BIM implementation within infrastructure projects

A study to evaluate the work and information flow within the construction industry

Master's thesis in Master Program Design and Construction Project Management

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Abstract

The construction industry has for many years worked hard to streamline communication and information flow as digitalization grows rapidly within the industry. The Swedish construction industry's clients, contractors and consultants are dependent on each other and contribute together to create societal benefits. A new approach called Building Information Modeling (BIM) has during the last decade been the most promising and well known development system in the AEC industry. This approach works like a support function and allows information in a project to be shared in an efficient way through 3D models and visualization techniques. To be able to follow the digital development in the sector, AFRY and the other actors in the industry have to become more digital and productive. This study has been carried out in collaboration with the business area Transportation Sweden at AFRY, which currently strives to develop a new internal framework in order to improve the work and information flow in their projects.

The aim of this master thesis is to investigate and establish how the business area Transportation Sweden is working towards innovation and digitalization. By studying the business area's current framework, an analysis has been conducted in order to identify the opportunities and challenges with BIM implementation within infrastructure projects. An abductive method approach has been applied which includes both qualitative and quantitative data. The collection of data starts with a literature review, followed by a questionnaire survey and an interview study to gain an understanding of how BIM maturity levels are perceived within the business area Transportation Sweden and how the employees can contribute to streamline the work and information flow.

Conclusively, this study demonstrates that there are numerous potential possibilities and benefits when working with model-based projects. The overall perception of the main challenges points at a lack of collaboration skills and knowledge regarding models within project management. Moreover, there are technical challenges and a lack of overall knowledge of the subject which creates confusion and can be a restricting factor for the BIM implementation process. However, the main possibilities are that this working procedure gains time and economical benefits for clients and other actors in the industry. This study confirms the benefits of BIM, if applied right in appropriate projects.

Keywords: BIM, workflow, information flow, construction industry, implementation, communication, collaboration

BIM Implementering inom infratrukturprojekt
En studie som utvärderar arbetssätt och informationsflöde inom byggbraschen

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Sammanfattning

Byggbranschen har under många år jobbat för att effektivisera informations- och kommunikationsflödet inom infrastrukturprojekt, detta i samband med den snabba digitala utvecklingen inom branschen. Svenska byggbranschens beställare, konsulter och entreprenörer är beroende av varandra och bidrar tillsammans till samhällsutveckling. Ett nytt arbetssätt, Building Information Modeling (BIM), har under de senaste åren varit det mest omtalade och lovande systemet i AEC branschen. Detta arbetssätt fungerar som en stödfunktion och bidrar till informationsutbyte genom 3D modeller och visualiseringsteknik. För att vara delaktig i branschens digitala utveckling, måste AFRY såväl som andra aktörer jobba mer digitalt och effektivt. Denna studie har genomförts i samarbete med affärsenheten Transportation Sweden på AFRY, som för nuvarande jobbar med att utveckla ett nytt arbetssätt internt i syfte till att förbättra och effektivisera informationsflödet i projekten.

Syftet med detta examensarbete är att undersöka och påvisa hur affärsenheten Transportation Sweden jobbar med innovation och digitalisering. Affärsenhetens nuvarande arbetssätt har studerats för att identifiera möjligheterna och utmaningarna med BIM implementering inom infrastruktur projekt. Detta har genomförts med en metodkombination bestående av båda kvalitativ och kvantitativ data. Rapporten börjar med litteraturstudie, följd av en enkätundersökning och intervjustudie för att skapa en uppfattning om hur anställda på AFRY jobbar med BIM samt kan bidra till och påverka utvecklingen av BIM inom branschen.

Resultaten i denna studie visar att de potentiella möjligheterna och fördelarna är enorma när man jobbar med modellbaserade projekt. De största identifierade utmaningarna grundar sig i bristande samarbete och kunskap om modellbaserad projekthantering inom projektledning. Det finns även tekniska utmaningar så väl som kunskapsbrist inom ämnet, vilket kan skapa förvirring och leda till fördröjning av BIM implementeringen. Dock medför denna arbetsmetod stora ekonomiska och tidsmässiga fördelar för beställare och övriga aktörer inom branschen. Denne studie bekräftar fördlerana med BIM om arbetsmetoden används på rätt sätt och i rätt projekt.

