of results. The aim of reliability is thus to limit bias and errors (Yin, 2009). In order to increase reliability of the research the preceding sections present the research process and the sequence of data collection and processing. Furthermore, the data on which the conclusions have been made are displayed in condensed versions in appendix 2 (Miles & Huberman, 1994). To ensure reliability we have also sought consistency in the process of the study over time and across researchers and methods (Kirk & Miller, 1986; Miles & Huberman, 1994). The aim of this study has been to compare and contrast different contractual models in regards to effective use of BIM. Hence, case studies that were relatively similar in all regards, except contractual model and BIM use, was chosen to ensure consistency with the research question and setting. The project phase of the various projects differed, still the projects was either in its later phases or had already been completed. This was considered beneficial for our study, as we wanted to study effective use of BIM throughout the contracting period. Further, consistency among the researchers has been sought throughout the study. Interviews were conducted in a similar manner, using an interview guide. The interviews were recorded and later transcribed. Coding of the results were carried out individually and the individual codes showed adequate agreement (Miles & Huberman, 1994).

Validity

Validity concerns the consistency between observations and theoretical ideas developed (Bryman & Bell, 2015). Construct validity was ensured by linking the contracting modes of the construction industry to contracting categories developed by transaction cost theory and relational contracting theory. The presented characteristics of an exchange was further compared and contrasted to transaction characteristics identified in prior emerging theory (Miles & Huberman, 1994). According to Yin (2009:40), internal validity is about "seeking to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships". In order to increase the internal validity of our results we have engaged in pattern matching and addressed rival explanations, as described in section 3.4. This study also combines the analysis of documents and interviews to cross-verify the gathered information. Finally, the application of multiple case studies might increase the validity of our findings (Yin, 2003).

3.6.2 Limitations of the Study

A common critique of the case study method is the issue of reliability, validity and generalizability. Case studies are generally relevant in a specific context and is thus not widely applicable (Hamel, 1993). Another limitation of case study research is the subjectivity of the researchers involved. According to Yin (2008) the contact with interview objects during interviews might lead to informal manipulation and bias. Additionally, we were predisposed to confirmation bias, because literature was read prior to the coding process. Confirmation bias is the tendency to search for, interpret, favor and recall information in a way that confirms one's preexisting beliefs (Plous, 1993). One of the consequences of confirmation bias is the tendency to mistakenly perceive connections and meaning between unrelated things.

Further, due to a restricted time frame for the research, some trade offs had to be made. Because the aim of the study was to compare different project delivery methods with regards to effective BIM use, it was deemed necessary to conduct multiple case studies. We needed to study projects that differed in terms of their contracting scheme, but also projects with similar contracting forms, to carry out pattern checking. Due to time restrictions we were not able to carry out observations, which may have increased the validity of our research (Yin, 2009). In addition, a limited number of persons in each case was interviewed. Interviewing additional people in each case might have increased the depth of our findings (Saunders et al., 2009). Furthermore, there was a predominance of contractors in our study, compared to other industry players, which may have skewed our results. Yet, the people interviewed was chosen on the basis of their knowledge of the particular topics studied, as well as their knowledge of the project. Hence, the answers from the chosen interview participants were considered sufficient to answer our research question.

An additional limitation was that parameters of effective BIM use was not clearly enough defined before case selection, so that variations in the use of BIM were not as strong as originally intended. Stronger variations might have increased the possibility of identifying causal relationships between the independent and dependent variable. Finally, we encountered some difficulties in obtaining the necessary supporting documents for the studies, due to confidentiality issues. Still, most of the confidential documents were adjusted versions of standard documents, which were publicly available for our review.

3.6.3 Ethical Considerations

We ensured that the process of gathering and analyzing data were ethical by following the principles of Diener & Crandall (1978). The first principle regards the vulnerability of interview objects, while the second principle refers to making a sufficient amount of information available to the interviewees prior to the interviews. None of the interview objects is part of vulnerable populations such as children or intellectual disabled. Moreover, we ensured that the interview objects freely participated in the study and were familiar with its purpose prior to the interview. An informational letter including the purpose of the study, what the data would be used for and how we would handle it, was sent out to all of the interview objects prior to the interview. Before the interviews started, the participants signed the letter. The third principle concerns the privacy of the interview objects. Within the informational letter, we informed the participants that they by any time could leave the study without providing any reasoning behind this decision. Moreover, we ensured their anonymity and that the data would be handled in a sensitive way. As such, the privacy of the participants was not invaded. Avoiding to frame or deceive the participant is the last principle. The information letter also explained the purpose of the study where the overall research question and sub-questions were presented. However, framing the interviewees were prevented by not providing any hypothesis or too specific questions in this letter. As such, attention was made to ensure that the study was presented in the correct manner to avoid deceiving the participants.

CHAPTER 4: EMPIRICAL FINDINGS AND ANALYSIS

In this chapter, the empirical findings of our study will be presented. The three sub-questions will guide the structure of this chapter, and will eventually enable us to answer our research question: *How do contractual models act as boundary conditions for effective BIM use?* The quotes presented in the text can be found in appendix 2. This appendix also contains additional quotes which are not included paper, yet support our findings.

4.1 How is BIM Currently Used in Construction Projects?

To answer the question of how BIM is currently used in construction projects, we first examine the BIM-competence across the industry. Later, we provide an overview of how BIM is generally used in the different stages of a construction project before moving on to its application between actors and project phases. Finally, we describe differences and similarities across the cases studied.

4.1.1 Competence

The overall trend from the findings show that the BIM competence varied among industry players, companies and individuals. The range of BIM competence is illustrated by a subcontractor: "*It is very variable. Some are very competent, while others don't know what it is.*" (Subcontractor).

It is also suggested that, although varying across the industry, one can observe that some actors tend to be more familiar with BIM than others. In particular, the findings suggest that key members of the design and engineering team have acquired the most BIM experience and competence, compared to other industry players. As noted by interview participants: *"The competence within the design team is very high. Otherwise, it varies."* (Contractor), *"The majority of the engineers, especially the main engineers, have started to use it. While across the supplier side, our subcontractors, it is more variance in terms of how familiar they are with drawing [in the model]."* (Contractor).

In conclusion, the level of BIM competence varies across the construction value chain, yet the general competence for designers and engineers tend to be relatively high compared to other parts of the value chain.

4.1.2 In Project Phases

In this subsection, we discuss how BIM is currently used in the different project phases by the different industry players. Based on the reflections of the interview participants, it appears that the use of BIM is most extensive in the design and engineering phase of a project, and that the subsequent phases rely more on 2D drawings. In similarity with the overall industry trend, we observed high variance in how BIM used across the different industry players and individuals.

Design and Engineering Phase

It appeared that the architects and engineers were the most active users of BIM during the design and engineering phase. However, we also observed cases where other actors utilized or benefited from the tool. With an active use, we refer to modeling or adding information to a building information model, while passive use means using the model purely for visualization purposes. The active and passive use of BIM can be illustrated by interview objects with different roles in the industry. *"The building information model is made by the design team. They are the ones to draw the model."* (Contractor), *"In project this project the design and engineering team were the main users. BIM was used for visualization purposes to* *the owner of the project and its users, yet quite limited compared to other projects."* (Consulting Engineer).

The interview objects have mainly focused on the high competence and advanced use of BIM by the design and engineering teams. In general, these actors rely extensively on 3D modelling, rather than 2D drawings. However, this might not be the case for all of the design and engineering disciplines, as some still rely on 2D drawings. This is exemplified by several interview participants: *"One of the current main challenges is the fact that landscaping architects don't use BIM."* (Contractor), *"Currently, it is quite usual to receive 3D models from architects and others. However, some disciplines are still lagging behind."* (Subcontractor)

> *[...] All the design is conducted within the building information model , with the exception of armature drawings. Some of the armature drawings are only made in 2D and are not included in the model, while all other installations are included in the model.* (Consulting Engineer)

Moreover, we found that some project participants outside the design and engineering teams also utilize BIM prior to the construction phase. This was the case for one of the contractors who used BIM during the bidding process.

Construction Phase

In the construction phase, actors still rely heavily on 2D drawings: *"We are not moving away from the papers."* (Contractor), *"When it comes to the execution of the project, we are still dependent on paper drawings."* (Contractor). However, the adoption of iPads and BIM kiosks at the construction site is increasing, and was used in several of the projects studied.

Instead of depending solely on BIM during the construction phase, it seemed like the tool was rather complementary to the construction drawings, which are still handed over to the contractors and subcontractors in paper format in most cases: *"The construction drawings are handed over to us in 2D. These drawings are the foundation for the construction and what the workers on the construction site* *receive."* (Contractor), *"BIM is a supplement used to understand the construction drawings."* (Contractor).

In similarity to the design and engineering phase, the usage of BIM in the construction phase appears to differ across the participants, as pointed out by one of the contractors: *"By some, BIM is used purely for visualization purposes, where they check the information. Others measures and uses the information for what it is worth."* (Contractor).

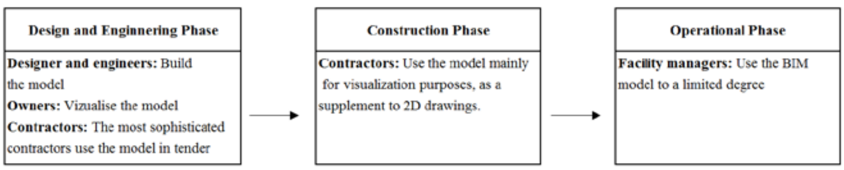
Operational Phase

According to the interview objects, BIM was mainly used during the design and engineering and construction phase. BIM use during the operational phase was only mentioned by two interview objects, both of which were talking about pilot projects. A project manager in one of these projects explain the process as follows:

> *We will choose 5 to 10 objects where operational documentation linked to the respective objects are added to the building information model. [...] The goal is to provide a building information model of the construction for the operational department. If an armature or radiator breaks, one can easily click on the object and find a phone number, if one needs to repair the object or information regarding the type of bulb, instead of navigating through 8000 pages without finding the information of relevance* (Project Management).

The figure below summarizes how BIM is used by the different actors in the various project phases.

Figure 6: BIM in Different Project Phases



4.1.3 Between Actors/Project Phases

The majority of the projects studied used open BIM, where IFC is the file format most commonly used for sharing the building information model between project participants. *"The delivery is IFC, open BIM."* (Architect), *"We use open BIM and share the files as IFC."* (Contractor)

Although the model is shared between project participants, it appears from the majority of the interviews that most of the different actors work in separate building information model s, and not simultaneously in the same model. *"The different disciplines work separately on their own model. Afterward, these IFC files are shared between the actors quite frequently."* (Subcontractor), *"Every discipline BIMed by themselves, then it was compiled in IFC."* (Contractor)

4.1.4 Variance in BIM Use Across Projects and Delivery Models

The studied projects showed certain similarities and differences in the way BIM was used between actors. In the majority of the cases, different actors had separate models, which were distributed as IFC files, and combined to create a shared model. However, the frequency to which these models were updated differed across projects. A few of the projects also had a common BIM server, which allowed the building information model to be updated instantaneously.

