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BIM Coordination practices in the Swedish AEC Industry

With focus on procurement strategies, information management and BIM Execution Plans

Master's Thesis in the Master's Programme
Design and Construction Project Management

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Abstract

BIM (Building Information Modelling) is one of the latest developments in the construction industry which introduced new technology and practices to improve performance of projects. However, this may not be achieved if BIM technology and practices are not implemented effectively. For effective implementation of BIM technology and practices, it is important to have well organized BIM coordination in projects.

Organization and management of BIM coordination in projects is affected by the choice of procurement strategy. Although, integrated procurement has been considered as best fit for BIM projects, it is not applicable to various local markets. In Sweden, Design-Build and Design-Bid-Build are the main procurement strategies in projects where BIM is implemented. In both procurement routes, project BIM coordination can have either a centralized or decentralized structure on large and small sized projects respectively. In a centralized structure, usually either one of the design consultancy and contractor parties or third-party BIM consultant company manages project BIM coordination. In decentralized BIM coordination, parties manage BIM coordination between themselves without involvement of a managing party.

Another important characteristic of successful BIM coordination is to have well-coordinated information workflows, including process information which refers to discussions and decisions made during coordination meetings. It is important to store and communicate the process information in effective and efficient ways. Since current BIM tools are lacking these features, Common Data Environment Solutions are implemented in parallel with BIM tools to solve this problem.

For attaining effective BIM coordination processes, many countries implement BIM execution plans (BEPs). BEP is an important project document which links the project coordination and BIM coordination processes. Therefore, it is important to have some standard BEPs in companies operating in similar projects to prevent inconsistencies. In Swedish AEC industry, there is a lack of standard BEPs, and it causes less efficient and inconsistent BIM coordination practices. Therefore, there is a need for national BIM guidelines for preparation of consistent and proper BIM execution plans which in turn would lead to have more efficient and standard BIM coordination practices.

Notations

AEC – Architecture, Engineering and Construction
BCF – BIM Collaboration format
BEP – BIM Execution Plan
BIM – Building and Information Modelling
BIP – Building Information Properties
CAD – Computer-aided Design
CE – Concurrent Engineering
CDE – Common Data Environment
DB – Design-Build
DBB – Design-Bid-Build
HVAC – Heating, ventilation, and air conditioning
ICE – Integrated Concurrent Engineering
IFC – Industry Foundation Classes
IPD – Integrated Project Delivery
LOD – Level of Development
MEP – Mechanical, Electrical and Plumbing
NWD – Navisworks file format
SMC – Solibri Model Checker
VDC – Virtual Design and Construction

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1 Introduction

This chapter aims to provide some information about purpose and aim of the master thesis and introduces the main scopes of the study. Furthermore, in this chapter the main research questions, and the limitations of the study are presented.

1.1 Background

In Architecture Engineering and Construction (AEC) industry projects get larger, more complex and thereby increase risks. It forces building owners, main contractors and engineering consultants to focus on improved processes related to professional management of projects, increased interaction between the project actors, and increased exploitation of available and innovative technology (Mejlænder-Larsen, 2018).

Since resources are becoming scarcer, and globalization continues to open up exciting opportunities, while at the same time increasing the level of risks and complexities, the importance of inter-organizational collaboration increases. Nowadays it is required to have a diversity of knowledge, skills, philosophies, and practices to address problems in collaborative ways, where once upon a time the aim was to ensure team members were as similar as possible (Clegg, 2015).

In order to have a better performance in a construction project, not only a function of the expertise of individuals but also their full collaboration as a team is needed. As the projects in the AEC industry involve tasks that are interdependent on each other, it requires more interaction in terms of communication and coordination among the project team participants (Garcia et al., 2004). The coordination and integration aspects across the multiple disciplines have a significant impact on the outcome of projects (Tamblyn et al., 2018).

Building Information Modeling (BIM) is one of the most promising developments in the AEC industry and it helps to construct one or more accurate virtual models of a building digitally. An accurate building model benefits all members of the project team (owners, architects, engineers, contractors, subcontractors, and suppliers) by allowing for a smoother and better-planned construction process and reducing the potential for errors and conflicts (Eastman et al., 2011).

In order to implement BIM technology and processes effectively it is important to have well-managed BIM coordination processes. The choice of procurement strategy, BIM information management and BIM Execution Plans (BEP) are important BIM coordination aspects and affect BIM coordination process from different perspectives: the choice of procurement strategy defines who will coordinate BIM in projects, information management defines how different solutions facilitate BIM coordination process and BEPs support to have standardized coordination process for strategic BIM implementation.

As mentioned above, one of the most important factors that affects the coordination processes is procurement structure of the projects. There have been few studies conducted that look into different procurement strategies in relation to BIM coordination. Although according to those studies integrated procurement has been considered as best fit for BIM projects, it is not applicable to various local markets (Aibinu and Papadonikolaki, 2016). Therefore, this study will focus on how BIM coordination is organized and managed mainly in Design-Build and Design-Bid-Build procurement strategies.

Communication and collaboration are considered to be the main two pillars for successful implementation of BIM (Azhar et al., 2012). The introduction of BIM in projects increased the need for a lot of specialist knowledge and technical information. When there is a lot of volume of technical information, it is required to have well-coordinated information workflows (Hooper and Ekholm, 2010). Although, BIM helps to store and represent the information related to models, it lacks the features to capture information which related to coordination processes (Wang et al., 2015). There have been many studies that discussed BIM's capabilities and its support to overall project coordination, but there have been few studies that look into different information management solutions that support BIM coordination process. Therefore, this study will look into the use of different solutions for effective BIM coordination process.

BIM execution plans (BEP) are implemented in many countries for attaining effective BIM coordination processes. However, it is important to have some guidelines for preparation of BEPs by companies operating in same projects, because when everyone prepares BEPs in their own way, this can lead inconsistencies in achieving desired project goals (Hardin and McCool, 2015). However, according to different studies (Hooper, 2012; Hooper, 2015) carried out in Sweden, there is lack of standard and comprehensive BEPs in Swedish AEC projects. Therefore, this study investigates how current BIM delivery plans are prepared and used in Swedish AEC companies, and how BIM coordination can be improved with the help of BEPs.

1.2 Purpose and Project aim

The purpose of this study is to analyze BIM coordination processes in different procurement routes, mainly Design-Build and Design-Bid-Build, to explore current information management in projects as part of BIM workflows and investigate the potential advantages of implementing BIM execution plans in Sweden.

By studying and evaluating recent literatures available for BIM coordination processes, this study compares the findings with the current practices in Sweden. Current practices are studied by conducting interviews with firms operating in the Swedish AEC industry which already have long experience with applying BIM technologies in their projects.

Furthermore, the authors try to compare current company-based BIM delivery plans in Sweden with BIM execution plans which exist in other countries and make recommendations how BIM delivery plans should be improved for better BIM coordination.

1.3 Research Questions

In order to fulfil the major goal and clarify the areas that are intended to cover in this master thesis, the authors have defined the following questions to address:

1) How is BIM coordination organized in different procurement strategies (mainly DB, DBB)?
2) How is current BIM information management performed in projects?
3) How can BIM coordination in Sweden be improved with the help of BIM execution plans (BEPs)?

1.4 Delimitations

One of the limitations of the study is that the practices (included in the empirical data that collected from companies) are applicable to mainly Swedish AEC industry, not internationally. Since the interviews are made with eight companies that have a good reputation in the construction industry, some practices might not be applicable to other companies. Furthermore, this study is more concerned with building construction projects, while some information might be applicable to infrastructure projects as well.

Although some of the interviews are made with contractor company representatives, BIM coordination processes discussed in the study mainly cover the design stage.

The procurement routes are analyzed particularly from a BIM coordination perspective only. Besides, mainly Design-Build and Design-Bid-Build procurement routes are discussed in this study.

1.5 Thesis Structure

As the figure 1 below shows, there are six chapters in this thesis. Chapter one is introduction which includes background, purpose and project aim, research questions, and limitations of the study. Chapter two is literature study which provides the readers with the theoretical understanding of the main concepts. Chapter three explains the methodologies that are used for conducting this study. Chapter four presents the collected empirical data that is used for testing the theories. Chapter five is presenting the analysis of empirical data with the help of theories from the literature study. And finally, chapter six is concluding the findings of the study and provides recommendations for future research.

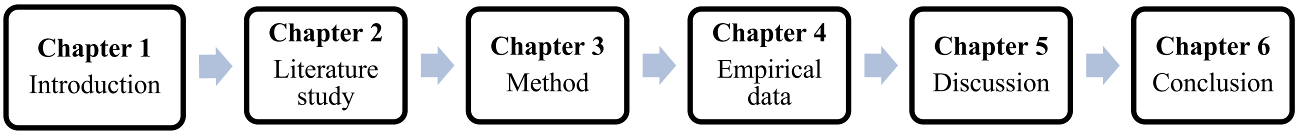

Figure 1: Thesis Structure

2 Literature review

This chapter is aimed to provide a theoretical understanding of the main concepts related to the area of study and theories that are used in the analysis and discussion of empirical data. Firstly, the main BIM concepts are introduced including the BIM roles and the responsibilities. Secondly, procurement strategies are briefly explained with more focus on two of them (DB and DBB), and the role of those strategies on BIM implementation in projects are elaborated. Thirdly, managing information and communication flows in relation with BIM are discussed, and finally, the concept of BIM Execution plan is presented as a main project document to be used for achieving more effective and standard BIM practices in projects.

2.1 Building Information Modelling.

2.1.1 The concept of BIM

The introduction of lean processes and digital modelling have been considered as a revolution in Architecture, engineering and construction (AEC) industry, which required both process changes and paradigm shift from 2D-based documentation to digital and collaborative workflow (Eastman et al., 2011).

According to Czmocha and PĊkala (2014), the abbreviation BIM can be understood in two ways: either as Building Information Modelling or Building Information Management. By providing a basis for design and construction and introducing changes in the roles and relationships among a project team, BIM supports many functions which are useful for modeling the lifecycle of a building. It facilitates the integration of design and construction process, which allows to deliver buildings with better quality, lower cost and reduced project duration (Lu et al., 2013).

BIM facilitates not only design process but also the construction process in conjunction with a digital documentation workflow. It provides the project staff both in design and construction stages with a better way of working and many tools that were not available before. BIM means not only using three-dimensional intelligent models but also making significant changes in the workflow and project delivery processes (Hardin and McCool, 2015).

According to Czmocha and PCkala (2014), there can be some difficulties of implementing BIM technology and practices in organizations, which include high-implementation cost, training of the staff, incomplete or inaccurate model production, lack of legal regulations and incompatibility between different partners.

2.1.2 Virtual Design and Construction (VDC)

The term Building Information Modelling (BIM) was introduced by Autodesk a long-time ago, whereas the term Virtual Design and Construction (VDC) was used first time in 2001 at the Center for Integrated Facility Engineering (CIFE) at Stanford University (Kunz and Fischer, 2012). However, both of these terms are used to explain the implementation process of parametric CAD models for analysis of design and construction (Olofsson et al., 2007).

Virtual design and construction -VDC is a process including BIM as part of work process. While, BIM more focuses on the VDC model elements. In other words, having VDC without BIM is impossible (Kunz and Fischer, 2012).