Nyckelord: BIM, arbetssätt, informationsflöde, byggbranschen, implementering, kommunikation, samarbete

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Thank you!

Shakrin Ahmed, Gothenburg, June 2022

Contents

Dictionary

Authority	Myndighet
BIM Coordinator	BIM-samordnare
Contractor	Entreprenör/konsulter
Clash detection	Kollisionskontroll
CAD designer	CAD-projektör
Client/Owner	Beställare
Contract changes	ÄTA-arbeten
Data Coordinator	Data-samordnare
Discipline	Teknikområde/disciplin
Design review	Granskning av handlingar
Design-Bid-Build	Utförandeentreprenad
Design-Build	Totalentreprenad
Design document	Bygghandling
Design manager	Projekteringsledare
Design phase	Projekteringsfasen
ECI	Samverkansaentreprenad
Facility management	Förvaltning
Feasibility study	Förstudie
Municipality	Kommun
Maturity level	Mognadsgrad
Level of Development/Detail	Informationsgrad
Procurement process	Upphandlingsskede
Procurement approach	Upphandlingsform
Project manager	Projektledare
Pre study	Förstudie
Project planning document	Systemhandling
Quantity take-off	Mängduttagning
Requirement	Krav och förfrågan
Subcontractor	Underentreprenör
Stakeholders	Intressenter
STA	Trafikverket
Swedish Public Procurement Act	LOU (Lagen om offentlig upphandling)
Tender	Anbud
Tender documentation	Förfrågningsunderlag

List of Abbreviations

AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
CAD	Computer Aided Design
CDE	Common Data Environment
DBB	Design-Bid-Build (Swedish AB)
DB	Design-Build (Swedish ABT)
BA	Business area
ECI	Early Contractor Involvement
IPD	Integrated Project Delivery
IFC	Industry Foundation Classes (general file format)
STA	Swedish Transport Administration
3D	Geometrical model in three dimensions
2D	Geometrical model, two-dimensional drawings
VDC	Virtual Design and Construction
LOD	Level of Development/Detail
AIA	American Institute of Architects
NPS	Net Promoters Score
PDF	Portable Document Format
LOU	Lagen om offentlig upphandling
DISC	Dominance, Influence, Steadiness and Compliance (personality test)
ÄTA	Ändrings-, Tilläggs- och Avgående arbete
AB	Allmänna bestämmelser för Utförandeentreprenader
ABT	Allmänna bestämmelser för Totalentreprenader

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1
Introduction

This chapter provides the background, aim and research questions for this study. Moreover, the delimitation of this study will be explained and presented as well.

1.1 Background

In the last decades, the infrastructure industry has worked hard to digitally streamline information flow and communication within infrastructure projects. To solve this issue, the construction industry is evolving and undergoing major changes throughout different project phases in Architecture, Engineering and Construction (AEC) projects (Barlish and Sullivan, 2012). A new approach called Building Information Modeling (BIM) has during the last decade been the most promising and well known development system in the AEC industry. This approach works like a support function and allows information about the project to be shared in an efficient way from 2D-drawings to 3D-models in a digital environment (Azhar, 2011).

Enterprises, stakeholders and authorities are undergoing development towards BIM and digitalization in the construction industry (Trafikverket, 2021). The Swedish construction industry's clients, contractors and consultants together contribute to create societal benefits. These actors are dependent on each other as their cooperation is necessary and based on e.g., the understanding of each other's driving forces, demands and needs. Infrastructure projects are critical in the industry for both regional and economic development due to its large contribution to economic and societal growth. Annually, the Swedish government invest approximately 111 billion SEK in the construction industry (Byggföretagen, 2021).