The projects also differed in terms of the degree of information that was included in the model. While some projects merely included three dimensional (3D) information in the building information model , others included up to seven dimensions (7D) of information. Although all of the studied projects had relatively high ambitions with regards to the level of information to be included in the model, not all projects were able to reach this level. It was also possible to observe slight variations in which disciplines that modelled in 3D and to what degree BIM was used by the different actors. Still, a common pattern between the projects, was that certain disciplines did not utilize BIM.

To summarize, Table 3 shows the variance in BIM use between project phases and actors.

Table 3: Variance in BIM use

	Design and Engineering	**Construction**	**Operational**
Owner	Visualization	Visualization	BIM is used by facility management e.g.: info related to repairment of an armature
Users	Visualization	Visualization	
Engineer and Design Team	Build the model, the model is shared in IFC, mainly 3D drawings except for some disciplines	Makes the model available for constructors	
Contractor	Some contractors use a model in the bidding process	Use the model for construction: high variance in the individuals BIM use, mix of 2D and 3D	PPP: Used by the contractor for facility management
Subcontractor	Some disciplines who are a part of this phase, will add information to the model	Use the model for construction: High variance in the BIM use across the disciplines, industry players and individuals, a mix of 2D and 3D	

In conclusion, the effectiveness of BIM use varies across actors, project phases and projects studied. Part of this variation may be attributed to the choice of delivery model. The elements of the delivery models which may influence BIM use is outlined in section 4.2. Moreover, similarities and differences in the use of BIM were observed within both the transactional and relational categories of delivery models. This implies that the choice of delivery model alone cannot ensure effective use of BIM. The effective use of BIM is also contingent on other factors that may mediate or moderate the effectiveness of delivery models in facilitating effective BIM use. These factors are highlighted in section 4.3.

4.2 How do the Elements of the Different Contractual Models Influence the use of BIM?

In this section, the elements of the different contractual models that has been found to influence the use of BIM will be outlined. The chapter will be divided into transactional and relational contracting and we will investigate how the elements of DBB, DB, Partnering and IPD affect BIM use.

4.2.1 Transactional Contracting

In the following, we will present findings related to DBB and DB, in addition to general notes on the transactional way of contracting. One of the main themes that occurred during the interviews was the necessity of collaboration for effective BIM use. As we will describe in the following, the interview objects highlighted three main elements of transactional contracts that affects the collaboration between the project participants: I) The incentive scheme, II) timing of participant involvement, and III) the degree of flexibility within the contracts.

Incentive scheme

With the incentive scheme in the delivery models, we refer to how and what the different actors get compensated for. In the transactional contracting scheme, actors are compensated for their own delivery. Thus, there are no incentives for adding information, which may be useful for other actors or later phases, to the model. As one contractor notes, this incentive scheme might make it possible to monetize from adding wrong information to the model: *"DBB and DB enables us to succeed at the expense of others. Additionally, the opportunity to monetize from mistakes is high."* (Contractor) This implies that the transactional incentive schemes may create opportunities for opportunistic behavior, which can result in less reliable building information models.

It appears from our results that the DB incentive scheme is preferred over DBB because the contractor in a DB will get compensated for being involved at an earlier stage. Indeed, a contractor suggest that early collaboration between designers, engineers and contractors is discouraged when the contractor does not receive such compensation:

> *Collaboration between actors is needed in order to use BIM. Collaboration is difficult when you only are paid for the construction. There is no point for us to get involved with the design and engineering if we don't get paid for it* (Contractor).

In sum, transactional contracting deter collaboration and information input in the building information model, by not compensating actors for these actions. Due to the low margins in the construction industry in general, being incentivized for all contribution and involvement is considered by interview participants as particularly important.

Timing of participant involvement

The challenges with using BIM effectively under DBB was elaborated by a contractor in one of the projects studied. Not only did the lack of early contractor involvement lead to less collaboration, a prerequisite for effective BIM use, it also led the contractors to lose control over the updating routines of the model. The contractor is dependent on an updated model for effective BIM use as suggested by one contractor:

> *The fact that we are not involved in the engineering and making the solutions is a disadvantage in that we don't possess control as for when the model is updated. I cannot come up with a single reason for why DBB should be of advantage concerning BIM, except from visualizing it digitally, and have a model. It is not a suitable model for collaboration.* (Contractor)

In comparison, the DB delivery model involves contractors at an early stage. It is suggested that getting involved as early as possible in the project and spending a sufficient amount of time prior to the construction phase, is optimal for effective use of BIM.

Degree of flexibility within the contract

The rigidness of the transactional delivery methods also seems to influence the use of BIM. Under transactional delivery methods, project participants will have little room to use BIM differently than what is specified in the contract, even if the contract is unsuitable for using BIM effectively.

> *The contract governs a tight budget. You obey and your actions are governed by this contract. If you do not follow the details of the contract, you might end up getting law sued. And if the contract is unsuitable for using BIM effectively for interaction, it will not happen* (Subcontractor).

This implies that a transactional contract might negatively influence BIM when the terms in the contract does not foster effective use of BIM. The same subcontractor adds that the two transactional delivery methods are unequally flexible and the purest transactional approach – DBB – is the most rigid model of the two.

In conclusion, several elements of transactional delivery models seem to limit effective BIM use. This is related to their incentive scheme, rigidness and late involvement of project participants. However, DB seems to be more beneficial for effective BIM use than DBB, due to earlier contractor involvement.

4.2.2 Relational Contracting

In the following, we will present the findings related to the relational contracting models in Norway, namely Partnering and IPD. We will examine how the elements included in these contracts affects collaboration, which is considered necessary for effective BIM use. Two main contractual elements within the relational contracting models were suggested to influence the effectiveness of the BIM use: I) the incentive scheme and II) early involvement of project participants.

Incentive Scheme

The financial incentive scheme was the most frequently mentioned factor which seemed to have an impact on the use of BIM. The importance of financial incentives was for example expressed by one of the contractors in our study. With the incentive scheme, the contractor refers to the principle of shared risk and reward where the project participants will be rewarded based on the overall outcome of the project. Therefore, the project participants' behaviors will be guided by what is best for the project. As such, participants may share information which is not useful for the actor itself, but might improve the overall quality of the building information model and therefore project performance.

> *IPD prioritizes the project, and is the first delivery method where no actor can succeed on the expense of others. Previously, this has been a common mentality within the construction industry and an embedded part of our mentality. [...] The contracts are formulated after the zero sum principle, I can only win at your expense. Or if I make a profit, it will affect the profit of other project participants negatively. IPD removes this obstacle – there are two outcomes; we all win or lose together.* (Contractor)

An architect suggested that the general incentive scheme of IPD might be inappropriate to foster effective use of BIM. Instead, it was suggested that the incentive scheme should PPP, where incentives are tied to the operational phase to ensure effective life-cycle BIM use.

> *"IPD fosters collaboration between actors in the design and engineering, and construction phase. However, we need to keep in mind that in order to make good decisions, we need to include the operational phase. The decisions are not always optimal for the operational phase, due to a strict budget governing the project. To stay within the budget, you will either reduce the quality of the materials used or go for solutions which are not optimal for the operational phase. The IPD contract is very good at integrating the phases prior to the operational phase, but does not include an appropriate incentive scheme to create constructions which performs well during the operational phase. If anything, this would have been better if we used a PPP where the incentives also includes the operational phase."* (Architect)

Early involvement of project participants

Compared to transactional delivery models, relational delivery models features earlier involvement of project participants. Our findings suggest that early involvement positively influence effective use of BIM. For example, one contractor argued that they should be included earlier in the project to define BIM use in collaboration with the owner. When the project participants that are going to use BIM are included in the process of defining BIM use, this might improve the effectiveness of the model as a plan for construction .

> *Under a DB with Partnering we have the opportunity to join forces with the owner and define it. The owner is not always good at doing such. If we were involved earlier than under a normal DB, this issue would have been resolved. If the owner includes BIM, they only define if BIM should be included or not. But what should we actually use BIM for?* (Contractor)

Early involvement as a key element to effective BIM use, was mainly mentioned by the contractors and most of the interview objects focused on early contractor involvement. However, as one contractor suggests, the early involvement is not limited to include contractors. He suggests that the users of the construction also needs to be involved in the early stages. The contractor believed that early involvement in the partnering model fostered information exchange in BIM.

> *A partnering model with an active owner and contractor. In such models, it's all about finding good and rational solutions. The owner is also more aware of the final delivery. To create good models with the right information, you need to involve the users, clear up all potential changes and adjustment prior to the construction phase. Compared to DBB and DB, I believe that this model offers the highest potential.* (Contractor)

The main challenge with the partnering model is to govern conflicting forces surrounding the project participants. It is suggested that providing guidelines prior to the construction phase might mitigate the confusion caused by these conflicting forces.

> *Partnering is an interesting model. However, it is also quite challenging. You need to collaborate and align interests, while simultaneously having conflicting interests [...]. You cannot be too rigid and not too flexible. You need to be more discretionary. Lack of discretion in the contract represents a challenge, with no guidelines for what is right and wrong. The definition of such is important to make prior to construction start. We still have a long way to go.* (Contractor)

4.3. What are the Factors Mediating and Moderating the Influence of Contractual Models on Effective BIM use?

In the following section, factors which may explain variation in BIM use across projects will be outlined. The identified factors may either mediate and moderate the relationship between contractual models and effective BIM use. Mediating factors are causal results of the contractual models and a causal antecedent of effective or ineffective BIM use. Moderating factors affect the strength of the relation between contractual models and effective BIM use (Baron & Kenny, 1986). Our data showed some overall categories of factors, namely technology, competence, mindset, relational procedures, project resources, demands and guidelines and ambiguity. The interview objects mentioned additional factors that were not included in the overall categorization. When selecting the overall categories of factors, we only included the factors most frequently referred to by the interview objects. Each of these categories will be explained in more detail, in order to provide a richer overview of these factors. Even though the factors are separated for the purpose of this paper, they may also influence each other.

4.3.1 Technology

Several of the interviewed people have highlighted that technological tools influence the effectiveness of BIM use. One contractor, reflecting on why the project did not reach the BIM ambitions established at the outset, concluded that the main reason was that the organization's information technology (IT) was insufficient: *"For us, the issue was technological. Its related to the IT we have in the organization"* (Contractor).