The Virtual Design and Construction approach defines project models based on integrated POP- models including Product, Organization and Process, which helps the designers and contractors to build an integrated multidisciplinary project design concurrently for fast delivery (Garcia et al., 2004).The representation is Product-represent the design of the product to be constructed, Organization- represent the design of organization which execute design and construction, and Process- represent the execution procedures that the organization follows (Kunz and Fischer, 2012).

2.1.3 Levels of Development (LOD)

It is very important in BIM modelling, to make sure to understand the degree of information required for the elements in the model. According to Hjelseth (2015), it is necessary to set same level of development in different disciplines for achieving successful multidisciplinary BIM coordination.

The Level of Development (LOD) is the level that is usually defined by project members as important and satisfactory for the properties and geometry to be included in BIM models (Nawari, 2018). According to Solihin and Eastman (2015), LOD is a specification that supports BIM process by articulating with clarity the content and reliability of models.

There are different Levels of Development depending on different levels of geometry and properties (Table 1). During different phases of project objects and features may have different LODs (Solihin and Eastman, 2015). For example, it is possible to develop models with high level of geometry without having much properties information (Grytting et al., 2017; BIMforum, 2016).

Table 1: Levels of development (Grytting et al., 2017; BIMforum, 2016).

LoD100	Approximately information, often generic representation. Seldom geometry.
LoD200	Approximately geometry as a system or element with size, form and location.
LoD300	Element represented as a specific system or object with size, form, location and amount.
LoD350:	As 300, including interface with other building elements. Example: *Assembly plate between columns and foundation*
LoD400:	The element is modelled sufficient to exact production as bases for fabrication.
LoD500:	The element gives an exact picture of the real element. As built.

2.1.4 BIM Maturity levels

Succar and Kassem (2016) have introduced BIM implementation as a three-phased approach separating organization’s readiness to adopt; capability to perform; and its performance maturity. The term of readiness here encompasses organization’s level of preparation, potential to participate and capacity to innovate. Capability refers to technological, process and policy topics and represents organization’s minimum ability to deliver a measurable outcome. Maturity represents the level of maturely of BIM implemented throughout an organization.

The Figure 2 describes different levels of BIM Maturity:

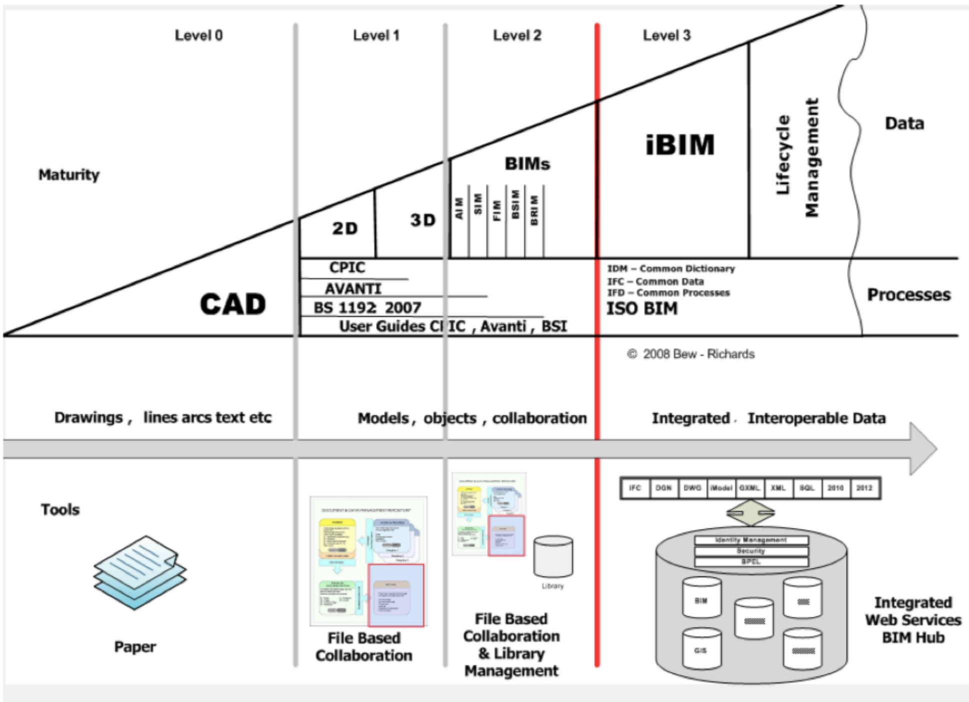

Figure 2: BIM maturity levels (BIM Industry Working Group., 2011)

Level 0 – main data exchange is through 2D CAD (unmanaged) printed papers;

Level 1 – Common Data Environment (CDE) solutions are used as a collaboration tool for exchange of data in 2 or 3D CAD (managed) format possibly some standard data structures and formats. There are separate finance and cost management packages for management of commercial data.

Level 2 – Separate disciplines have BIM tools with attached data in 3D environment (managed), while 4D Programme data and 5D cost elements may also be used. ERP (Enterprise Resource Planning) tools are used to manage commercial data. There is middleware called pBIM for referring integration of proprietary interfaces.

Level 3 – IFC/IFD is utilized for data integration in fully open process and BIM is managed by a collaborative model server. There are concurrent engineering practices applied and this level is regarded as IBIM or integrated BIM.

2.1.5 BIM Roles

According to Davies et al. (2017), it is becoming increasingly evident that BIM is not just about software solution or technology upgrade, but it also involves process change and change management. From a project collaboration perspective there are two main categories of BIM roles: an over-arching project management and coordination role; a second tier of specialist managers or BIM coordinators from different design disciplines and construction team.

As one of the seven core elements of BIM execution plan framework suggested by Lin et al. (2016), 'Development of BIM implementation team", it is important to identify a suitable team including people with different BIM roles and from different disciplines for effective utilization of BIM.

The research carried out by Bosch-Sijtsema et al. (2019) based on recent studies suggest mainly three roles as BIM actors: BIM manager, BIM coordinator, and BIM modeler.

BIM Manager Role: According to Davies et al. (2017) responsibilities of project BIM manager role include the development and delivery of the BIM execution plan, and establishing BIM protocols for the project, organizing BIM project meetings and managing project records. Barison and Santos (2010) present the main task of the role BIM Manager as managing people in the implementation and/or maintenance of the BIM process. BIM managers should prepare a plan to meet the requirements and desires of clients as well as competences of the project team and resource availability.

BIM Coordinator Role: The role and responsibilities of BIM coordinators are not consistent in different BIM studies and there are differences based on some factors, for example, the BIM maturity of the organizations, project size, etc. Davies et al. (2017) classifies the role and responsibilities of BIM coordinators into three different perspectives: technical, process and people (Table 2).

Table 2: BIM Coordinator role responsibilities (Davies et al., 2017, p.193)

<table>
<tr><td rowspan="5">BIM Coordinator Role</td><td>Technical</td><td>Process</td><td>People</td></tr>
<tr><td>Carrying out clash detection & providing clash reports</td><td>Providing guidelines for discipline team on agreed project rules;</td><td>Being team contact person in matters connected with BIM</td></tr>
<tr><td rowspan="3">Ensuring functionality of team contribution to merged models/ integration of design models</td><td>Contributing to keeping BIM Execution Plan up-to-date;</td><td>Managing discipline-based quality assurance</td></tr>
<tr><td>Managing discipline-based quality assurance, formulation of BIM reports & data management</td><td>Allocating and coordinating BIM tasks within own discipline</td></tr>
<tr><td>Ensuring discipline model complies with BIM Execution Plan</td><td>Representing team at interdisciplinary model co-ordination meetings</td></tr>
</table>

Although, these responsibilities are similar with other BIM studies (Jacobsson and Merschbrock, 2018; Kreider and Messner, 2013; Wang and Leite, 2014), there are some other literature studies that separate discipline-based coordination responsibilities from interdisciplinary coordination. Discipline based role responsibilities are assigned to the role of Discipline BIM Coordinators or Model Managers (Barison and Santos, 2010).

Furthermore, BIM coordinators are also responsible for leading coordination meetings, where people from different disciplines are involved to discuss clashes and other issues with models (Wang and Leite, 2014).

BIM Modeler Role: The BIM Modeller role is named in different ways including model author, BIM operator, BIM user or BIM technician (Davies et al., 2017). However, the typical responsibilities of this role are similar to different literature (Barison and Santos, 2010; Davies et al., 2017) and include authoring the model and taking responsibility for that, production & modification of information in discipline- specific model, etc.

As represented in the section above about roles, one of the responsibilities of BIM coordinators is leading BIM coordination meetings. Despite the several benefits of BIM mentioned in above sections, Wang and Leite (2015) remark that BIM models cannot help to record process information properly, which includes discussions and decisions made during design coordination meetings. There has been little discussion about the possibilities of capturing and representing process information in a computer-interpretable manner.

Therefore, recently cloud technologies have been more popular to be utilized as a facilitator to building information modeling process in AEC industry (Alreshidi et al., 2015). Since most of today's BIM software's solutions lack the features of providing direct accessibility and integration, common data environment solutions (CDE) close this gap and adds management functionality into standard BIM tools (Preidel et al., 2017).

2.2 Procurement Strategies

According to Potts and Ankrah (2014), project procurement strategy defines the overall project management requirements, the employment of consultants and contractors, the allocation of risk between them, and overall design strategy. The term procurement strategy may be referred as delivery method (Hardin and McCool, 2015), organizational method (Potts and Ankrah, 2014), contracting type (Borg, 2010), procurement approach (Jamil and Fathi, 2019) in different literature. The procurement strategy supports the coordination activities throughout the project, by setting an environment which facilitates concurrent interactions among project members (Aibinu and Papadonikolaki, 2016).

There are many types of procurement strategies: Design-Bid-Build, Design-Build, Integrated Project Delivery, Performance-based contracts, Public-private partnerships, etc. However, two main groups of procurement strategies in Swedish construction sector are Design-Bid-Build and Design-Build procurement (Borg, 2010). According to Borg and Lind (2014) the main difference between DBB contracts and DB contracts is: in the first the client takes responsibility for the design while in the second the responsibility lies with the contractor.