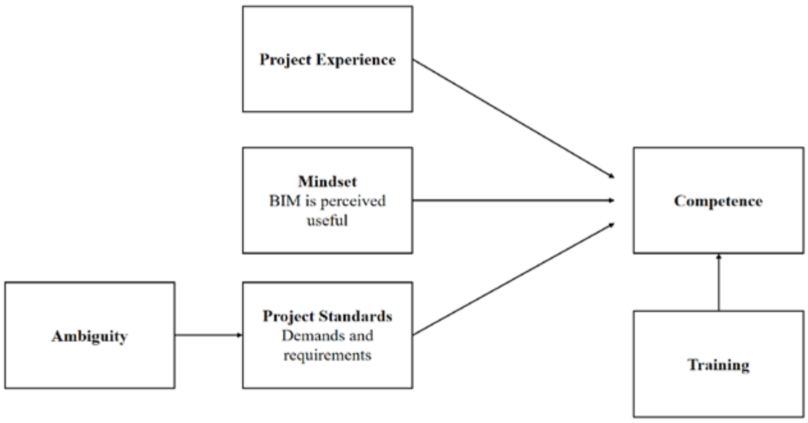
The findings further show that collaboration in BIM requires the parties to make investment in technological tools, based on the tools utilized by other actors. A project manager interviewed emphasized this: *"You need to have proper tools. There is no use in having the cheapest computer and so on. You need to make some investments, depending on which programs the different actors use"* (Project Manager). This opinion was supported by an engineer from a different project, who argued the following: *"The main challenge is that everybody has to use the same tool, or at least tools that are compatible, in order to realize the positive effects of BIM"* (Consulting Engineer). Interoperable tools allows information to be shared between project participants and phases more effectively.

Accordingly, the findings imply that investments in technological tools are needed and that interoperability between tools impact the effectiveness of BIM use, regardless of the contractual model. Thus, technology can moderate the relationship between contractual models and effective use of BIM.

4.3.2 Competence

The data shows that competence is a recurring factor in explaining effective or ineffective use of BIM in the projects studied. For instance, a contractor expressed the following *"The big challenge is competence. It always will be"* (RF). Competence refers both to the process of building the model and using it effectively. Although a lack of competence in BIM appears to be a general issue across the value chain, several respondents expressed significant concerns regarding the competence of subcontractors. A quote from an architect in our study illustrates this concern *"It is about competence. Consider the subcontractors. They just do not know what it is"* (Architect). An engineer in our study further contends that competence across the value chain is a key to productivity realization from BIM: *"If you are going to realize the productivity value from using BIM, you depend on sufficient competence across the entire value chain"* (Consulting Engineer). Throughout the interviews, we identified several factors that seemed to influence the actors' BIM competence illustrated in figure 7. The interview objects also highlighted that these factors could explain the lack of competence among subcontractors. In particular, the low competence among subcontractors was believed to be caused by the low BIM standards demanded by the contractors.

Figure 7: BIM competence



Source: own analysis

In sum, BIM competence is considered to moderate the relationship between contractual models and effective use of BIM and the competence of participants in a project is influenced by the factors highlighted above.

4.3.3 Mindset

The data shows that the mindset of project participants has a significant influence on the effectiveness of BIM. The mindset refers to an established set of attitudes towards collaboration and BIM. It includes a general collaborative attitude and an interest and motivation to use BIM.

Several interview participants say that the benefits of BIM are realized when project participants have a collaborative attitude. A contractor summarizes this point as follows: "*Everything relies on the parties playing on the same team. That the whole industry is collaborating. That there is good communication, so that you do not design poor or expensive solutions. That it is coherent throughout the project*" (Subcontractor).

Moreover, the construction industry suffers from low margins and silo thinking, which can affect their willingness to add information to the building information model, beyond what is necessary for the actor itself. However, when the project participants have a more collaborative mindset, they will be more likely to do what benefits the project as a whole. One designer expressed his concerns regarding the difficulty of making people add additional information to the model:

> *Much of the benefits an actor realizes from BIM, is based on what others have done, and not what you do yourself. What is important is to make people understand that they have to do something for others. That is, they should include something in the model, for others to gain from it; they will not receive the benefits themselves. To get someone to do something just to help someone else is quite difficult, especially when you are trying to make money* (Consulting Engineer).

Several actors imply that when project participants are interested in BIM, it will positively influence its use in the project. For example, a project in our study, that showed a generally high level of BIM maturity, was said to be driven by project managers that had a great interest in BIM and other digital tools. A project manager further elaborated on this saying that *"It depends on the people. […] If you have the right chemistry or if the people are interested in using it [the building information model] it will flow more easily."* (Project Management).

Furthermore, the data implies that the BIM-interest of project participants influence the quality of the model, because more relevant information will be added and higher demands will be made towards subcontractors, as noted by a contractor in our study:

> *It can also depend on the people. If we are in a team where nobody is interested in the realization of BIM, I would say that would show in the quality of the model, because nobody will point out or ask the right questions to those who include things in the model. They will also not be as good at including it in the contract to the subcontractor and that will show in the*

> *quality. If we have someone that is very interested in BIM, then he would probably be better at including it in the contracts with subcontractors* (Contractor).

Finally, the findings imply that the interest and motivation to use BIM depends on whether the project participants perceive the tool to be useful or not. Specifically, several contractors say that they have started using BIM more actively after they realized that it was actually useful for themselves, and consider the same to be true for their subcontractors.

The mindset of project participants can affect the degree to which the different actors add information to the model, to what extent the model is used and collaboration in BIM. As previous findings suggest, the contractual scheme might impact the mindset of project participants. Yet, interview participants suggest that it may also be influenced by other factors, such as the age and personalities of project participants or the time frame of the project. This implies that mindset can both mediate and moderate the relationship between contractual models and the use of BIM.

4.3.4 Relational Procedures

The findings imply that relational procedures including collocation and team meetings can influence BIM use through its effect on collaboration. As such, a contractor highlighted colocation as a factor easing collaboration in BIM: *"They have large projects where the whole team is collocated. It is a lot easier then, because you can have one system, as opposed to having one system for us and then maybe another one for the architects"* (Contractor). The project manager of a different project shared this understanding:

> *It is important that everybody sit together so that we can discuss solutions, presentations and direction together. […] It is a benefit that everybody is located in one place, as you are dependent on being located in front of one screen and being collocated, if not one hundred percent of the time, than at least a lot of the time* (Project Management).

Another contractor emphasized that frequent engineering meetings are necessary to ensure increased quality of the building information model :

> *In order to successfully complete this project, we needed collaboration between all engineers to achieve a good building information model . A key factor was that there was a good communication between the engineers, in order to develop a good building information model . Frequent engineering meetings led to a more detailed building information model . If you do not have enough information, you have to look at drawings and you lose information and make mistakes.* (Contractor).

In sum, relational procedures may ease collaboration in BIM and increase information quality in the model. Frequent meetings and collocation is oftentimes associated with relational contracting. However, projects can also display this feature independent of delivery model. Thus, relational procedures is considered a factor mediating the relationship between relational contracting and effective BIM use, and a factor moderating the relationship between transactional contracting and effective BIM use.

4.3.5 Project Resources

Another factor found to impact effective use of BIM is the project's resources, that is the budget and scheduled time. Several actors mention limited funds as a factor leading to under-prioritization of BIM use. An engineer in our study notes that although there were ambitions to use BIM at the construction site, BIM was under-prioritized because the project was pressured on costs. Additionally, participants in our study identify that investments in a BIM coordinator and a mutual BIM server will positively impact the level and quality of BIM use in a project.

Furthermore, our findings imply that when the project has been devoted a sufficient level of time, project participants will be more devoted to achieving an effective BIM use. This is illustrated by an architect in our study:

> *It depends on the owner. That is, if you have enough time. For this solution, it's about getting compensated for each hour worked. You have a limit of course, but you are paid for what you do. This lowers the level of stress at each individual firm. I think this contributes to the good atmosphere we have in this project. People are willing to take on extra responsibility and take initiative. If you are determined on a fixed price, you increase the stress level* (Architect).

Accordingly, project resources might impact both how BIM is used between actors and the level to which additional information is included in the building information model . Project resources is not necessarily a factor influenced by the contractual model, yet relational delivery models includes a more lengthy planning process, as project participants are involved earlier. Hence, project resources can moderate the relationship between contractual models and effective use of BIM.

4.3.6 Demands and Guidelines

A recurrent theme throughout the interviews are BIM-demands and BIM-guidelines from the owner. There is a general consensus among project participants that in order to increase the use of BIM in a project, the owner must demand this in the bidding process. Additionally, it is considered important that the demands of the owner should be reflected in the relationship between contractor and subcontractor, as one contractor highlights *"You need to carry forward the level that the owner demands from us. We have to carry that forward in the contracts we enter with our subcontractors"* (Contractor). Yet, a pattern throughout the data collected is that the building information model is not referred to in the contracts, neither as a demand nor as a contractually binding document. As one actor illustrate: *"Neither this or the previous contract demanded that you should use BIM. It is not any guidelines on it either"* (Contractor). This is further
highlighted by an interviewed engineer:

> *The contracts as they are formulated today; 8401/8402, 8407 the design-build contracts, and 8405 which is the contract with the contractor, none of these contracts regulate the exchange such that it is beneficial to work*

> *digitally. It gets complicated when none of the contracts regulate it. The contracts are not suitable for a digital future.* (Consulting Engineer)

The fact that BIM is not contractually binding undermines the reliability of the building information model as a guideline for building. As such a subcontractor in our study says:

> *It is pretty rare today that the contract refers to the building information model. We have the old contractual models, which only refer to some specifications and drawings, and this is what is contractually binding. It does not help to have a great building information model, which you are not certain refers to the exact same thing* (Subcontractor).

Still, an architect in our study argues that there are some hindrances in demanding BIM from industry players that are less advanced in BIM:

> *It is a combination. On the one side, you have not been good enough at demanding BIM in the bidding phase. On the other side, you have been careful to do that, because you see that by doing so you exclude many from the market, thus you get less competition and higher prices* (Architect).

In sum, an owner or contractor who demand BIM is considered to positively impact BIM use in construction projects. Demands can be stated in the contract, but is not necessarily influenced by the choice of delivery model. As such, demands and standards moderate the relationship between contractual models and the use of BIM in construction projects.

4.3.7 Ambiguity

An issue consistently brought up by interview participants were ambiguity related to the meaning of BIM-related terms and methods. It is evident from our data that a barrier to effective use of BIM is that different actors have various perceptions on the specification of terms, what should be included in a building information model , to what level of detail and in what ways the different actors should work with the tool. When the terms are not sufficiently specified from the outset and the practices and routines not agreed upon, it is believed to negatively influence BIM use. As such, a contractor notes that there is a lack of specification on the term BIM competence:

> *We often use the same terms, but talk about different things when it comes to BIM competence. […] It is not enough to write in an offer that you know BIM. Because what is BIM? It's a whole world of practices. It's about how good you are at modelling, what information you include, and so on* (Contractor).

He further contends that this was the reason why the BIM competence within the project differed, even though it had been a demand for participation in the project.

Another contractor expressed that it was a challenge in his current project, that project participants had different interpretations of what was to be included in the building information model. This might impact the quality of the model.

> *This is the challenge of BIM. There are very different perceptions of what is needed, what is necessary and what open BIM means. That everything is supposed to be modelled in BIM is undefined. For example, on this project we have external electro, which is not common to make in models. Yet we interpret all engineering to include external electro. But we will not have that, because others do not regard that to be included* (Contractor).

Similarly, a contractor in a different project explained that the project participants, including the owner were uncertain in terms of the appropriate level of information to be included in a building information model:

> *The challenge is to make the owner understand how much information is sensible to include in the model […] What will be the benefit of making a good model? There is no need to make more than we need either. […] Where*

> *is the boundary between what is rational to include in a model? How detailed is it actually going to be* (Contractor).

Additionally, our findings suggest that there is a significant level of ambiguity surrounding the way of working under the new relational contracting schemes, which can impact the effectiveness of BIM. As one contractor explains:

> *The main challenges are [...] new ways of working. It is about stitching together a new project management system. Are you going to send an email or make an issue in the issue-system? Are you going to take the conversation over the desk because you are collocated? Or is that too informal for that exact decision? Should I just make changes to the model and upload?* (Contractor)

Thus, ambiguity might affect the process of collaborating in BIM, the level to which BIM is used, and the degree of information added to the model. It is suggested that unclear demands can explain this ambiguity. Ambiguity appears to be present in both the transactional and relational contracting methods in our study. However, the relational contracting scheme is considered to lead to a higher level of ambiguity, due to the flexibility of the contracts and the ambiguity related to the process of working under these contractual models. Ambiguity thus moderates the relationship between contractual models and effective BIM use.

4.4 Summary of Findings

The following section will highlight our findings on the contextual effectiveness of transactional and relational contracting. As such, the findings build on the data collected from the previous sub-research questions and connect them. It also builds on reflections made by interviewed actors with respect to the effectiveness of different contractual models, under different circumstances.

4.4.1 Transactional Contracting

In general, our findings show that some elements typical of transactional contracting is considered ineffective in governing BIM transactions. The interviewed personnel has especially noted that a design-bid-build delivery model may be ineffective, although, this is a reflection most often brought forward by contractors. However, our observations additionally show that under certain conditions, BIM might be effectively used under a transactional contracting scheme . Indeed, one contractor argued that the effectiveness of the design-bid-build delivery model with regards to BIM depends on the competence of the owner as the contractor is not involved in the early stages of the project. This suggests that under the conditions of a BIM-competent owner, a design-bid-build contractual model can facilitate effective use of BIM. He sums up his interview as follows:

> *To sum up, BIM is a very good tool independent of the delivery model, but it is easier to gain control over the information you need if you have a design-build or partnering delivery model. Except if the owner in a design-bid-build is very advanced. It is up to the owner what you get* (Contractor).

Furthermore, our findings show that when project participants are competent and have a mindset that involves positive attitudes towards BIM and collaboration, this may lead to more effective BIM use. One actor, when comparing two different projects, one with a IPD model and another with a DBB contractual model, suggests:

> *It should be mentioned that this project is a design-bid-build, which is the opposite of an IPD. Every specialization has their own contract. In principle, this should open up for a lot of disputes regarding what to deliver and what not to deliver. I just do not see this. There is a really good atmosphere - people are supportive and communicate well. We also have some very skilled project managers. I think this helps a lot, but I think it depends on the people. That there are many people who take initiative and have the right attitude. People that do not just try to deliver the minimum* (Architect).

The importance of having the right mindset was confirmed by another project in the study, which followed a DB contracting method. In this project, the effective use of

BIM was attributed to the mindset of project participants. This suggests that in the presence of competent people, with the right attitude, transactional delivery models can still lead to effective BIM use.

4.4.2 Relational Contracting

The data shows a general consensus among the interviewed actors that relational contracting has the potential to lead to more effective use of BIM, mainly through its effect on collaborative practices, as one subcontractor highlights: *"When you have a good partnering contract you actually have to do your best to collaborate effectively"* (Subcontractor)

Moreover, the interviewed subcontractor argued that even though relational contracting can facilitate collaboration, it does not necessarily ensure positive attitudes towards collaboration. According to the subcontractor, a positive attitude towards collaboration, is a key factor for effective BIM use. The findings, thus, suggest that relational contracting is only effective if project participants have positive attitudes towards collaboration and BIM.

Further, relational delivery models are relatively novel to the construction industry, and this is highlighted as a challenge. As such, even though relational contracting is considered the contracting method with the most potential with regards to effective BIM use, the findings imply that it is only effective in cases were sufficient time and resources are allocated to training in terms of competence, process and team building, as another participant in the IPD project suggest:

> *If you are going to spend less time in the construction phase, you have to spend more time in the planning phase. In this project, you tried to cut both. It is not only the contractor, engineers and consultants. It is also the owner who has underestimated how difficult it would be to get a large team to work in a completely new way. BIM is in place, it was more about the process of using BIM in decision making. That was a challenge.* (Architect)

The architect further contends that it is not the relational contracting scheme that limit the project, but it is about learning how to work under this type of contract.

Moreover, the data suggest that shared incentives are considered a positive feature of relational contracting. However, it is considered a facilitator of effective BIM use, only under the conditions of BIM-competent project participants. The interview data suggest that when certain actors are not competent in using BIM, this affects the profit of all the other actors.

> *When we have to make drawings because the market is immature, it reduces the profit of the project. It affects everybody, architects, contractors and consultants, even though they are competent in using BIM. In an IPD contract, everybody is exposed to the costs of the weakest link. In this project it was, among others, the subcontractors who could not use BIM. That is a challenge. You have not taken that into account to a sufficient degree in this project, how immature the subcontractor and supplier market was* (Architect).

CHAPTER 5: DISCUSSION

The use of BIM in construction projects offers the opportunity to increase integration, and therefore contributes to reducing the issues of uncertainty, complexity, and lack of coordination in the construction industry (Fergusson, 1993; Eikeland, 1998; Briscoe & Dainty, 2005; Bråthen et al., 2016). Our findings suggest that, in order to gain the potential integrative benefits of BIM, every part of the value chain has to use BIM at a high level. Further, our findings show that the current use of BIM is relatively ineffective, as there is a high variance in the BIM maturity level and the degree and quality of information added to the model throughout the value chain. The project delivery models in the construction industry determine roles and responsibilities, risk sharing, project organization, information flow, and the collaborative model. Together these factors can act as boundary conditions for integration in BIM (Lædre, 2009; OSCAR, 2016). In the following sections, we aim to answer how contractual models can act as boundary conditions for effective use of BIM. First, we will discuss how elements in the different contractual models can influence BIM use. Later, we discuss the influence the different contractual models may have on factors leading to effective BIM use. Finally, we discuss the circumstances under which the different contractual models are effective, in light of the contextual factors which may strengthen or weaken the relationship between contractual models and effective use of BIM.

5.1 The Contractual Elements Influencing BIM

In the literature review, we established that DBB and DB displayed many of the characteristics of transactional contracting and that the characteristics of Partnering and IPD resembled those of relational contracting. In this section the elements that differ between these contractual models, and in which way these elements were found to benefit or limit BIM use, is discussed. These elements can be summarized as follows: I) degree of flexibility, II) Incentive scheme, III) timing of participant involvement

One of the main differences between transactional and relational contracting is the degree of flexibility they offer. Transactional models are rigid, meaning that they are specified and relies on third-party enforcement of agreements. Relational models are more flexible (Macneil, 1977; Poppo & Zenger, 2002), as they are less specific and self-enforcing (Telser, 1980; Dyer & Singh, 2008). Ahmad and colleagues (2018) found that limited liability inherent in self-enforcing agreements positively influenced collaboration and thus effective use of BIM. Our findings support the notion that limited liability positively influences BIM use. We find that self-enforcing contracts, such as IPD, removes the fear of suffering economically from being law sued. Under self-enforcing contracts, project participants would more likely seek effective BIM use, even if this means deviating from the contractual terms. Further, our findings extend previous literature by suggesting that all types of flexibility may not lead to effective BIM use. We found that flexibility in contractual specifications led to confusion among project participants, because there are no guidelines specifying appropriate behaviour. This implies that project actors should clearly define guidelines for appropriate behaviours prior to construction start, when working under flexible contractual models.

Transactional and relational contracting also differ in what will happen in the incidence of burdens and benefits (Macneil, 1977). The transactional route shifts the burden or benefit to one part, whereas relational contracting offer an undivided sharing benefits and burdens between project participants. In contracts, these elements are present through formal safeguards such as the financial incentive scheme (Klein, 1980; Williamson, 1983). Relational contracting methods, including Partnering with incentives and IPD, seek to align the financial incentives of the project participants, and thus shifts the attention from individual goals to the overall project goal (AIA, 2007; 2011; 2014; Ghassemi & Becerik-Ghassemi, 2011; Fischer et al., 2017). Relevant literature proposes that a sharing of risk and reward might lead to more effective use of BIM (e.g. Sebastian, 2011; Ahmad et al., 2018). Our study empirically confirm that when financial incentives are aligned, participants are more inclined to share information that improve the overall quality of the building information model , even though sharing this information does not yield any direct reward to the respective actor. Our results suggest that aligning financial incentives is critical for both collaboration and for the quality of information in the building information model, and that this should be the standard for BIM-enabled construction projects.

Transactional and relational contracting are different in the expected length of the relationship between the parties to exchange (Ring & Veen, 1992). Within the AEC-industry, the length of the relationship can be reflected in the timing of participant involvement (El Asmar, 2013). Liao and Teo (2018) suggest that this early involvement will positively influence BIM use. The positive relationship between early participant involvement and effective use of BIM was confirmed by our findings. Early involvement was particularly emphasized by the contractors who wanted to be involved in the early stages to assist in defining the BIM use in the project. In this way, the contractor can define BIM use so that it aligns with what they perceive as effective. Moreover, the interview objects highlighted that early involvement was not limited to include the contractor, but also key participants. Our findings extend the prior literature by suggesting that including the contractor in the operational phase is crucial for effective life-cycle BIM. When the contractor is involved in the operational phase, they will focus on creating a building information model that contains sufficient information, so that it may be utilized for operational purposes.

In conclusion, relational delivery methods seem to be most beneficial for effective BIM use due to their flexibility, early participant involvement, and that they foster alignment of interests through their financial incentive scheme. In contrast, transactional delivery methods have certain limitations to effective BIM use, as they are rigid, involves project participants relatively late, and that they foster sub-optimization through their financial incentive scheme and two-party contracts. The findings support previously conducted research as we found that relational delivery models are more preferable to effective BIM use compared to transactional delivery models (Kuiper & Holzer, 2013; Hardin & McCool, 2015; Holzer, 2015; Bråthen et al., 2016). We, therefore, propose that:

Proposition 1a: Transactional contractual models negatively influence effective BIM use, due to I) their rigid enforcement, II) late contractor involvement, and III) individual performance-based incentive scheme.