Design-Bid Build: Design-Bid-Build (DBB) strategy is also called traditional method of procurement in some literature. In projects with DBB strategy, client assigns team of consultants to undertake detailed design. Then contractor is awarded based on tender (usually the lowest price) which takes care of the construction process (Potts and Ankrah, 2014). Hardin and McCool (2015) describes DBB strategy as a linear process since there is no overlap of the design and construction stages. The Figure 3 below describes the structure of DBB method:

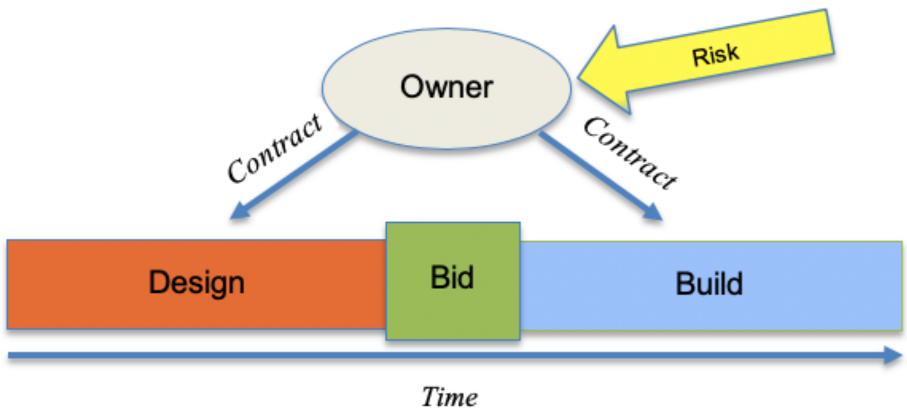

Figure 3: Design-Bid Build Strategy (Hardin and McCool ,2015, p.48)

Design and Build: According to Potts and Ankrah (2014) in Design-Build strategy the client enters into a single contractual relationship with the contractor who takes overall responsibility for both design and construction. Borg (2010) states that main goal of DB contracts has been to give the contractor flexibility of doing the detailed design, choosing working procedures and building techniques and materials they prefer, and build the facility with better quality. In DB procurement, the contractor-client relationship has been extended from the DBB contract and it allows to have cooperation and efficiency in the construction sector. Hardin and McCool (2015) state that DB procurement is one of the best methods which stimulates collaboration between contractors and consultants because they work as a team and their services overlap completely. The Figure 4 below describes the structure of DB method:

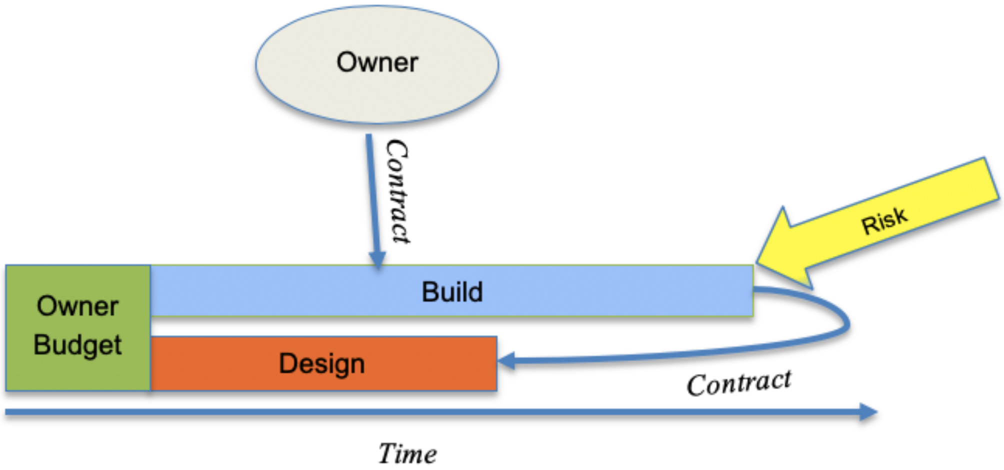

Figure 4: Design-Build Strategy (Based on Hardin and McCool ,2015, p.56)

2.2.1 BIM and Procurement Strategies

All project life-cycle stages starting from feasibility studies until demolition are affected by the implementation of BIM, though the role of the procurement on BIM implementation is underestimated. When considering BIM and procurement strategies together, not only the role of the choice of procurement on BIM implementation should be taken into account, but also the opportunities of BIM for revolutionizing procurement should be considered (Holzer, 2015).

Many studies recommend construction industry to move toward Integrated Project Delivery (IPD), but few identify that IPD as the ultimate objective of construction project delivery method strongly demands closer collaboration and more effective communication (Eastman et al. 2011). Although integrated procurement has been considered to be best fit for BIM implemented projects, it is not applicable to many local markets (Aibinu and Papadonikolaki, 2016).

There have been some studies which focus on BIM coordination in Integration Project Delivery (IPD) projects, few studies primarily focused on BIM coordination process in either DB or DBB procurement routes except the study carried out by Aibinu and Papadonikolaki (2016).

BIM in Design-Bid-Build Procurement: According to Hardin and McCool (2015), since the contractors are not engaged in the design phase in DBB procurement, the potential benefits of BIM for the success of the projects decreased. Holzer (2015) lists some of the drawbacks of the DBB approach from the perspective of BIM: (1) there is a disconnection between design party and contractor models; (2) design and construction stages can have separate BIM Management Plans; (3) BIM requirements set by contractors cannot always be perceived by designers in a way as it is expected; (4) use of models for precise quantity surveying and tendering purposes are not guaranteed;(5) when delivering models, designers may be worried about their professional indemnity; (6) contractors cannot always acquire necessary information from models; (7) there is little consideration about operational needs when models are created. However, BIM still can add value to DBB by allowing contractors: to coordinate with subcontractors more efficiently; to prefabricate the building systems using models; carry out initial estimation with help of models, etc. (Hardin and McCool, 2015).

BIM in Design-Build Procurement: Hardin and McCool (2015) states that the DB approach creates opportunity to fully leverage BIM technology and practices. In DB procurement, designers can create more constructible BIM models which may have two aims: (1) eliminate doubling of work between engineers and subcontractors; (2) allow the team to be proactive with issues.

According to Holzer (2015), in DB projects the models are created more accurately by consultants since they know that models will be used for high precision tendering and other knowledge transfer purposes. The typical benefits of DB approach from the perspective of BIM are: (1) design consultants can consider construction BIM requirements when creating the models; (2) there is more information flow between consultants & trade-contractors in construction documentation (3) it is contractor's responsibility to maximize knowledge transfer of BIM; (4) contractors are required to have enough understanding of BIM workflows.

2.2.2 Centralized and Decentralized BIM Coordination

According to Aibinu and Papadonikolaki (2016), BIM coordination in DB projects can be centralized (Case A, Figure 5) and decentralized (Case B, Figure 5). In centralized BIM coordination, the contractor is hiring a BIM consultant firm and consultants work under supervision of BIM consultant. However, in decentralized BIM coordination is managed without involving another party, between contractor, consultants and suppliers although the project management was centralized and held by the contractor. There are usually high- quality standards in centralized BIM coordination from the BIM consultant firms that may be challenging in decentralized BIM approaches.

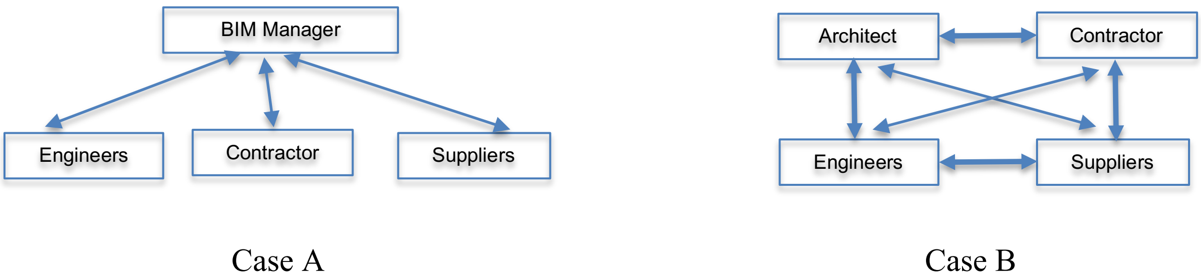

Figure 5: Project Procurement in DB (Based on Aibinu and Papadonikolaki, 2016, page 20)

2.3 BIM Information Management

According to Jacobsson and Merschbrock (2018), one of the main parts of BIM coordination is managing information and communication flows in projects. Hardin and McCool (2015) explain the choice of different communication modes usually depends on purpose of communication and desired clarity of information. When there's little chance of misinterpretation of information emails are more effective and efficient to use, while physical meetings are better when there is more chance for confusion regarding the information.

As mentioned in section above about roles, one of the responsibilities of BIM coordinators is leading coordination meetings. According to Kerosuo et al. (2015), in coordination meetings not only the representatives from different design disciplines, but also project developers, supervisors and contractor party representatives are coming together to discuss current status of works and raise practical matters for collaborative problem-solving.

One other type of meetings recommended with introduction of BIM in AEC industry is Integrated Concurrent Engineering (ICE) meetings (Fundli and Drevland, 2014). ICE approach helps to increase the pace of conceptual design by gathering all relevant personnel to carry out focused, collaborative one-week design studies. It is meant to eliminate all physical and organizational boundaries to communication so it took some days to complete the design tasks which otherwise may take months or years (Avnet and Weigel, 2010). According to Chachere (2009), in comparison to traditional methods, ICE achieves extraordinarily rapid design with a quality similar to or surpassing and a lower cost. ICE uses include: a singularly rapid combination of expert designers; advanced modelling, visualization and analysis tools; a set of consistent social processes, and a specialized design facility; to create preliminary designs for complex systems.

When discussing meetings, it worth to mention the fact by Wang et al. (2015) that BIM models do not support recording process information properly, which includes discussions and decisions made during design coordination meetings. According to Preidel et al. (2017) integration of Common Data Environment Solutions (CDE) with standard BIM authoring tools will provide solution for that problem.

2.3.1 Common Data Environment Solutions (CDE)

According to Sawhney et al. (2017), the idea of CDE was initially proposed in BS 1192 (British Standards Institute, 2007) and PAS1192 (British Standards Institute, 2013). CDE is a single information centre for any given project, which is utilized for collecting, managing and disseminating all relevant approved project documents. Preidel et al. (2017) defines CDE as a common digital project space which provides specialized access areas for different project stakeholders with clear status definitions and a robust workflow description for sharing and approval processes.

CDE solutions support the implementation of BIM both from a technological as well as process perspective. By centralizing all the project information, CDE minimizes risks of data redundancy and provides access to the up to date data at any time, leads higher rate of reusability information and simplifies the aggregation of model information (Preidel et al., 2017).

There are several benefits of CDE solutions: decreasing the time and effort for to checking, versioning and reissuing information; obtaining the latest approved data from the common platform; decreasing the need for coordination checks; reusing the information to support construction planning, estimating, cost planning, facilities management, and many other downstream activities; decreasing the time and cost of producing coordinated information (Boxall, 2015; Sawhney et al., 2017).

Aibinu and Papadonikolaki (2016) highlights the use of CDE solutions in association with centralized BIM coordination where everything is more structured.

2.3.2 Interoperability

According to Eastman et al. (2011), interoperability is the ability to exchange data in order to get well-organized workflow and overall system. Furthermore, interoperability reduces the need of traditional transfer of data that leads to errors and data inconsistency problems. According to Santos (2009), interoperability is one of the pillars of BIM and a key term for capability of the exchange of information among professionals. Participant parties including architects, structural engineers, MEP (Mechanical, Electrical and Plumbing) engineers, and contractors ought to be able to access to modify and update the data which created by others discipline. Therefore, interoperability is an important factor to ensure successful implementation of BIM.

Common exchange formats

According to Eastman et al. (2011), while the size of the project grows, the project files usually get more sophisticated. The need of effective workflows and suitable system of documentation also increase. Consequently, use of IFC (Industry Foundation Classes) or BCF (BIM Collaboration format) are initiated. In addition, some other less recognized standards also available in the industry.

IFC- Industry Foundation Classes: according to Eastman et al. (2011), IFC is the 'only public, non-proprietary and well-developed data model for buildings and architecture existing today'. Interestingly, IFC is accessible in many BIM software to prevent inconsistent collaboration among professionals. Furthermore, Santos (2009) summarizes that IFC is most mature technology and that helps to well-organized collaboration among disciplines with respect to their specialized software. It is best option to accomplish interoperability both at design and construction phase as well.