Proposition 1b: Relational contractual models have a positive influence on effective BIM use, due to I) their self-enforcing nature, II) continuous contractor involvement, and III) shared performance-based incentive scheme.

5.2 The Mediated Relationship Between Contractual Models and BIM

Both previous literature and our findings have found several factors that can affect the use of BIM. This study further suggests that some of these factors can be influenced by the choice of delivery models. Especially, the mindset of project participants and the relational procedures are considered causal antecedents of the relationship between contractual models and effective BIM use. The following section will, thus, discuss how these factors mediate the relationship between the different contractual models and effective use of BIM.

The literature on BIM has found that effective use of BIM requires a change in mindset, towards a more collaborative (Sun et al., 2017). Furthermore, the literature on contractual models suggest that transactional contracting foster a silo mentality - the opposite of a collaborative mindset (Ghasemi and Becerik-Gerber, 2011). Our findings combine the insights of previous literature and suggest that transactional contracting negatively impacts effective use of BIM because it encourages project participants to act in their self-interest, at the expense of others and project outcomes. We thus propose:

Proposition 2a: Transactional contractual models negatively influence effective use of BIM through fostering a silo mentality.

Relational contracting theory suggests that relational contracts foster cooperative and collaborative processes, which is essential for the effective use of BIM (Jobidon et al., 2019). The relationship between collaboration and relational contracting in construction has for instance been established by Sive (2009), who found that the IPD method enabled higher trust and collaboration levels than transactional contractual models. Our interview participants similarly contended that relational contracting positively influenced the collaborative mindset of the different stakeholders. The actors in our study argue that the shared economic incentive scheme offered by relational contracting reduced the silo-thinking of project participants, and allowed them to focus on a common goal.

Our findings also extend previous literature by suggesting that relational procedures might lead to a more effective use of BIM. Particularly, colocation and frequent meetings between project stakeholders, which are common features of relational contracting, was highlighted by interview participants as contributors to effective BIM use. Hence, we propose the following:

Proposition 2b: Relational contracting positively influence effective use of BIM through fostering a collaborative mindset and encouraging colocation and frequent stakeholder meetings.

5.3 The Circumstantial Effectiveness of Contractual Models

Existing literature on the relationship between contractual models and BIM has mainly focused on how the contractual models influence BIM use, without attending to the particular circumstances in which the different models are appropriate (e.g. Sebastian, 2011; Ahmad, 2018). We therefore look to transaction cost economics to answer this question and discuss the circumstances under which the different contractual models are effective, in the light of the contextual factors which may strengthen or weaken the relationship between contractual models and effective use of BIM. Thus, we hope to contribute to theory by offering empirical insights on the effectiveness of different contractual forms in governing BIM exchange.

A relatively large body of research has identified numerous factors that may influence the use of BIM in construction projects (e.g. Sun et al., 2017; Alreshidi et al., 2018; Jacobsson & Merschbrock, 2018). This study has empirically confirmed a number of these factors and proposed additional antecedents for effective BIM use (see table 4) Some of the identified factors are not affected by the contractual model. Therefore this research suggests that they are contextual factors that moderate the relationship between contractual models and effective use of BIM. Thus, according to TCE, the level to which they create asset specificity and uncertainty will influence the appropriateness of the different governance models.

Table 4: Comparison of findings

Previous research on the factors influencing BIM use	Current findings
Functionality and accessibility of BIM tools	√
Interoperability	√
Lack of technical training	X
Requirement of computable design data	X
Need for sophisticated data management	X
Costs of training, software, and hardware	√ For smaller firms and projects
BIM competence	√
Attitude towards change	√ Collaborative mindset
Perceived usefulness	√
Strategies, standards and guidelines	√
Definition of roles and BIM scope	√
Cooperation from industry partners	√
BIM coordinator	√
Cultural differences	X
Digital information and documentation standards	√
Definitions of responsibility for adding incorrect	
Information to a BIM model	√
Intellectual propoerty rights	X
	+ Frequent stakeholder meetings
	+ Colocation

We have found that effective use of BIM requires interoperable BIM tools, implying that actors must invest in tools that speak the same language as the tools of other project participants. Thus, it represents a physical asset specificity. Consequently, an increasing adoption of interoperable BIM tools across the industry, might reduce the need for asset specific investments. Additionally, the need for integration in BIM creates human asset specificity among parties, beyond the human asset specificity already present in construction projects (Eccles, 1981; Winch, 1989). Moreover, ambiguity seems to be an overarching characteristic of information exchange in BIM. More specifically, we found that there was a lack of common understanding and definition of what qualifies as being BIM competent. The different project participants also have diverging understandings of what is to be included in the model, which participants are to use the model and in what way.

Ambiguity appears to be particularly connected with relational contracting, due to the novelty of these contractual models in the AEC-industry. Conversely, our findings show that when owners and contractors demands BIM in the contract and provide guidelines with regard to BIM scope and roles, it positively influences BIM use. Hence, demands and guidelines are considered as factors reducing the ambiguity inherent in BIM transactions.

According to TCE, the need for relational contracting and hierarchical control is not large enough to compensate for the additional costs related to these forms of governance, when there are low levels of uncertainty and asset specificity (Williamson, 1979). Consequently, literature on transaction cost economics predict that transactional contracting is effective under conditions of lower levels of volatility, complexity, and asset specificity and under medium levels of ambiguity (Williamson, 1996; Carson et al., 2006). Thus, we suggest that under the conditions of industry-wide technological interoperability, clarity in the definition of BIM scope, roles, and competence, transactional contracting will more effectively govern BIM exchange. In addition to the predictions of TCE, our results suggest some additional conditions that must be present for BIM to be used effectively under transactional contracting. Especially, BIM competent owners are important in DBB delivery methods, because when the contractor is not involved in an earlier phase, the owner alone must define an appropriate information level for the building information model. Additionally, the response from our interview participants show that BIM effectiveness rely on the mindset of the people involved. If the people have positive attitudes towards collaboration and perceive BIM to be useful, then BIM use will be effective, even though it is governed by a transactional contract. We further find that when sufficient time is allocated to the design and engineering phase and teams are collocated and engage in frequent meetings with other actors, BIM will be used more effectively.

In sum, when the abovementioned conditions are present, it is suggested that the identified negative relationship between transactional contracting and effective use of BIM will diminish. Conversely, when these factors are not present, the negative relationship between transactional contracting methods and effective use of BIM will be strengthened. Therefore we propose:

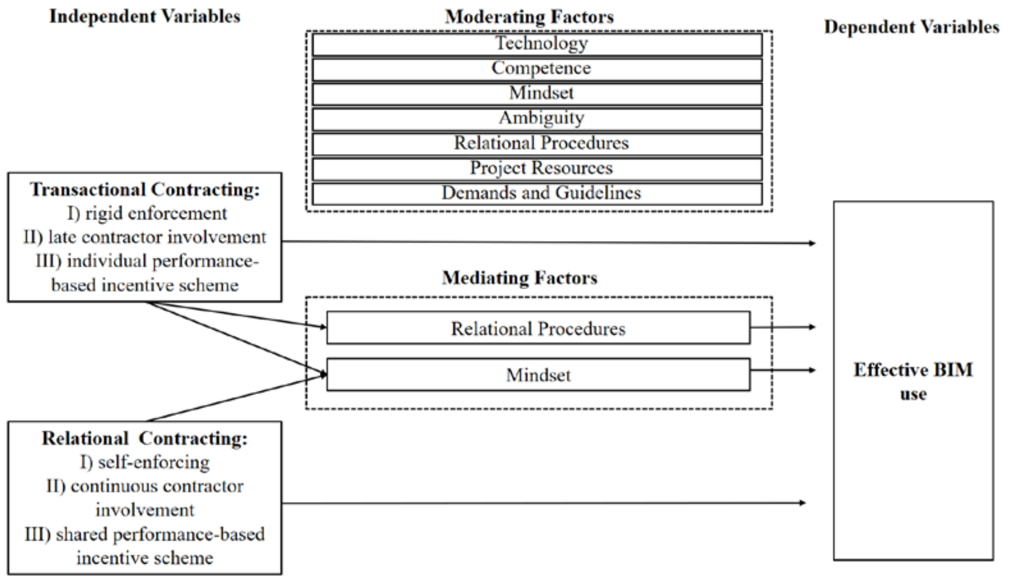
Proposition 3a: The possible negative effect of transactional contracts on the effective use of BIM is diminished when there are I) industry-wide interoperability, II) term specificity, III) competent project owners, IV) collaborative mindsets among project participants, V) sufficient time allocated to planning, VI) colocation and frequent stakeholder meetings. When the opposite is true, the relationship is strengthened.

Furthermore, TCE argues that the need for relational contracting increases when transactions are characterized by a greater degree of asset specificity and uncertainty (Williamson, 1979). We have established that exchange in construction is characterized by high levels of uncertainty and complexity, and that the BIM exchange in particular is characterized by relatively high levels of physical and human asset specificity. Our findings, suggesting that relational contracting models positively influence BIM use, provide empirical support for the propositions of transaction cost economics. However, Carson (2006) found that relational contracting is ineffective under conditions of high ambiguity. This is supported by our findings. Due to the novelty and flexible nature of relational contracts, the additional ambiguity surrounding BIM-related terms, scope and processes creates a higher level of confusion for project participants. This implies that relational contracting is more effective in governing BIM when they are complemented by formal demands and guidelines. It was, further, found that because the stakeholders did not know how to work under this type of delivery method, it was a factor limiting the effective use of BIM. This was especially the case for the IPD model, implying that sufficient resources should be allocated to competence, team and process building under relational contracting. We therefore propose that:

Proposition 3b: The positive effect of relational contracts on the effective use of BIM is diminished when there is ambiguity surrounding BIM-related terms, scope and processes, and when insufficient resources are allocated to competence, team, and process building. When the opposite is true, the relationship is strengthened.

The proposed relationships between contractual models and effective use of BIM is further summarized in figure 8. The model illustrates the direct relationship between contractual models and effective BIM use, described in section 5.1. It further shows that this relationship is mediated by other factors, as highlighted in section 5.2. Finally, it shows that there are a number of moderating factors which influence the strengths of the identified relationships between contractual models and effective BIM use, as proposed in section 5.3.

Figure 8: The relationship between contractual model and effective use of BIM



Source: Own Analysis

5.4 The Relationship Between Transactional and Relational Contracts

Finally, there is no general consensus among scholars on the relationship between transactional and relational contracting. Whilst certain studies consider the two to be substitutes (Dyer & Singh; 1998; Gulati; 1995; Macaulay, 2018), other studies argue that they play a complementary role (Cao & Lumineau, 2015; Lorenz, 1999; Poppo & Zenger, 2002; Sitkin, 1992). Our findings show that when relational safeguarding mechanisms, such as interpersonal relationships among stakeholders, are present, transactional contracting schemes can be effective. We also find that, when relational contracting schemes are complemented by specific formal demands and guidelines, they may be more effective in governing BIM transactions. Thus, our findings imply that transactional and relational safeguarding mechanisms act as complements.

Proposition 4: Transactional and relational contracts play a complementary role in governing BIM transactions.

CHAPTER 6: CONCLUSION

The aim of this thesis was to investigate how contractual models can act as boundary conditions for effective use of BIM. We have proposed that the choice of contractual model can influence the effectiveness of BIM. However, the essential conclusion of this research is that contractual models alone does not have a significant impact on the effectiveness of BIM use. Rather, the contractual models have an impact on collaboration and relational procedures, which in turn influence the use of BIM. Further, the relative effectiveness of the different contractual models in governing BIM transactions depends on a set of conditional factors.

Our research contributes to theory in several ways. First, we contribute to the body of research on TCE by identifying characteristics of exchanges in construction, and more specifically, the characteristics of the exchange of information in BIM. Second, we respond to the call of advancing research on the effectiveness of different contractual models under varying degrees of uncertainty, frequency and asset specificity (David & Han, 2004). As such, we offer some insights on the contextual appropriateness of different delivery models in governing BIM exchange. Finally, this thesis contributes to our understanding of the relationship between transactional and relational contracting, by suggesting that they play a complementary role in the exchange of information in BIM.

Although, this thesis advance our understanding of how contractual models act as boundary conditions for effective BIM use, future research is needed to confirm these relationships. As such, this research forms a foundation for future research. Researchers could focus on conducting interviews with a more extensive set of project participants in each case and accompany this with observational data, to provide a more detailed understanding of the findings in the present study. Future research would also be needed to quantitatively test the proposed relationships in this study, in order to generalize these findings to other contexts.

Furthermore, this study offers several practical implications for the owners of construction projects. As such, Partnering and IPD should be the primary choice of delivery model, when ambitions to achieve effective BIM use are high. However, in order to realize the full positive effect of relational contracting, it must be accompanied by a clear definition of BIM scope and BIM-related terms. Additionally, because relational delivery models are fairly novel to the construction industry, sufficient resources should be allocated to learning how to work under these types of contracts. In order to reach effective life-cycle BIM use, the owner should tie the financial incentives of the contractor to the operational phase. Nevertheless, under conditions of industry-wide interoperability, DBB and DB can be more effective. DBB and DB should also be accompanied by specified BIM-related terms and relational procedures, such as colocation and frequent stakeholder meeting. BIM use under DB and DBB can be enhanced when sufficient time is allocated to planning. Finally, in order to ensure effective BIM use, project participants should be motivated to use BIM and have a collaborative mindset.

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APPENDICES

Appendix 1: Interview Guide

INTERVIEW GUIDE

Introduction

- Presentation of ourselves and the topic of relevance
- Explain what we are looking for; the interview object's experiences and reflections
- Inform about the recording of the interview and how the quotes will be used in the paper
- Ensure participant's confidentiality and anonymity
- Expected time use for the interview
- Informational letter

QUESTIONS
In the current project:
Background information about the interview object

1. For how long have you worked in this organization?
2. What is your position within the organization you are currently working in?
3. For how long have you had this position?
4. Have you previously had any other positions within the AEC-industry?
5. What kind of projects have you previously been a part of?

Background information about the current project

1. Information about the project you are currently a part
    1. Size
    2. Kind of project
    3. Project phase
    4. Delivery method used

BIM

1. Did the project participants have BIM competence prior to joining this project?
2. Who required and set demands to the BIM use in this project?
3. Do you have a BIM manual in the project?
4. Who uses BIM?
5. How is BIM currently used?
    1. Only paper drawings → do not use BIM
    2. A mixture of 2D and 3D
    3. 3D is used, which is sent in a file to the other project participants
    4. Works simultaneously with other actors in one model
6. How is BIM used between the different actors in this project?
7. What kind of barriers for BIM did you encounter during the engineering and design, and construction phase?

Contractual model and BIM

1. How do you think the contractual model of this project influence the use of BIM?
    1. Specifiy
2. Weaknesses related to this contractual model with regards to BIM?
3. Opportunities related to this contractual model with regards to BIM?

4. What could have been changed/added to the contract in order to facilitate information exchange in BIM?
5. Do you think that there are any other factors influencing the use of BIM?

In general:

BIM

1. How is the general BIM competence within the company you are employed by and collaborate with?
2. In general, is a BIM manual used?
3. How is BIM currently used within the company you are employed by?
    1. Only paper drawings → do not use BIM
    2. A mixture of 2D and 3D
    3. 3D is used, which is sent in a file to the other project participants
    4. Works simultaneously with other actors in one model
4. How is BIM used between the different actors?
5. What kind of barriers for BIM have you encountered in the projects you have previously been a part of?
6. What are the effects of increased use of BIM on the projects' schedule, total budget and quality?

Contractual model and BIM

1. How do you think the choice of contractual model influence the use of BIM?
2. Weaknesses related to the currently available contractual models with regards to BIM?
3. Opportunities related to the currently available contractual models with regards to BIM?
4. What could have been changed/added to the currently available contracts in order to facilitate information exchange in BIM?
5. What kind of contractual model do you think is optimal in facilitating information exchange in BIM?
    1. Why?
    2. What are the elements in this contract which leads to information exchange in BIM?
6. Do you think that there are any other factors influencing the use of BIM

Appendix 2: Quotes

4.1 How is BIM currently used?

4.1.1 Competence

Variance

“It [the BIM competence] is very variable. Some are very competent, while others doesn’t know what it is.” (Subcontractor)

“The competence within this design team is very high. Otherwise, it’s varying.” (Contractor)

“Our employees, which has the design contract on the technical disciplines such as HVAC and electro, have been working with BIM for a long time and are familiar with it. The architects are also BIM competent. Yet, BIM competence varies a lot among clients and other project organizations” (Consulting engineer)

“The majority of the engineers, especially the main engineers have started to use it. While for the supplier side, our subcontractors, it is more variance in terms of how familiar they are with modeling in BIM.” (Contractor)

“Informative discussions have enabled us to work effectively [in this project]. However, I receive multiple disputes between contractors and engineers which implies that this might not be the case in all construction projects in Norway. There is a huge variance. Some are simply not at a high BIM level.” (Architect)

Internal

“We have combined BIM delivery and contracts, which normally receives little attention among architects. Those who enters into agreements with customers does not pay attention to what we have agreed to deliver. When we make offers, we say that the offer is based on our own BIM-standard with a certain information and quality level. That allows us to build competence, which ensures that every person in the organization delivers in the same way. We are 500 people in this organization, where 400 of us are architects. I would say that we deliver to a very high level. This ensures that we are compensated for the additional services we are asked to deliver.” (Architect)

“According to my own experience, there is a high competence internally in the organization, but there is still some challenges regarding the exchange of digital information with other organizations” (Consulting engineer)

Competence as Demand

“The recruitment process was very thorough and high demands were made to advisors. We have also had a large BIM-focus on our side. The client itself is very BIM competent, which correlates with the fact that the client had a high competence in BIM and VDC where IPD is the central contractual model.” (Architect)

4.1.2 In Project Phases

Design and Engineering Phase

“In this project, the design team were the main users, that is the architect and consulting engineers. BIM was used for visualization purposes to the owner of the project and its users, yet quite limited compared to other projects.” (Consulting engineer)

“The building information model is made by the design team. They are the ones to draw the model.” (Contractor)

"In organization x, they work simultaneously in a single model. They upload IFC files for each discipline, which is combined in one model." (Contractor)

"We use BIM in the tender" (contractor)

"One of the current main challenges is the fact that the landscaping architects don't use BIM." (Contractor)

Construction Phase

"In this project, all of the design is conducted within the building information model, with the exception of the armature drawings. Some armature drawings are only made in 2D and are not included in the model, while all other installations are included in the model. That is quite common. The work drawings of the contractors are still 2D drawings, which are just a picture of the model" (Contractor)

"BIM is the main tool in the design phase. BIM is also starting to be used more frequently at the construction site. A lot has happened there during the past few years. There are many good tools that can use our model for scheduling, quality control and monitoring on the construction site. Still, it is not about adding additional information to our mode, but about making that information available to other people" (Consulting engineer)

"All design and engineering in our organization is conducted in the building information model and the model is combined for all actors. It is the basis for the work drawings. When it comes to the execution, we use BIM actively in production. We have BIM stations. All actors: carpenters, electricians and so on, can go directly into the model to print or study things." (Consulting engineer)

"BIM is a supplement used to understand the construction drawings." (Contractor)

"Originally, we were not supposed to use paper. The project was supposed to be paperless and have less drawings. That is, the lowest level of digital drawings possible. In the design phase, this has not been an issue, we are completely free of drawings, and that is also the case for the communication with the main contractor. Yet, collaboration with subcontractors has required many drawings. There are three main technical subcontractors, which are a part of the IPD agreement. And there is a large quantity of larger or smaller subcontractors with traditional contracts with the main contractor. There is great variation in the digital maturity level amongst the subcontractors. Some are very good at delivering BIM and others refuse"

"The 2D drawings form the basis for the construction process, and BIM was essentially a tool to understand 2D drawings. The carpenters were probably the ones who used it the most, while the technical used mainly 2D drawings" (Architect)

"A building information model was included in the tender, but it is written very clearly that it is only a guideline. It is a tool but not a contractual demand" (Project manager)

Construction

"It is quite common today to receive 3D models from architects and other actors, but some disciplines are lagging behind. I think that piping and electrical, in general, are lagging behind. I think that ventilation is taking advantage of BIM to a greater extent" (Subcontractor)

"We have BIM-kiosks and iPads on the construction site" (Contractor)

"It varies whether the suppliers use BIM or not. At the construction site and at progress meetings with clients, BIM is used as a visualization tool." (Contractor)

“The construction drawings are handed over to us in 2D. These drawings are the foundation for the construction and what the workers on the construction site receive.” (Contractor)

“By some, BIM is used purely for visualization purposes, where they check the information. Others measures and uses the information for what it is worth.” (Contractor)

“When it comes to the execution of the project, we are still dependent on paper drawings.” (Contractor)

“Originally, we were not supposed to use paper. The project was supposed to be paperless and have less drawings. That is, the lowest level of digital drawings possible. In the design phase, this has not been an issue, we are completely free of drawings, and that is also the case for the communication with the main contractor. Yet, collaboration with subcontractors has required many drawings. There are three main technical subcontractors, which are a part of the IPD agreement. And there is a large quantity of larger or smaller subcontractors with traditional contracts with the main contractor. There is great variation in the digital maturity level amongst the subcontractors. Some are very good at delivering BIM and others refuse” (Architect)