BCF-BIM Collaboration format: Eastman et al. (2011) defines BCF as open file format which allows additional features including textual comments to provide a much-improved workflow as well as the size of file. In simple word, it is 'the younger brother of IFC'.

2.4 BIM Execution plans

A BIM execution plan (BEP) is broadly accepted project document which provides general guidance and consistent workflow for BIM utilized projects (Wu et al., 2014; McArthur and Sun, 2015). Many scholars and organizations have defined the BEP, according to Sawhney et al. (2017: p20):

"The BIM Execution Plan is a crucial document as it helps to link the BIM implementation on the project with the overall project management plan. It documents the processes and procedures required to achieve BIM objectives that ultimately allow the accomplishment of project objectives".

The BEP describes how is BIM monitored, executed and controlled in projects. The detailed plan includes main information and data management plan, model creation roles and responsibilities, etc.(Bloomberg et al., 2012).Wu et al. (2014) further explain BEP as a standard document in all BIM projects which mainly provide general guidance in the preliminary planning, design and construction periods and stay as main reference throughout construction phase as well.

The main objective of the BEP is, along with technical and administrative BIM guidelines, to provide an outline that will help all the parties which involved to implement BIM technology to reduce design and coordination problems regarding BIM (Bloomberg et al., 2012).

According to McArthur and Sun (2015), a well detailed BEP should consider the needs of all stakeholders.

Hardin and McCool (2015) state that the BEP is different than the governing legal contracts (DBB, DB, IPD, etc.) and BIM addenda. It includes participant parties' goals and objective of the project in addition with instructions for executing BIM as a tool and as process. BEP provides a framework for the project procurement strategy and guide to pick the needs of procurement (Bloomberg et al., 2012).

2.4.1 History of the BIM Execution Plans

The first BIM execution plan templates were introduced around 2007, including Penn State BIM Project Execution Planning Guide and the Autodesk Communication Specification templates. The main target of these templates was to fill the need for a standardized document which helps parties to collaborate, discuss goals and define the use of BIM at the beginning of the BIM boom (Hardin and McCool, 2015). Based on Hooper and Ekholm (2010), many countries and companies have developed national standards and BIM guideline documents. For example, the US-NBIMS 2007 was the first comprehensive standard, then Norway, Netherlands, Denmark and Australia also implemented various forms of national guidelines as well. Even though, in Sweden, there are some guideline documents which include guidance on more of technical and administrative aspects of BIM with reference to other Swedish standards, it lacks some framework elements and standard methods of planning with respect to project participant parties for BIM implemented projects.

While early development and effective use of BEP has big impact on the success of BIM implementation (McArthur and Sun, 2015), Hardin and McCool (2015) show that when there was no reference to follow up exactly how to execute BIM, most AEC companies prepared their BIM manual or instructional document for successful implementation of BIM. Because there was inconsistency in achieving the desired goals and objective since each party has a different interest throughout design and construction processes.

Eventually, Hardin and McCool (2015) conclude that recently the AEC industry understood that to 'BIM execution plans were necessary in order to implement BIM successfully'.

2.4.2 BIM execution plan framework

Although, it is possible to provide general BEP for the Projects, the execution process of BIM usually varies based on type of the project and experience of the companies. Usually, the BEP process is dependent on size of organization, planned time of delivery and budget, and time of experience working with BIM (Lin et al., 2016). Therefore, researchers have prepared BIM execution plan frameworks which are intended to help companies to solve inconsistency problems by developing BIM execution plans.

McArthur and Sun (2015) proposed a framework (see Table 3) which describes each individual BEP element based on the predefined project goals and objectives.

Table 3: BIM execution plan framework (McArthur and Sun, 2015, p.8).

BEP element	**Description**
BEP overview:	Describe the outline of BEP and participant parties.
Project information:	Describe Project address including name, location and schedules.
Project deliverables:	Describe the time of delivery and project success.
Project goals and objectives:	Describe project goals and objectives.
Key teams and project members:	Project manager, BIM manager, BIM coordinators, Discipline BIM coordinator, BIM actors, other consultants and general and sub-contractors.
Organizational roles:	Develop a personnel organizational chart including all whom involved with BIM models.
BIM uses:	Identify the benefit of BIM based level of development.
BIM process diagram:	Develop BIM implementation diagram throughout the process.
BIM as technology tool:	Define type and version of software to be used, and hardware and CDE to facilitate coordination.
Model structure:	Define model components and how they will interface with in interdisciplinary parties.
Collaboration Procedures:	Define model coordination procedures, permissions, ways of model upload and information exchange schedule.
BIM facility data requirements and data ownership:	Describe third party data required for BIM and end users
BIM information exchange-interoperability:	Define the ways of information exchange among professionals and standards e.g. IFC/ BFC.
Model quality control:	Defines quality control procedures e.g. Design review, check, approval, and clash detection.

2.4.3 BIM Addendum

According to Hardin and McCool (2015), BIM addendum is an additional obligation to prevent the problems which occur due to the improper execution of BIM in the project. However, BIM addendum is outside of the main contracts and it can be a bit difficult to understand for a new team that utilized BIM at the beginning of the project. Because it requires each participating party to have knowledge about LOD and use of a model, exchange of information, etc. Lowe and Muncey (2009) state that BIM addendum is a legal sub forum which forms specific standard agreements between both owner and designers, and owner and contractor. Lowe and Muncey (2009) prepared a compiled document and stated that BIM addendum is a type of contract which defines the specific right and obligations for participant parties to simply and effectively execute BIM process into construction industry instead of making privity of contract among participant parties.

3. Methodology

In this chapter, research methods for conducting this study are presented, and the reasons why specific methods were chosen are explained. This is a qualitative research study and we have used eight interviews for empirical data collection.

3.1 Research Strategy

According to Creswell et al. (2018), in a qualitative research, assumptions are presented, and theoretical frameworks are used to inform about the research problems. One of the main purposes of a qualitative research study is to develop already existing theories which do not capture complexity of subject problems. Since we have found that there is lack of empirical research focusing on our research questions which capture the complexity of the problems, and it was important to understand the people's experience in a more comprehensive way, we have decided to carry out a qualitative research study.

There are different approaches to inquiry, collection, and analysis of data in qualitative research studies, mainly inductive and deductive approaches. The main difference between inductive and deductive approaches to research is that a deductive research approach assesses a known theory or model and it tests if the theory is valid in a given circumstance. In other words, general to the particular. Deduction is used to make deductions from the provisional hypothesis. This hypothesis is tested to either lead to confirmation or rejection. However, induction is the opposite, it is dependent on the researcher's brilliance, persistence, knowledge and sometimes luck. In other words, the inductive reasoning from the particular to the general (Snieder and Larner, 2009).

In this study, we used deductive approach by firstly conducting a literature review and then collecting and analysing empirical data to test if the empirical data confirms or falsifies or extends the literature.

3.2 Interview data collection method

According to Kvale and Brinkmann (2015), an interview is where a diffusion process of wisdom or informational data due to the interaction between the interviewer and the interviewee.

Creswell et al. (2018) states that interview questions are usually prepared based on the research questions in a way that interviewees could understand easily. The interactions between interviewer and interviewee are dependent on the preference, which can be face to face either physical meeting or face to face using technology. sometimes, as an alternative, the interaction facilitates using text messaging and online chat function as well.

According to DiCicco-Bloom and Crabtree (2006) semi-structured and unstructured interviews are more useful when the purpose is to receive qualitative data. Semi-structured interviews are mainly used in qualitative research projects. Usually there are open-ended questions for semi-structured interviews which are predetermined, however, there can also be questions which arise during the actual interview process.

Semi-structured interviews were used for collecting empirical data for this research study because the intention was to receive more comprehensive answers in order to be able to analyze the data in a better way. Interview questions were adapted to the nature of the local construction industry to make sure that we can get a comprehensive response to our questions during interviews. We have used an interview guideline and ask similar questions to all interviewees.

Furthermore, depending on the company type (client, contractor, and consultant), some questions were skipped or accustomed in a way that interviewees can grasp the intention of the questions. All the interviewees were provided with representative questions and context of the interview and some of them were provided a full list of questions based upon their request.

In order to be able to define the initial research questions, we made an initial literature study in our interest area. Initially, literature study helped to find out where there is a lack of research and what would be potential challenges in getting the data in the Swedish AEC industry. Our literature study included previously published research studies in similar areas based on both local (Sweden) and international level.

After defining the initial research questions, we formed our interview questions based on those research questions. The target group was chosen based on our previous information about which companies have gone so far within our research area. People from around fifteen companies were sent a request for having interviews with by including representative interview questions.

Finally, we had eight interviews (in person and Skype) with people from seven different companies. One of them is a public client company, five of them are from architectural and engineering consultancy companies and two of them are construction contractor companies operating in Sweden. One of the consultancy companies are specialized in structural design while others are providing other design services as well. Expectedly, some of contractors and consultants are engaged in similar projects, so that helped us to have a better picture about the information we got from interviews, and comparison of responses from two different parties from the same project helped to make sure that information we got is not biased.

Table 4: Information about interviewees

Role	**Organization**	**BIM experience**	**Interview Type**
BIM Strategist	Public Client	3 years	Face to face
Head of VDC	Contractor	4 years	Face to face
Department BIM Manager	Consultant (general)	8 years	Skype
BIM Coordinator	Consultant (general)	7 years	Skype
Structural Engineer	Consultant (general)	8 years	Face to face
BIM/CAD engineer	Consultant (structural)	3.5 years	Face to face
VDC-Developer	Contractor	4 years	Skype
Model Manager	Consultant (general)	4 years	Face to face

People whom were interviewed have different years of BIM experience, and they have used BIM for various purposes in accordance with the requirements of their company roles (Table 4). Some of them are BIM actors who are creating the BIM models and some of them have the role of coordinating BIM models and workflows etc. Having different perspectives from different players helped us to have more comprehensive data. Since providing the names of the companies is not significant with the purpose of our study, we decided not to provide them.

3.3 Analysis of data

Several authors have advanced a series of steps in a procedure for conducting qualitative research interviews. Mainly, Kvale and Brinkmann (2015) argue that there are seven logical sequence stages of an interview such as: thematizing, designing the study, interviewing, transcribing, analyzing the data, verifying the validity and reporting of the study.

Almost universally, coding is used as an analytical process in qualitative research in which researchers break down their empirical data to make something understandable according to their study (Creswell, 2018). In addition, Elliot (2018) also argues that coding is one part of the decision-making process as a researcher. For example, after transcribing process of data, coding is processed to identify and picking where someone has said something relevant from every question answer, rather than following answers in chronological order.

After we have completed the interviews, we started to transcribe and analyze the data. There were almost no major contradictions between the responses from people. The results that were common among consulting companies and among contractor companies can be associated with having similar roles in the construction market, providing the same kind of services, working in similar environments, utilizing the same kind of work systems, etc. There were also similarities between results from the contractor and consulting companies' respondents based on their collaboration on the same projects, the way how BIM is utilized as a technology and as a process. There were also notable differences between different responses which are elaborated more in the empirical data section.

3.3 Research Validity and Reliability

According to Elo et al., (2014), trustworthiness is an important aspect to consider for the main qualitative content analysis phases from data collection to reporting of the results. Some of the aspects of the research validity and reliability are the choice data collection method, sampling strategy, representativeness, etc.