Operational Phase

“We will choose 5 to 10 objects where operational documentation linked to the respective objects will be added to the building information model. [...] The goal is to provide a building information model on the construction for the operational department. If a armature or radiator breaks, one can easily click on the object and find a phone number, if one needs to repair the object or information regarding the type of bulb, instead of navigating through 8000 pages without finding the information of relevance.” (Project manager)

4.1.3 Between Actors/Project Phases

“Except for the largest projects, the vast majority have not included the cost of BIM servers in their budget. The hospitals and health organizations are early movers [...]. Usually, every single discipline work in a separate model, and then these models are distributed as IFC-files between actors at a regular basis. We receive the models from architects, contractors, and the technical disciplines that we are not responsible for. And then we compile them through for example the Solibri tool. In that way we can carry out clash controls and coordination up front. [...] In fact, that is the typical way of doing things today.” (Subcontractor)

“The different disciplines work separately on their own model, then these IFC files are shared between the actors quite frequently.” (Subcontractor)

“At that time, we used Solibri to compile the models in one model. We worked with Solibri on a server and all the model files on the server as well. Thus, if an architect updated the model, he could press update and the whole model would be updated” (Contractor)

“In this project, the models were uploaded regularly on a shared server via IFC. All the project participants were then able to download the model and use it to carry out interface controls. In our organization, we work in the same model, so that when HVAC are modeling ventilation channels and pipes, for example, they have the possibility to see the other constructions without going through IFC” (Consulting engineer)

“We have IFC as a shared platform and use StreamBIM to follow-up. So we exchange IFC files and combine the files into a single model” (Contractor)

“We use BIM for coordination in project meetings and so on. We mainly work in BIM during project meetings. We rarely review 2D drawings” (Project manager)

“We use open BIM and share files as IFC” (Contractor)

"The main design and engineering actors arrange ICE meetings. We use the building information model actively in these meetings" (Contractor)

"Everybody has their own IFC files. We do not have a shared model, but we use separate files for separate disciplines and then we combine them in StreamBIM" (Contractor)

"You cannot work on this project without using BIM. The delivery is IFC, open BIM" (Architect)

"Open BIM, object based geometry" (Architect)

"If we are going to view some issues, we always look to the building information model. You will not find any drawings" (Architect)

"Every discipline modeled alone, then it was compiled in IFC." KH

"There some disciplines that do not implement their files into the building information model. That is something we have to work on, so that every discipline that is supposed to deliver something, deliver this in the model, so that it will be as complete as possible. That will result in a more effective use of the model" (Contractor)

"The model is updated instantaneously. It is a living tool" (Contractor)

4.2 How Do The Elements of The Different Contractual Models Influence the Use of BIM?

4.2.1. Transactional

"The contract governs a tight budget. You obey and your actions are governed by this contract. If you do not follow the details of the contract, you might end up getting law sued. And if the contract is unsuitable for using BIM effectively for interaction, it will not happen." (Subcontractor)

"In general, the contracts within the construction industry enables us to success on the expense of others. Additionally, the opportunity to monetize from mistakes is high." (Contractor)

"Interaction is needed to successfully carry out the design and engineering phase with regards to BIM. It requires more interaction than what DBB facilitates. It [interaction] is a lot easier under DB or Partnering." (Contractor)

DBB

"The fact that we are not involved within the engineering and making the solutions is a disadvantage in that we don't possess control as for when the model is updated. I cannot come up with a single reason for why DBB should be of advantage concerning BIM, except from visualizing it digitally, and have a model. It is not a suitable model for collaboration." (Contractor)

"Collaboration between actors is needed in order to use BIM. Collaboration is difficult when you only are paid for the construction. There is no point for us to get involved with the design and engineering if we don't get paid for it."(Contractor)

DB

«Under DBB we are made responsible for one function and have a higher flexibility in defining the solutions by ourselves […] yet, also more responsibility. We are more dependent on BIM under DBB." (Subcontractor)

"There is not that big of a difference between Design Build and Partnering. If anything, it has to do with the amount of time we have to collaborate prior to the construction phase. The best projects are the ones where the client comes directly to us and the project sketching is made collaboratively." (Contractor)

4.2.2. Relational

"Additionally, we are participating in partnering projects [...]. In this projects, BIM becomes increasingly important for every part involved." (Subcontractor)

"It [the willingness to share information through BIM] will probably increase. I believe that partnering contracts represents the future, where you have an economical incentive to share the information" (Subcontractor)

Most suitable contract for governing information exchange in BIM:

"That has to be the partnering model. [...] This contracting type facilitates [BIM use], and will positively influence our efforts towards BIM." (Subcontractor)

Do you think the incentive scheme was crucial [for using BIM]? "Yes, in the end this if what live off. It is a very tough industry" (Subcontractor).

"A partnering model with an active client and contractor. In such models, it's all about finding good and rational solutions. The client is also more aware of the final delivery. To create good models with the right information, you need to involve the users, clear up all potential changes and adjustment prior to the construction phase. Compared to DBB and DB, I believe that this model offers the highest potential." (Contractor)

"The partnering model. If the delivery method facilitates collaboration and BIM use, we will use it. Additionally, I believe that the choice of delivery method might also influence it – if something is included in the budget or how to use BIM is specified, or a certain amount of resources allocated towards BIM, it will guide the usage. We are highly profit driven. But if something is included in the contract or the contract opens up for innovative solutions, we will do so." (Contractor)

"Under a DB with Partnering we have the opportunity to join forces with the client and define it. The client is not always good at doing such. If we were involved earlier on than under a normal DB, this issue would have been resolved. If the client includes BIM, they only define if BIM should be included or not. But what should we actually use BIM for?" (Contractor)

Partnering

"Partnering is an interesting model. However, it is also quite challenging. You need to collaborate and align interests, while simultaneously having conflicting interests [...]. You cannot be too rigid and not too flexible. You need to be more discretionary. Lack of discretion in the contract represents a challenge, with no guidelines for what is right and wrong. The definition of such is important to make prior to construction start. We still have a long way to go." (Contractor)

" We concluded that partnering contracts in itself is neither beneficial nor limiting [to the BIM use]. [...] There are several other factors than the choice of delivery model [for effective BIM use]." (Architect)

IPD

"IPD prioritizes the project, and is the first delivery method where no actor can succeed on the expense of others. Previously, this has been common within the construction mentality and an embedded part of our mentality. This is quite unfortunately as we would like to succeed together. However, the contracts are formulated after the zero sum principle – I can only win at your expense. Or if I make a profit, it will affect the profit of other project participants negatively. IPD removes this obstacle – there are two outcomes; we all win or lose together." (Contractor)

"In many others, with regards to the BIM use, it doesn't really matter if the model is not sufficiently updated or if it contains conflicting information. In this project, it will however affect the the project as a whole. If the modeling is poor, not sufficiently updated, or if the information shared is wrongful [...] it will negatively influence yourself. [..] Therefore, I believe that IPD has positively influenced the culture needed to successfully use BIM in a project." (Contractor)

"More requirements would have benefited BIM [...] To me, this indicates that we should have been better in formulating the BIM competence within the contracts." (Contractor)

"It requires a new mindset which have been challenging for many to adopt. There are many experienced and competent workers here. Yet, removing the traditional way of working is highly challenging. Even if the traditional way of working includes BIM, it does not necessarily include the VDC concepts, that is the process for a more effective decision making process. This is a challenge." (Architect)

"Under IPD, everyone has to work towards the overall goal of the project, and not only towards their own part of the delivery. [..] This has also affected the BIM use. Everyone will try to put more effort in [BIM]." (Architect)

"In IPD, all parts are made responsible for the final delivery. Following, fewer requirements have been made. The way of organizing has been quite unclear. The collaboration between the designer and engineers and those at the construction site has been beneficial. But who are made responsible for the decision making? [..] To succeArchitectfully carry out a project, good decision making is needed. This [the lack of good decision making] is a definite weakneArchitect [with IPD]. It's not really about the contract itself, rather how the project is carried out due to the lack of experience with IPD." (Architect)

"In IPD, the focus will be on the overall goals made collaboratively. Following, there is no room for variation in the quality of the delivery. Under two party contracts with e.g. a normal firm, these discuArchitections might occur." (Architect)

"IPD fosters collaboration between actors in the design and engineering, and construction phase. However, we need to keep in mind that in order to make good decisions, we need to include the operational phase. The decisions are not always optimal for the operational phase, due to a strict budget governing the project. To stay within the budget, you will either reduce the quality of the materials used or go for solutions which are not optimal for the operational phase. The IPD contract is very good at integrating the phases prior to the operational phase, but does not include an appropriate incentive scheme to create constructions which performs well during the operational phase. If anything, this would have been better if we used a PPP where the incentives also includes the operational phase." (Architect)

4.3. What are the Factors Mediating and Moderating the Influence of Contractual Models on Effective BIM use?

4.3.1. Technology

"The main challenge is that everybody have to use the same tool, or at least tools that are compatible, in order to realize the positive effects of BIM" (Consulting Engineer)

"For us, the issue was technological. Its related to the IT we have in the organization." (Contractor)

"You need to have proper tools. There is no use in having the cheapest computer and so on. You need to make some investments, depending on which programs the different actors use." (Construction Management)

4.3.2. Competence

"I think the main barrier is competence and what you can achieve with that and the understanding of open BIM formats and how you should do that." (Architect)

"It varies a lot. Some are really good, and others do not know what it is." (Architect)

"It varies a lot. If you are referring to BIM competence and how you actually take advantage of it, the difference between open BIM, how you can use IFC-standards and other things for collaboration, or if it is only about using BIM tools." (Subcontractor)

"The big challenges are competence. It always will be. A driver towards that is to allocate enough time and resources to training." (Contractor)

“When it comes to realizing the value from it, the barrier is competence. Primarily. of course in our own organization, but not the least for those who are going to use the result of it.” (Consulting Engineer)

“We learn new things all the time about how large a model should be and how to split it up for it to be useful. [...] If you are going to realize the productivity value from using BIM, you rely on sufficient competence across the entire value chain.” (Consulting Engineer)

“It must be the barrier for the subcontractor. To get more subcontractors to draw in 3D. However, it is limited what you may actually expect from some types of subcontractors. Some subcontractors have small niche tasks, so to expect that they are going to draw in a model is not so easy.” (Contractor)

“It is a combination. One the one hand, you have not been good enough at demanding BIM in the procurement phase. On the other hand, you have been careful to do so, because it excludes many actors from the market, resulting in competition and higher prices.” (Architect)

Barrier for BIM: “It is about competence. Consider the subcontractors. They just do not know what it is." (Architect)

“It is about competence and that people do not understand the poArchitectibilities that BIM provides. And that BIM is often boring, people do not take the time to read through all the pages with the demands, they just agree and think that it will probably be okay. That is not a very good strategy is you are going to make money while your are delivering. It is probably a little more about busineArchitect understanding, that BIM is not just a technical thing, but completely integrated in our delivery and how we make money.” (Architect)