As explained in the section above, interviews are chosen as the choice of data collection method because of the need for the comprehensive answers. Main strategy when choosing a sample group was ensuring to have interviewees from three main construction parties (client, contractor and consultants). Secondly, we also tried to have people with different years of experience and different kinds of involvement within the research context. Having one representative from each company (except the consultancy company where we had two interviews) can lead to biased data about companies. However, this study is mainly focusing project level collaboration rather than company level.

3.4 Ethics

According to Creswell (2018), good interview procedures are important for having an ethical interview. Some of these procedures are; stay within the study topic, use a framework to guide your questions, complete the interview within a given time, be respectful and offer a positive suggestion and advice. But more importantly, being a good listener rather than frequent and interruptive speaker during the interview.

In order to make sure that people feel comfortable during interviews, we tried to put our questions in a way that they can express themselves freely. We tried not to ask questions that can be company specific or confidential so that our interviewees may feel reluctant to answer. Before each interview, we provided some information about ourselves and the purpose of our study so that they can decide voluntarily to participate in interviews. At the beginning of all interviews, we asked all of our interviewees if they are fine with a recording of the talks so that we can make sure that we do not miss any important information and organize our work better. Further, at the end of the interviews, we asked them whether we can mention their company names if we decide later that it is important to mention.

4 Empirical data/Results

4.1 BIM Roles

Almost all of the respondents stated that the way how BIM collaboration team is set up is mainly based on project size and contract type. There are usually people representing different design disciplines (architectural, structural, HVAC, fire protection, landscape, etc.) as well as people representing construction team (construction engineers, quantity surveyors, installation manager, etc.). Those people representing different disciplines do control of models created inside the disciplines and present for control at further level, where different models are combined and linked, collision controls and other inspections are made. However, for example the way how parties are collaborating, when they should come together, who has more control on the processes are very much depended on different factors including choice of contract type and project size.

Usually BIM coordination is managed by the roles below:

Design Manager Role: Design Manager is leading the whole design team irrespective of BIM utilization. DMs have overall responsibility on the design processes and information management in coordination with BIM managers.

BIM Manager Role: BIM managers have a leading role on BIM processes and have more knowledge of LOD (Level of Development). When the contractor wins the new project, BIM managers set up the project teams who will be working with models. They also set up goals and VDC demands, as well as expectations from different stakeholders like project managers, site managers and others on BIM coordination process.

BIM Coordinator Role: BIM coordinators usually are people who are outside of production process and manage and support different design disciplines, perform clash controls on combined models. They are helping the modelers in different disciplines with potential questions and supporting BIM Managers in their work. BIM coordinators need to be more skilled on model checker (Navisworks, Solibri, etc.) tools than authoring (creation of models) tools (Revit, Tekla, Magicad, etc.). They need also to be knowledgeable in CDE (common data environment) solutions (BIM360, Dalux, BIMeye, etc.) in order to be able to coordinate the models and processes.

Discipline BIM Coordinator Role: Discipline BIM coordinators are responsible for BIM work in specific disciplines and need to be very skilled in authoring tools in their respective disciplines. They control project requirements on versions, software, naming of sheets and drawings. They make sure to use BIM in the best possible way in both ways, as a working method, and as a software. In some companies that role may be called Model Manager as well.

BIM Actors: BIM actors are designers who need to be skilled in BIM authoring tools in their specialization (architects, structural engineers, HVAC engineers). They are expected to act proactively and having coordinating behaviour in their daily work.

4.2 BIM Coordination in different procurement strategies

According to the respondents, the main type of contracts that they are working are Design and Build (DB) and Design Bid Build (DBB) and some collaborative types of contracts including partnerships (Figure 6).

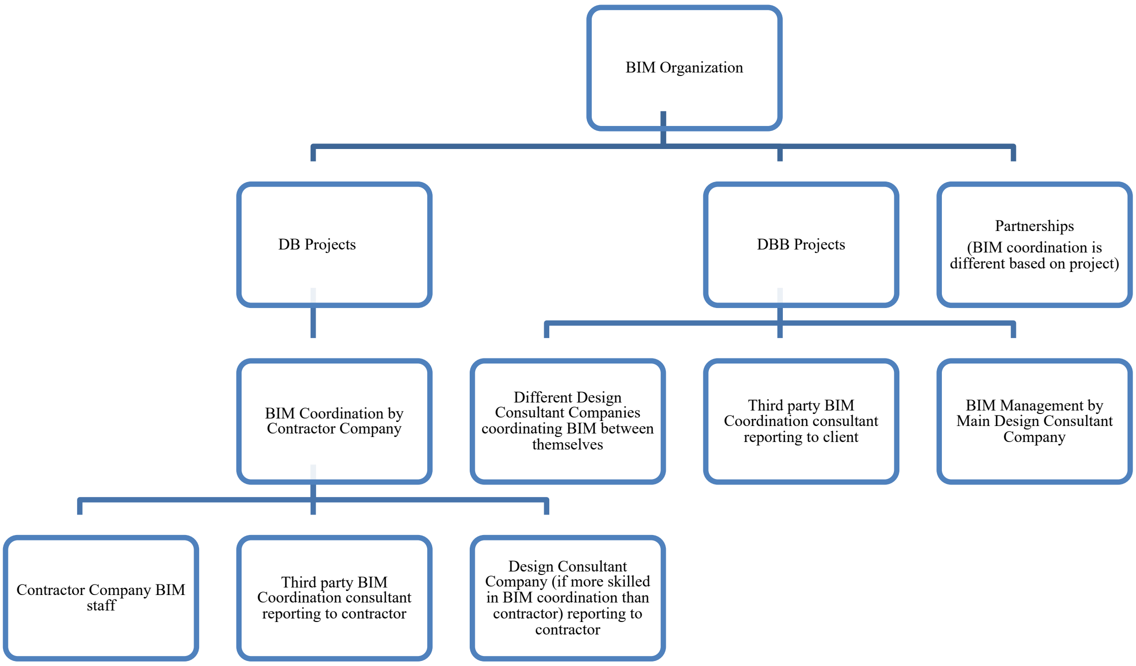

Figure 6: BIM Coordination in DB and DBB procurement

4.2.1 BIM Coordination in DB projects

According to interviewees, DB projects are seldom fully BIM enabled because of the its costs. For example, in one contractor company there is minimum budget defined for BIM utilization. BIM will only be enabled in projects that has budget more than that defined amount.

DB contracts are mainly preferred by the contractor company representatives, since in this way they have a more managing role in BIM coordination. However, some of the consultant company representatives also mentioned that it is easier to work with DB, because they can adjust the information to suit the actual needs of contractors. In this way it is more concrete for contractors to see how they are going to use data that come from consultants. BIM models created by consultants can visualize how the contractors are going to build. Therefore, DB procurement allows to have more effective collaboration, since usually there are a lot of discussions between contractor and consultants about how they are going to collaborate.

Sometimes, depending on the contractor's expertise on BIM, and the size of the project, BIM coordination can be managed by an external BIM consultant company or the design consultant company (if more skilled in BIM coordination than contractor) that is responsible for some part or the whole of the project design work and which reports to the contractor. However, it is usually tried to manage the coordination by themselves, in order to keep the information inside the company and be more prepared for future market.

4.2.3 BIM Coordination in DBB projects

According to the consultant companies' responses, they usually prefer to work in DBB projects, since in this way they have a more decision-making role in BIM coordination and management. However, the way how BIM coordination is managed depends on some factors including project size, client preference, how the design work is distributed among different consultant companies, etc.

BIM coordination in DBB projects is usually managed in three ways:

1) By a client assigned third party BIM coordination consultant;
2) Between different design companies themselves;
3) When the whole or majority of design work is assigned to one company, BIM coordination might be managed by that company as well.

BIM Coordination by third party consultants: Usually in large projects clients assign third party consultants for doing BIM coordination. Roles and responsibilities are similar to above mentioned roles; however, naming of roles can be sometimes different.

Third party BIM consultants work with different specialized design consultant companies, and for example specify what the disciplines are supposed to deliver, what information should be included in the model. They usually consider and require information that is necessary not only for interdisciplinary collaboration and production of the building, but also for the client to manage the facility after delivery and do renovation in the future. In this way collaboration is more structured. BIM consultants are also responsible for data validation of models. They receive the models (usually in IFC format) from different disciplines, do necessary controls, and send out models (usually in SMC or NWD) with notes for corrections, and keep track of all outstanding issues.

According to our public client interviewee, now they are trying to make more contracts with companies that are specialized in BIM collaboration and coordination.

BIM Coordination between different design disciplines themselves: Usually in small projects, disciplines can manage BIM coordination between themselves. Inside the different disciplines there is a BIM manager who is usually the most interested in BIM. That BIM manager is checking client requirements, does internal model checking, and coordinates with other disciplines' BIM managers.

In this way project collaboration can be less efficient, since for example, after architects and structural engineering disciplines combine their models and solve the issues between themselves, the revised model might have problems when combined with HVAC model, and double work could be needed. Also, another possible disadvantage could be that different specialized design consultant companies can deliver useful information to each other, but they can miss some information that can be very valuable to the client in the future.

BIM Coordination by Main Design Consultant Company: When majority of the design work (architectural, structural, HVAC, etc.) is assigned to one consultant company, that company is usually doing BIM Coordination between its own disciplines. The roles are similar to contractor companies BIM coordination roles, however there can be some differences as well.

4.3 Project Information Management

According to the interviewees BIM has a big role in the facilitation of communication processes. Main project communication channels are periodic BIM meetings, emails as well as different common data environment solutions to collaborate on projects.

4.3.1 Meeting Procedures

Almost all of the respondents stated that there are several coordination meetings in the projects once every week or once in two weeks. In meetings everyone sits together, discuss issues and solve the problems together. In some projects there are usually lunch meetings every two months where whole buildings organization are invited. It includes both physical meetings in the office and skype meeting the next day for explaining topics where they are going, what is happening.

Clients sometimes participate in meetings to discuss a specific issue. People try to solve as much as they can without involving the client if it is possible to do so. But sometimes if the possible adjustment can lead to major consequences in the product quality, and cost a lot of money, then usually the client is also invited to meetings.

Type and purpose of meetings are usually different based on the company, project phase, participants, etc. There are usually Design Meetings, Project BIM meetings, Model Coordination Meetings, etc.

Project BIM Meetings: In BIM meetings mainly BIM related issues are discussed, how the data is handled, how analysis is going to be carried out, how the information from analysis are going to be handled, and how different parties are planning to work with BIM, etc. Especially in the beginning of the project there are more BIM meetings where people representing different disciplines and construction team are participating. Usually Design Manager, BIM manager, BIM coordinator, discipline BIM coordinators and sometimes modelers are participating in these meetings on behalf of the design team. Project Managers, Contract Engineers, Site Managers and Installation managers are also participating in these meetings on behalf of the project team. In contractor companies, Project Managers are the ones who are usually responsible for gathering people, to help all to come to a decision and to collaborate in these meetings.

According to one contractor company representative, participation of Installation Managers is very important in these meetings, since they usually have full overview of projects and have better idea about how for example, installation, HVAC should be executed. Usually Design Manager and BIM manager do not have that special knowledge, they just work with clashes or issues.

In one of the contractor companies there are meetings called ICE (Integrated Concurrent Engineering) meetings, where all the parties (consultants, architects, engineers, constructor plus project manager and site chief) involved in project phase gathered in one room to work together during the whole day and have a shorter time period for decision-making. A common thing of these people is they can make decisions on modeling, solutions, and system. That is shortening the amount of time spent on planning in the project phase. The project team is coordinated by the project manager. Usually maximum two people from each discipline are participating. They can have breakout sessions between different disciplines throughout the day to be more efficient. Introduction of ICE meetings with BIM in the company also reduced the need for communication a lot.

Model Coordination Meetings: Usually in consultant companies there are model coordination meetings, where BIM coordinator use clash detection software (Navisworks or Solibri) and takes all the models (architectural, structural, ventilation, plumbing models) together and check the models if there are problems. Discipline BIM coordinators also participate and look at the models and discuss around the table if they understand each other in same way. Typical discussion topics are checking of clashes, setting gridlines, setting plane heights, roof constructions, isolation thicknesses of walls, etc. depending on the sort of the project. The contractor might be involved in these meetings well.

Usually in model coordination meetings, discussions are held with participation of the project manager who can make decisions after discussing issues with everyone. And also, if there are some issues later between different disciplines, they can communicate formally or informally and set up a meeting.

Usually in contractor companies, there are special type of meetings where people representing different disciplines and construction come together and spend one workday together and discuss all project BIM/VDC issues and try to make decisions. Depending on the size of the project these meetings can take 2-3 days as well. ICE meetings and Project Studio meetings are typical examples for these meetings.

Virtual Meetings: Since the different disciplines and parties usually work in different places, virtual meetings play an important role in communication as well. Virtual meetings are used to follow up with issues and virtual teams can also share screens and use 3D models during the conversations to make everything is easier to understand.

4.3.2 Common Data Environment Solutions

According to the respondents, almost in all projects there are shared platforms that serves for different collaboration purposes. Some of these platforms help to share BIM models between different disciplines, some of them help to create issues and remarks on 3D models and share with responsible parties and other collaboration purposes.

The main purposes that our respondents mentioned that they use these platforms for are:

1) Avoiding one to one emailing; enquiring and answering in a centralized portal;
2) Having a shared place where everyone can upload and download models from, i.e., document management platforms;
3) Commenting on and sharing, viewing live BIM models in an online environment, i.e., BIM specialized platforms.

Centralized questions & answers: Some of the portals are used by companies for posting questions regarding BIM centrally and tagging the relevant people for answering, keeping track of outstanding issues. People usually login to that portals and check if there are messages directed to them.

Document Management Platforms: Some portals allow to share project files and BIM models in common platforms where everyone can access, upload, download the different versions of project files. There are several of these platforms that our interviewees stated that they are using for these purposes. One of the consultants stated that every two weeks structural engineers and architects, HVAC engineers upload and exchange their models through the portals. Files are exported in IFC format with a geometry of everything so different disciplines can do clash controls. Consultant companies (specialized) download the updated files from the portal and replace them with the files in their local file system.

BIM Specialized Platforms: There are also some portals that allows commenting on and sharing, viewing live BIM models in an online environment. However, if they are not always enforced specifically in projects, it is up to the individuals to communicate in a way that they are accustomed to, how they feel safe with the tools that they are using. Our public company representative highlighted that they need to have a smart system which shows the last model which includes all the updates at any given time. Different consultant companies mentioned different platforms and software that they use for various purposes.

4.3.3 Internal BIM Servers

Contractor company representatives also stated that their companies are developing internal servers and software for keeping models in their internal database, because BIM models are carrying a lot of information. If different disciplines need to work on something, they get the models from the server, make necessary changes, and send the results back to the server. They also mentioned that, it is important to structure the data, and if the data is structured, they need to be really strict on where the data is put and with what parameters and how the parameters are called. However, some other company respondents mentioned that they are tending to use more cloud-based software rather than one that are accessible internally.

4.3.4 BIM Workflow and Model sharing

All our respondents emphasized the importance of using the right software for the right tasks. Often architects and structural engineers work in Revit, Tekla or Archicad and HVAC engineers work in Magicad. Whatever program they use today can be useless tomorrow. Therefore, it is being tried to be open with the choice of software as long as the final file can be exported to IFC (Industry Foundation Classes) file to share with others.

Although the interviewees highlighted the use of IFC file as a unique language for projects, they also stated that when delivering IFC files, it is also important to provide files in original formats. Because for the client side, IFC is the like as pdf format, it is impossible to make changes, therefore parties ask for original files.

Our interviewees mentioned an importance of delivering 2D drawings, that is something consultants are legally responsible for. They mentioned that drawings are considered as valid deliverable according to their agreements. Therefore, sometimes they do not care about the accuracy of the BIM models. Although, they deliver the models with 2D drawings, in case of potential conflicts between 2D drawings and 3D models, drawings will be treated more valid. However, when the models are delivered for specific purposes like quantity takeoff or fire specifications where the mistakes in the model can be problematic, they deliver more accurate BIM models. Sometimes, people from the contractor side can ask the consultants to deliver accurate models, or it can be stated in specifications.

4.3.5 Software and Version Control

According to our respondents, it is important to upgrade software when there is a new release of software because most changes will help professionals to get new features. However, sometimes it can be difficult to collaborate among professionals since everyone is not ready for the update. As an example, for smaller companies, sometimes it is rather expensive to change to new versions, so they prefer to stay in an older version, but then the bigger companies can not go for new versions since their preference is collaboration to work together.

There are usually problems related to file saving when upgrading. It is needed to save the file as a safety model and then upgrade it. It is usually possible to open older files in new versions of software, but new files cannot be opened in older versions of software. For example, the original file from Revit 2018 cannot be opened in earlier versions. When the older files are tried to open in new software version, it is being upgraded automatically.

It is usually decided and agreed on up front to how to work within file versions and software versions between contractors, consulting companies in the beginning of projects. Design manager and BIM managers prepare a meeting at the start of the project to settle down the version control issue. It is stated in manuals how the version control is being managed in projects. That manuals define which versions of software every discipline should work, for example, Revit 2018 or a certain version of Tekla, etc. Some design consulting companies have manuals which define the specific software versions should be used in company level for making drawings or calculations.

4.3.6 Data validation and Collision Control

One of the important parts of BIM coordinator's work and sometimes disciplines BIM coordinator's work is carrying out clash detections of models. According to our interviewees, there are usually clash detections on two levels. Initially after the modelers in different disciplines draft the models in their specialized software, they deliver models for preliminary checking by their respective Discipline BIM Coordinators (Model Managers in some companies). After Discipline BIM coordinators make sure that models are accurate and in accordance with requirements, the models are converted to IFC format and submitted to BIM Coordinators in order to carry out data validation and clash detections after models are combined and linked in that software. Usually, in projects there are deadlines for discipline BIM coordinators to submit the updated models in every week or every month.

BIM coordinators carry out clash detections with standard rule sets in specialized clash detection software (either Solibri or Navisworks model checker). There is Swedish standards rule set in Solibri from a BIM specialized company. Accessibility rules, fire rules, etc. are included in that ruleset. Usually, in some companies, collision controls are executed by running that rule set on the model. However, when there are a lot of number of rules, it can result 10,000 -50,000 collisions, and it might be hard to filter through all that content (collisions). So, BIM managers make some relevant decision to adopt that rule set to specific needs. Sometimes bigger companies use their own ruleset for carrying out clash detections. Because they need to have control over their data based on their company system. Usually, clashes are classified in different categories according to their significance.

Clash Category 1 - Very minor clashes, no action needed;

Clash Category 2 - Some action is needed, but not critical now;

Clash Category 3 - Clashes that should be solved as soon as possible;

However, quality control of the models does not only include clash detections. BIM coordinators also check the “hygiene” of IFC files and make sure that models are carrying the right amount of data in the right phase of the project. They go through all the objects in the models and make sure that all are named correctly.

After the quality controls, BIM coordinators send out compiled models usually in SMC (Solibri Model Checker) or Navisworks format with slides and notes to the relevant disciplines.

Some companies stated that they are trying to use BCF (BIM Collaboration Format) for sharing of combined models and to keep track of the issues found. When different IFC files are combined in collision control software and some notes and remarks are made on it, the final file can be exported to BCF file format that can be accessible with modelers’ specialized software (for example, Revit, Tekla, etc.). Usually there are meetings with participants of the disciplines, where all of the issues found are discussed and the disciplines are instructed to make the necessary changes till the next meetings.

4.3.7 Traceability

One of the key benefits of BIM is the ability to spot or trace every stage in the design process and which helps the design team to collaborate. But it is much harder to manage traceability as a system. Because sometimes even design team participants do not know if something is changed in the model. Cloud solutions help to have full traceability and track of what has been done where and by whom and so on. Sometimes parties use 3D clouds, where you put the file and additional notes that states what has been changed in the file. For example, In BIM360, it is possible to trace by fix overlays (for example green ones are new ones, yellow ones are changed ones, red ones are disappeared ones).

4.3.8 Data Ownership

Our respondents from Sweden mentioned that consultancy companies retain the ownership of models (if not otherwise stated) in accordance with ABK-The General Conditions of Contract for Consulting Agreements for Architectural and Engineering Assignments. Clients can use the result of the project only for the intended purpose of the assignment. However, clients sometimes can state in the contracts for taking the ownership of the models. And there can be some public clients who can ask destroying all the data after submission of the project.

4.4 BIM Delivery Plans

Almost all of our respondents emphasized the importance of having BIM delivery plans in order to manage BIM in a strict way and to have as few implications as possible. Some companies have delivery plans that help to ensure that all project participants - contractors and different design disciplines are working in accordance with same standards within projects.

The concepts that our interviewees stated that current delivery plans include:

- how different disciplines should work with the models;

- how the layouts of the drawings should look;

- how to set numbering of drawings and elements;

- some detail levels and some type of naming and BIP (Building Information Properties) code to identify the process;

- roles and responsibilities of different project participants.

Some interviewees talked about the benefits of using the same naming standards in different companies: BIP codes. It becomes easier when everyone works with this code from the beginning.

However, companies who are collaborating in projects are not enforced so much to use these delivery plans. They are allowed to use their own delivery plans if they have. But usually clients send out these plans to use if the consultant does not have their own similar one. Some big companies have their internal BIM delivery plans on a company level, and there are some in discipline level as well. However, it was also mentioned that it is important to consider LOD (Level of Development) when preparing BIM manuals, because otherwise it could be hard to deliver what is supposed.

We asked interviewees from companies operating in Sweden about their thoughts of having standard BIM execution plans (BEP) in projects. They mentioned that it would be better if BEPs include:

- BIM roles and responsibilities;
- Major BIM goals and objectives;
- Checklists and gates that specifies what should be done in every step;
- Level of Development (LOD);
- BIM Workflow and Model sharing;
- Quality control and Data Validation procedures;
- Software and Version Control Issues.

According to our interviewees there could be a lot of positive effects of having national level BIM guidelines for preparation of BEPs. It can help to decrease misunderstandings, because all can refer to one document. Standard BEPs would lead to more systematic processes that works with more efficient workflow: it would help to have the same communication lines in projects, for example, people may refer to that document to know whom they should contact/report. Small contractors, who do not have resources to have a BEP can use national guidelines as reference.