“I think that those who used it saw minuses, but if you do it again, there will probably be more plusses than minuses.” (Contractor)

4.3.3. Mindset

“I think there is a huge potential. To reach this potential I believe that we need to change the way of working.” (Consulting Engineer)

"Much of the benefits an actor realizes from BIM, is based on what others have done, and not what you do yourself. What is important is to make people understand that they have to do something for others. That is, they should include something in the model, for others to gain from it; they will not receive the benefits themselves. To get someone to do something just to help someone else is quite difficult, especially when you are trying to make money." (Consulting Engineer)

"The main challenge is that the contractors are at the forefront [...]. The architects and engineers in our geographical area have started to understand the benefit [of BIM]. However, as with everything new, it is considered risky.” (Contractor)

"It depends on the people. […] If you have the right chemistry or if the people are interested in using it [the building information model] it will flow more easily.” (Construction Management)

“We are perceiving BIM as useful. When the contractor perceives it as useful, it [the use] will automatically increase.” (Contractor)

"It can also depend on the people. If we are in a team where nobody is interested in the realization of BIM, I would say that would show in the quality of the model, because nobody will point out or ask the right questions to those who include things in the model. They will also not be as good at including it in the contract to the subcontractor and that will show in the quality. If we have someone that is very interested in BIM, then he would probably be better at including it in the contracts with subcontractors." (Contractor)

"Our personnel on this project have been quite young. This has been positive for the whole project, in that they handle every task their given with a positive attitude. If you don't have a positive attitude, you will not acquire knowledge." (Contractor)

"[...] however, they acknowledges BIM's usefulness. Following, they used it, even if we didn't push for it." (Contractor)

"Everything relies on the parties playing on the same team. That the whole industry is collaborating. That there is good communication, so that you do not design poor or expensive solutions. That it is coherent throughout the project." (Contractor)

"I am highly interested in digital solutions, and not afraid of using it." (Contractor)

"It's all about the attitude. You will come a long way with the right attitude without being negative." (Contractor)

4.3.4. Relational Procedures

"They have large projects where the whole team is collocated. It is a lot easier then, because you can have one system, as opposed to having one system for us and then maybe another one for the architects." (Contractor)

"The industry needs to understand that in order to get a good model, you need to spend more time in the phases prior to the construction starts. If the project is better designed and engineered, the additional time spent on this can lead to a faster construction phase." (Contractor)

"It is important that everybody sit together so that we can discuss solutions, presentations and direction together. […] It is a benefit that everybody is located in one place, as you are dependent on being located in front of one screen and being collocated, if not one hundred percent of the time, than at least a lot of the time." (Contstruction Management)

"I had a lot of freedom in making decisions and choices independently from him [the manager of the organization]. This freedom, in addition to quick clarifications, are crucial. We have also had a great flexibility in choosing the [BIM] platform. There were few requirements, but it also required that we did our research on the different tools." (Contractor)

"In order to successfully complete this project, we needed collaboration between all engineers to achieve a good BIM model. A key factor was that there was a good communication between the engineers, in order to develop a good BIM model. Frequent engineering meetings led to a more detailed BIM model. If you do not have enough information, you have to look at drawings and you lose information and make mistakes." (Contractor)

4.3.5. Project Resources

"Except for the largest projects, the majority of the projects have not included the cost of BIM servers in their budget." (Subcontractor)

"BIM coordinator is important." (Contractor)

"The BIM ambitions were high, but this project has been governed by its tight budget for a long time. Following, I don't think we have made an additional effort in using BIM on the construction site." (Consulting Engineer)

"It depends on the client. That is, if you have enough time. For this solution, it's about getting compensated for each hour worked. You have a limit of course, but you are paid for what you do. This lowers the level of stress at each individual firm. I think this contributes to the good atmosphere we have in this project. People are willing to take on extra responsibility and take initiative. If you are determined on a fixed price, you increase the stress level." (Architect)

"Using a BIM coordinator and getting the architects and engineers to include information in BIM exceeding what we had originally, is a question related to the budget of the project." (Contractor)

“You need a BIM coordinator. The BIM coordinator makes it cheaper by simplifying the tasks and coordinating all of the BIM files and units. As such, keeping everything updating in the project.” (Contractor)

4.3.6. Demands and Guidelines

“Setting demands to the modelling is important.” (Contractor)

“Neither this or the previous contract demanded that you should use BIM. It is not any guidelines on it either.” (Contractor)

“It is a combination. On the one side, you have not been good enough at demanding BIM in the procurement phase. On the other side, you have been careful to do that, because you see that by doing so you exclude many from the market, thus you get less competition and higher prices.” (Architect)

“There is no doubt that there are actors, such as Client x, which has gone in the forefront, saying that you cannot be in our project unless you can deliver. That has resulted in many engineers and architects that has turned around and started using it. Eventually they have embraced it and understood the value of it. The same needs to happen for the subcontractors. The subcontractors still have many drawings, incredibly many. You have not budgeted for that, so that has been a challenge.” (Architect)

“You need to carry forward the level that the client demands from oss. We have to carry that forward in the contracts we enter with our subcontractors.” (Contractor)

“Organization x has been a pioneer for digital development of the AEC industry. They have demanded [BIM] from us.” (Contractor)

“The client need to be active in setting requirements within the spec or in the execution of the construction process and the use of BIM. Everything is dependent on a demanding client.” (Contractor)

“The contracts as they are formulated today; 8401/8402, 8407 the design-build contracts, and 8405 which is the contract with the contractor, none of these contracts regulate the exchange such that it is beneficial to work digitally. It gets complicated when none of the contracts regulate it. The contracts are not suitable for a digital future.” (Consulting Engineer)

“It is a combination. On the one side, you have not been good enough at demanding BIM in the procurement phase. On the other side, you have been careful to do that, because you see that by doing so you exclude many from the market, thus you get less competition and higher prices." (Architect)

“It is pretty rare today that the contract refers to the BIM-model. We have the old contractual models, which only refer to some specifications and drawings, and this what is contractually binding. It does not help to have a great BIM-model, which you are not certain refers to the exactly same thing.” (Subcontractor)

“You also need to remove the barriers related to the contracts and how the different players in the industry actually makes money.” (Consulting Engineer)

“Neither this or the previous contract demanded that you should use BIM. It is not any guidelines on it either. That is the next step. How should you introduce BIM as a part of the contract?” (Contractor)

“Here are the 3D drawings [on paper], but they are quite inaccurate and not comparable to the model drawings [in BIM]. [...] They are very bad in displaying the details [..]. It would have been invaluable for us if this could have been replaced with an accurate and reliable model [...] Getting more info is a major advantage for us. I am certain in that we could have incurred in lower costs and less risks.” (Contractor)

“When making demands in a contract, the quality will automatically increase.” (Contractor)

“BIM is not a part of the contract, and not something we can refer to.” (Contractor)

4.3.7. Ambiguity

“It’s mainly about handling the risk. [...] Are the available information within the building information model reliable? To have a building information model is easy, but you need to assure that the quality of the model is sufficient enough to actually use it [for construction], which I don’t always think is the case.” (Subcontractor)

“The contracts seldomly refers to BIM. The old contractual models only refers to some specifications and [2D] drawings, which becomes contractually binding. Even if you have a good BIM model, you cannot use it, if you are not 100% sure that it displays the exact same details [as what is specified within the contracts.” (Subcontractor)

"We often use the same terms, but talk about different things when it comes to BIM competence. […] It is not enough to write in an offer that you know BIM. Because what is BIM? It’s a whole world of practices. It’s about how good you are at modelling, what information you include, and so on." (Contractor)

“In the bidding papers, 4D and 5D was included, [...] all the way up to 8D. There is a consensus in the industry around the meaning of 4D and 5D. [...] but what do we mean by 6D, 7D, 8D and even if you know what this means, there are several available methods. How should we then do it [BIM]?” (Contractor)

“What should be included in the model and why?” (Contractor)

“The main challenges are [...] new ways of working. It is about stitching together a new project management system. Are you going to send an email or make an issue in the issue-system? Are you going to take the conversation over the desk because you are collocated? Or is that too informal for that exact decision? Should I just make changes to the model and upload?” (Contractor)

“As a contractor, we have a differing perspective from the design and engineering team. It needs to be useable for us in the construction phase. [..] Clarifications needs to be made, that is the choice of platform and that everyone speaks the same language.” (Contractor)

“This is the challenge of BIM. There are very different perceptions of what is needed, what is necessary and what open BIM means. That everything is supposed to be modelled in BIM is undefined. For example, on this project we have external electro, which is not common to make in models. Yet we interpret all engineering to include external electro. But we will not have that, because others do not regard that to be included.”(Contractor)

“The challenge is to make the owner understand how much information is sensible to include in the model […] What will be the benefit of making a good model? There is no need to make more than we need either. […] Where is the boundary between what is rational to include in a model? How detailed is it actually going to be.” (Contractor)

“But then we have the definition of BIM. What should be included modelled in BIM and not, and the BIM maturity level?” (Contractor)

“There has been varying interpretations in terms of how you should use BIM.” (Contractor)

4.4. Summary of Findings

“When you have a good partnering contract you actually have to do your best to collaborate effectively” (Subcontractor)

"To sum up, BIM is a very good tool independent of the delivery model, but it is easier to gain control over the information you need if you have a design-build or partnering delivery model. Except if the client in a design-bid-build is very advanced. It is up to the client what you get." (Contractor)

"When we have to make drawings because the market is immature, it reduces the profit of the project. It affects everybody, architects, contractors and consultants, even though they are competent in using BIM. In an IPD contract, everybody is exposed to the costs of the weakest link. In this project it was, among others, the subcontractors who could not use BIM. That is a challenge. You have not taken that into account to a sufficient degree in this project, how immature the subcontractor and supplier market was." (Architect)

"I do not think that we are limited by the contracts. It is more about learning how to work under this type of contract [relational contract]. If I should add something, it is the competence, team and process development within this type of contractual model" (Architect)

"It should be mentioned that this project is a design-bid-build, which is the opposite of an IPD. Every specialization has their own contract. In principle, this should open up for a lot of disputes regarding what to deliver and what not to deliver. I just do not see this. There is a really good atmosphere - people are supportive and communicate well. We also have some very skilled project managers. I think this helps a lot, but I think it depends on the people. That there are many people who take initiative and have the right attitude. People that do not just try to deliver the minimum." (Architect)

"If you are going to spend less time in the construction phase, you have to spend more time in the planning phase. In this project, you tried to cut both. It is not only the contractor, engineers and consultants. It is also the client who has underestimated how difficult it would be to get a large team to work in a completely new way. BIM is in place, it was more about the process of using BIM in decision making. That was a challenge." (Architect)