If there is a national standard, this may lead discussions between professionals, and it can be improved step by step. Some people said that national guidelines would have a positive effect if it is mandatory like in the Denmark. However, there are some who also thinks that if it is forced legally, people would be more critical, but it may also lead complaints because some bigger companies may want their own guidelines and may not want to change the way how they work. Therefore, they say it would better if it is allowed to have some company level and project level changes on that.

5 Discussion

In this chapter the empirical data is analyzed with the help of theories from literature studies and the outcomes are presented within the context of research questions:

1) How is BIM coordination process organized in different procurement strategies (mainly DB, DBB)?

2) How is current BIM information management performed in projects?

3) How can BIM coordination in Sweden be improved with the help of BIM execution plans (BEPs)?

5.1 BIM coordination in DB and DBB procurement strategies

Parties and actors who are participating in BIM utilized projects perform managerial tasks and take different roles. For managing the projects successfully, well managed BIM coordination is important. The significance of BIM coordination either by a third party or from design and construction companies will be increased (Liu et al., 2017).

Although there have been some studies which focus on BIM coordination in Integration Project Delivery (IPD) projects, few studies primarily focused on BIM coordination process in either DB or DBB procurement routes except the study carried out by Aibinu and Papadonikolaki (2016).

As explained in the literature study chapter, Aibinu and Papadonikolaki (2016) categorize BIM coordination process as centralized and decentralized. In a centralized structure, there is always a selected party who takes responsibility for BIM coordination in projects. However, in a decentralized structure there is no selected party who manages BIM coordination instead parties manage coordination between themselves.

According to the empirical findings, management of BIM coordination process can be carried out by:

- Contractor Company BIM staff (DB projects)
- Third party BIM Coordination (DB and DBB projects)
- Main Design Consultant Company (DB and DBB projects)
- Between Different Design Disciplines (DBB projects)

According to our empirical findings, decentralized BIM coordination is applicable to DBB projects, where different disciplines manage BIM coordination without involvement of managing party. According to Aibinu and Papadonikolaki (2016), in DB projects, decentralized BIM coordination also exists, where contractor and designer companies manage BIM workflows between themselves as well. The Figure 7 below combines and explains the above-mentioned empirical findings and the theory of centralized and decentralized BIM coordination:

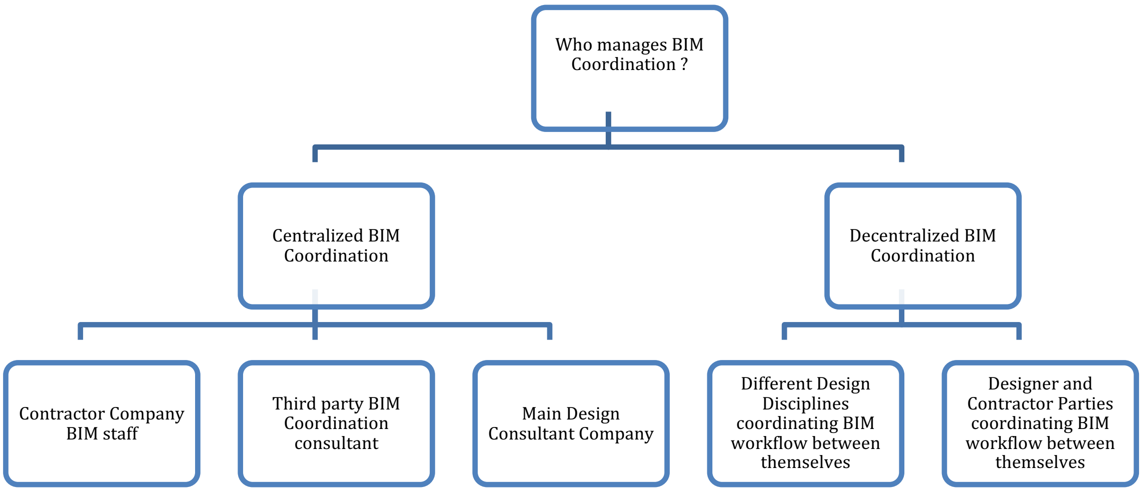

Figure 7: Centralized and Decentralized BIM Coordination

According to Figure 7, for centralized BIM coordination either the designer or contractor party can take the role of BIM coordination if they are specialized in that, or BIM coordination can be outsourced to a third-party consultant. As mentioned by our interviewees, since the BIM Coordination requires specialist knowledge, the party who is responsible for the overall management of projects cannot always manage both the project and the BIM coordination as well. In both procurement routes it is usually the party who is more skilled in BIM coordination that takes the role, although from a project coordination perspective there can also be another party who has more power in the project that takes this role. Even if there is third party who takes the managing role in BIM coordination, that party should report to the one who manages the project.

In decentralized BIM coordination, the two categories can be associated with the type of procurement route. According to our interviewees, usually in small DBB projects, different design disciplines manage BIM workflows between themselves. In DB projects, contractor and designer companies can manage BIM workflows between themselves as mentioned by Aibinu and Papadonikolaki (2016).

One interesting point is that, in the study by Aibinu and Papadonikolaki (2016) centralized BIM coordination is mainly considered to be carried out by the involvement of a third-party BIM coordination company within the context of Design and Build procurement route only. However, from the empirical findings we can conclude that, centralized BIM coordination is applicable to both DB and DBB procurement routes, and BIM coordination can be managed by either one of the designers and contractor parties, or a third-party BIM coordination consultant. The figure 8 below summarizes combination of the empirical findings with model by Aibinu and Papadonikolaki (2016):

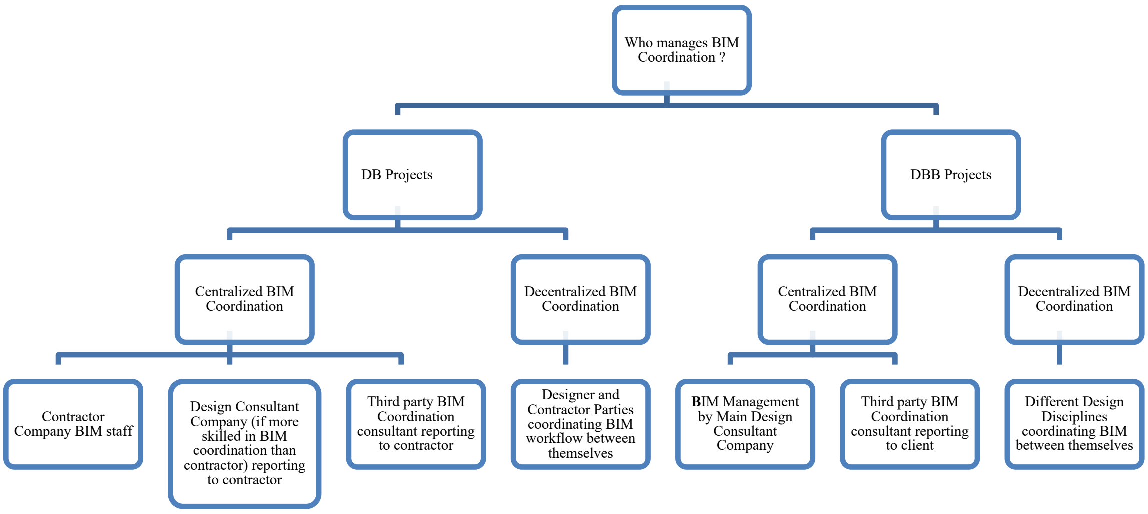

Figure 8: BIM coordination in DB and DBB projects

As mentioned in the empirical part, our interviewees (mainly design consultants) confirmed several benefits of having a specialized BIM coordinator party in projects for managing BIM workflows. They emphasized that BIM coordination becomes more structured and centralized in this way. One of the examples for benefits of centralized BIM coordination are: avoiding missing information on models, since BIM coordinators are usually stricter on checking if models are including all the necessary information. Another example from the interviewees was when the disciplines perform model coordination between themselves, they just mostly consider the design stage, so centralized BIM coordination forces designers to prepare models to suit the actual needs of the construction stage as well. Interestingly, similar results of having centralized BIM coordination are acquired by Aibinu and Papadonikolaki (2016).

Usually in projects where BIM coordination is centralized, there are people with different BIM roles who support BIM coordination process. Bosch-Sijtsema et al. (2019) mentions BIM actors as the term which represents three BIM roles (BIM Manager, BIM Coordinator and BIM Modeler). However, since according to our interviews the naming of the role that is responsible for authoring the models is different based on disciplines and companies, we therefore use the term BIM actor for referring this role. Davies et al. (2017) mentions BIM modellers for referring users who are drafting and taking responsibility for models. Although this is not typical role in the Swedish AEC industry, the interviewee from a Danish consultancy company mentioned the role of BIM modellers with the similar role responsibilities.

According to Jacobsson and Merschbrock (2017) the role and responsibilities of BIM coordinators include clash detections and model quality control; managing information and communication flows; monitoring and coordinating design variations in the production stage, etc. However, as mentioned by Davies et al. (2017), there can be similar role labels being applied to different role descriptions. This was what was also observed from the interviews in different companies.

In some companies the BIM manager role can have the same role responsibilities as a BIM coordinator role in other companies. Davies et al. (2017) cites the role of BIM manager as a person who develops and delivers BIM execution plans and BIM protocols. Although, BIM execution plans are not common in Sweden, the duties of the role can be similar. As mentioned in our empirical part, BIM managers have the role of setting up goals and VDC demands, as well as expectations from different stakeholders like project managers, site managers and others on BIM coordination process. The role of Discipline BIM coordinator is also named as Model Manager in some of the companies where we have made interviews. Davies et al. (2017) also stated that the BIM coordinator role can be named Model Manager for sub-trades and special consultants.

To summarize, well-managed BIM coordination is one of the essentials for successful implementation of BIM in projects. In both DB and DBB projects, BIM coordination can be centralized and decentralized. In a centralized structure, BIM coordination is more structured, there is usually a party who manages in BIM coordination. The party who takes the role of BIM coordination can be either a third-party BIM consultant, or one of the design and construction companies. While, in a decentralized structure BIM coordination is managed between parties without the role of BIM coordinator and it is usually common to small-sized projects.

5.2 BIM Information Management

One of the important aspects of BIM coordination is ensuring well-coordinated information workflows, including discussions and decisions made during coordination meetings. Hardin and McCool (2015) explain that the choice of different communication modes usually depends on the purpose of communication and desired clarity of information. Physical meetings are considered to be better when there is more probability of confusion regarding the information. As mentioned in the empirical part, usually in the early phases of the project when BIM roles and responsibilities of parties are decided, it is important to make sure that the possibility of information misinterpretation is low. Therefore, more BIM meetings are arranged by involvement of people who represent different design disciplines and construction team. In later stages of design, periodic BIM coordination meetings help to discuss model related issues, for example, clashes, quality control, etc. In BIM coordination meetings a lot of discussions are carried out, and decisions are made regarding BIM models and processes. However, as stated by Wang et al. (2015), BIM models do not support to record process information properly, which includes discussions and decisions made during design coordination meetings.

Alreshidi et al. (2015) states that sufficient management of BIM information could prevent data errors, inconsistency, and poorly produced documents, as well as specific data- related issues including data inconstancy, compatibility, accessibility, security, and data storage problems. According to our interviewees, there are many sophisticated tools that are used for this matter. Mainly, Common Data Environment Solutions (CDE) are helping project coordination and communication processes.

According to Sawhney et al. (2017), CDE solutions help to have a single source of information which facilitates collaboration between project team members and prevents duplication and mistakes. Some of the uses of CDE solutions are for example, workflow management, model management, communication, coordination and clash prevention, system administration, and facility management. As discussed in the empirical part, in the companies which were interviewed, CDE solutions are used for three main BIM related purposes: centralized questioning and answering, for sharing models and documents, and accessing and viewing models online.

Preidel et al. (2017) states that CDE helps the centralization of data storage which in turn decreases the risk of data redundancy and allows to have the up to date data at any point of time. These features are very important for facilitating BIM coordination, for example, the interviewee from a public client company stated that they can not manage BIM coordination effectively because of the lack of a smart system which shows the last model which includes all the updates at any given time.

Interestingly, Aibinu and Papadonikolaki (2016) associate the use of CDE solutions with centralized BIM coordination where everything is more structured. Although, during analysis of the empirical data this association was not clear from the interview material, it was easy to understand the correlation from the fact that CDE solutions are implemented mainly in big projects where BIM coordination is more centralized.

There are now many providers of such kind of CDE solutions. However, as mentioned in the empirical part, larger organizations in the Swedish AEC industry try to build their own platforms for meeting the collaboration and coordination requirements. Because, they think BIM models are carrying a lot of important information that can lead to problems if not protected accurately.

To summarize, although BIM helps to have more efficient project coordination and communication, it still lacks some important features such as storing process information (discussions and decisions) properly, allowing users to access up to date information at any point of time. Common Data Environment solutions are useful in this regard and can be best supplements to BIM processes for improving project communication and coordination.

5.3 BIM Execution Plans for BIM Coordination

Since many parties are coming together and collaborate in projects, it is very important to make sure that everyone has the same interests from the utilization of BIM. However, it is not easy to ensure that, because everyone in the project may not have the same level of knowledge to predict what is expected from the use of BIM with given project goals and objectives. As emphasized by Anumba et al. (2009), it is very important in project planning to define what the overall goals for implementing BIM are, in order to make it clear for project members what the potential value of BIM on the project is. The BIM goals can include decreasing the overall project duration and cost, and/or increasing overall project quality. When there are measurable goals both from company and project perspective, then specific uses of BIM in projects can be identified (Anumba et al., 2009). Some organizations use BIM Execution plans (BEP) for defining the BIM goals and objectives on the project.

A BIM Execution plan is an important document which is based on the goals and objectives defined for the project (Hardin and McCool, 2015). It helps to link overall the project management plan with the BIM implementation on the project (Sawhney et al., 2017). However, there is a need for standardization and guidance for companies to prepare BEPs. Because different companies are coming together in projects and when everyone prepares BEPs in their own way, this can lead to inconsistencies in achieving desired project goals (Hardin and McCool ,2015).

In Sweden some BIM organizations created guidelines for the preparation of BIM Execution plans. However, according to Hooper and Ekholm (2010), these guidelines do not include standard methods of planning and agreement on information exchange amongst project team members. Therefore, there are inconsistencies in different delivery plans that companies use for executing BIM in projects. This fact was confirmed by some of the interviewees as well, and they stated current BIM delivery plans mainly include technical and administrative aspects of BIM, but do not contain defined BIM goals and objectives for the projects.

The lack of proper BIM execution plans leads to less efficient work practices and less proper models. For example, according to the interviewees the accuracy of BIM models is not well taken care of when delivering models (if not otherwise stated), since the consultancy agreements prioritize drawings when there is mismatch between drawings and models. Holzer (2015) also emphasized that use of models for precise quantity surveying and tendering purposes are not guaranteed if the desired accuracy of the models is not agreed upon before the delivery.

According to different studies (Hardin and McCool, 2015; Wu et al., 2014) there are several important elements that should be contained in BEPs. McArthur and Sun (2015) suggested a framework for development of BIM Execution plans for efficient project delivery. In the below figure 9, the list of important aspects that our interviewees preferred to be included in BIM execution plans is correlated with the framework suggested by McArthur and Sun (2015). As the figure 9 clarifies, all of these aspects are included in one or more elements of a BIM Execution Plan Framework. Although, according to our interviewees, BIM delivery plans which are in use in the Swedish AEC industry include some of these aspects (Quality Control and Data Validation Procedures, Software and Version Control Issues) there is a need for execution plans which are more comprehensive and include all important aspects.

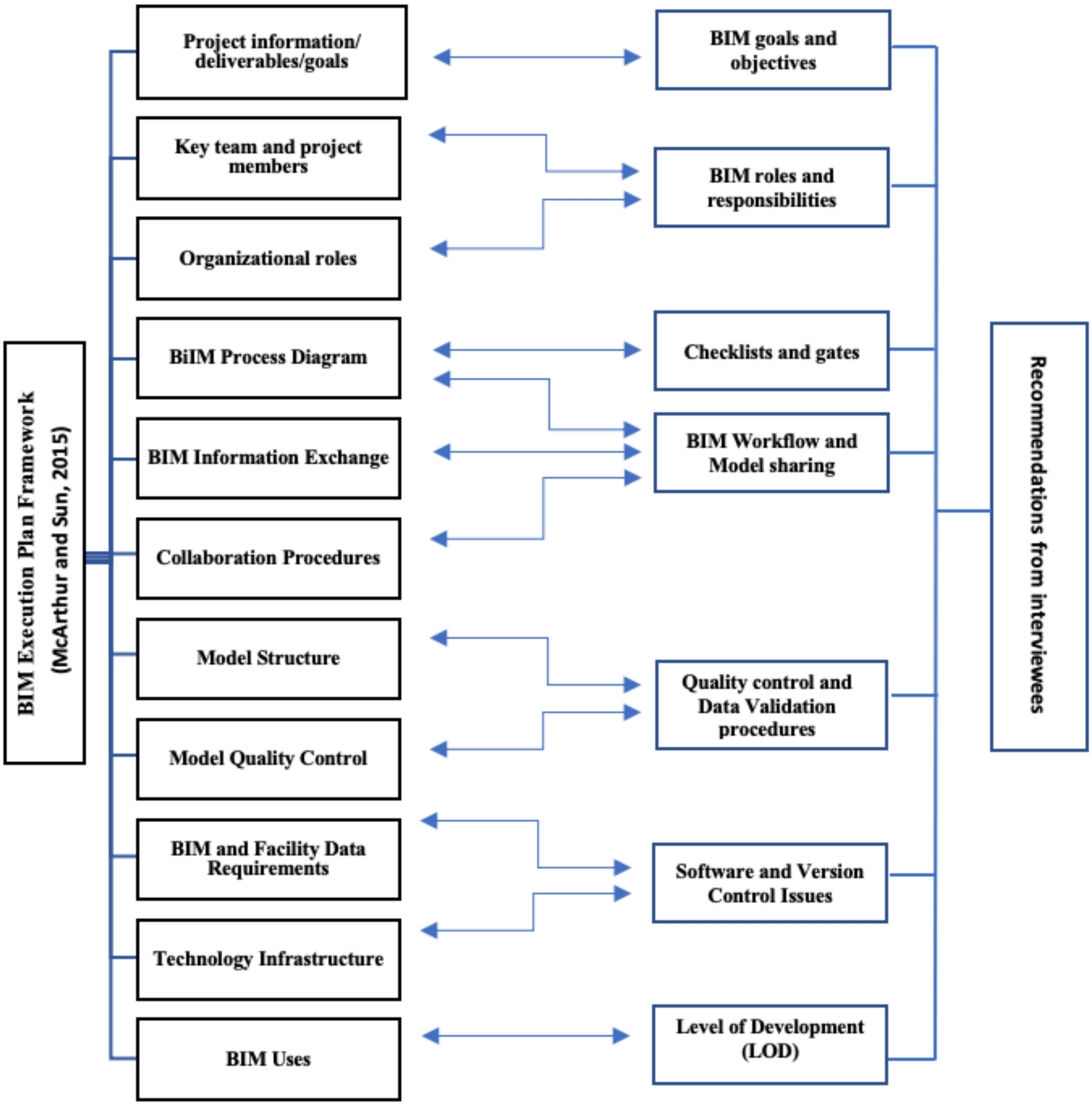

Figure 9: *BIM execution Plan Framework (McArtur and Sun, 2015) and its correlation with suggestions from interviewees.*

To summarize, having national BIM guidelines in Sweden will help companies to prepare consistent and proper BIM execution plans for efficient collaboration in projects. According to the interviewees having national BIM guidelines can be helpful from different perspectives. For example, it would stimulate the use of BIM in small companies which do not have enough knowledge capacity to create their own BIM execution plans, and it would help different project participants to work more consistently.

6 Conclusion

The purpose of this study was to analyze current BIM coordination practices in the Swedish AEC projects from three main perspectives: how it is organized and managed in Design-Build and Design-Bid-Build projects; how it is supported by different information management solutions; and how it can be improved with the help of BIM Execution Plans. The main data collection method has been semi-structured interviews, and eight interviews have been conducted with people from seven different design consultancy and contractor companies. Interview questions were prepared based on research questions and the main research areas of the study.

While analysing the empirical data, it has been found that there are similarities in practices of organizing and managing BIM Coordination in different companies in each of DB and DBB projects and theories from the literature study were applied to model those similarities. In both procurement routes, project BIM coordination can be managed in a centralized and decentralized structure. A centralized structure is common for big size projects, where BIM coordination is more structured, and usually one of the design consultancies, contractor parties or third-party BIM consultant company takes the role of managing project BIM coordination. In decentralized BIM coordination which is typical in small-sized projects, there is no party who takes the managing role, but parties manage BIM coordination between themselves.

Another main finding of the study was about the lack of features of BIM tools for storing and communicating process information and how Common Data Environment Solutions are implemented in parallel with BIM to close this gap. Interview results proved the use of these tools in Swedish AEC projects as well, mainly for the purposes of centralized questioning and answering, for sharing models and documents, and accessing and viewing models online. Some organizations use the CDE solutions offered by different providers, while bigger organizations even try to build their own platforms for meeting the collaboration and coordination requirements.

Finally, in order to study how overall BIM coordination in Sweden might by improved with BIM Execution plans, current BIM delivery plans implemented by different companies are compared with BIM Execution plans suggested by different authors and organizations. The most important elements suggested by the interviewees for the development of BEPs are summarized and compared with one of the BEP framework elements form the literature study. It has been concluded that standardization of BIM practices in Swedish AEC industry would support companies to have more consistent and proper BIM execution plans. This in turn would lead to have more efficient and standard BIM coordination practices in AEC projects since all the project members and parties would have a consistent standard to follow.

Furthermore, standardization of BEPs would support and increase overall work efficiency in construction sector which will lead to more sustainable practices due to decreased use of resources, time and cost. Moreover, having standard BEPs in projects would also create access for small enterprises in construction industry to enter collaboration in projects which are now affordable for bigger size companies.

A suggestion for future research is to conduct a study for how Integrated Project Delivery (IPD) can be introduced to Swedish AEC industry since it is being considered better fit for BIM in projects rather than DB and DBB. Furthermore, it would be valuable to research how BIM Execution Plans can be prepared in a way that fits to the nature of the local construction industry.

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