In order to identify the possibilities and challenges with digital technology, InfraSweden2030, which is an innovation program, has initially taken action to a "Digital (AI) Journey" (InfraSweden2030, 2020). The aim of the digital journey is to aid Swedish infrastructure projects to recognize the possible benefits of digitalization in the construction industry. AFRY is one of the members of the innovation program and actively works with innovation in the infrastructure sector. At AFRY, the business area Transportation Sweden strives to develop a new internal framework in order to improve the work and information flow in model-based projects. To be able to fulfill client demands and contribute to the innovation projects, AFRY, together with other actors in the industry must become more digital and productive.

1.2 Purpose and research questions

The aim of this thesis is to investigate and establish how the business area Transportation Sweden at AFRY is working towards innovation and digitalization. The thesis also strives to provide the business area a foundation to work on for further improvement of the internal everyday work procedure. Furthermore, the thesis aims to identify the challenges and issues with BIM implementation and provide knowledge about what the business area needs in order to improve and fulfill their BIM implementation successfully.

In essence, this study aims to answer these following research questions:

- What is the BIM maturity level at AFRY and what are the challenges when working with BIM in infrastructure projects?
- For which procurement approach is BIM most suitable?
- How can the workflow be streamlined within infrastructure projects?

1.3 Delimitation

The study will only concern the business area Transportation Sweden at AFRY, which primarily works with infrastructure and railway projects. A questionnaire survey will be provided only to handpicked clusters in order to obtain relevant answers to the research questions. Several interviews will be conducted among employees with experience within project management, BIM and digital tools. Moreover, this thesis will only consider the information flow and BIM usage level internally at the studied business area.

Complete answers of questions 25-36 from the questionnaire survey are presented in Appendix C. The most frequent answers are presented and discussed in Chapters 5 and 6.

2

Theoretical framework

This chapter will provide the necessary theory to comprehend the contents of this study. In order to give the reader a better understanding of the subject, the term BIM will be defined and explained. Furthermore, challenges and benefits of BIM implementation will be identified. Different maturity levels of BIM and its benefits throughout the different project phases will also be presented. Lastly, LOD within BIM models and the most suitable procurement approach for BIM utilization will be identified and explained.

2.1 BIM

"A set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life cycle".

In this definition of the term BIM by Succar (2009), it is stated that BIM is more than just software, also acknowledged by Azhar (2011) who describes BIM as a process which encourages integration among different actors in the construction industry. BIM is a complex concept and stands for Building Information Modeling (Azhar, 2011). Beyond software, BIM can be described as a culture or collaboration method within an organization or between different actors. This concept, in the construction industry, helps architects, engineers and designers to visualize their vision of a project in a simulated environment. When using BIM, it is not only about 3D models, it means making huge changes within the workflow and project delivery process which encourages integration of stakeholders (Azhar, 2011). With BIM technology, an accurate digital model can be created and used for i.e., visualizations purposes, cost estimations, 3D-rendering, collision detection, planning, design and operation of facility management (Bensalah et al., 2018).

BIM can be used for the following purposes:

- Cost estimation: BIM software can be used to export material quantities. The data updates automatically when changes are made in the 3D-model.

- 3D visualization: Photos and videos can be rendered through the 3D-model to simulate and obtain an overall picture of the project.

- Code review: Fire protection demands of different objects or other data such as sound requirements can be integrated in the model and used by designers for review purposes within their projects.

- Drawings: When the model is complete, fabrication or shop drawings can easily be generated for various building system such as duct work.

- Clash detection: When working with BIM, the model is created in 3D space which gives the possibility to combine all the major systems instantly and automatically. This means that collisions between different objects or systems can easily be identified such as collisions between piping and walls.

- Facility management: BIM is also beneficial for the facility management department. The model can for instance be used for restoration purposes and space planning.

According to Sebastian (2010), BIM has the potential to improve and streamline collaboration between different actors and reduce the project time duration and project

cost, granted that the technology is executed in the right way. Sebastian (2010) presents five success factors regarding collaboration and implementation of BIM in a hospital building project. The five success factors are identified as "POWER" (P= product information sharing, O= organization roles synergy, W= work process coordination, E= environment for teamwork, R= reference data consolidation).

Furthermore, Sebastian (2010) states that open data standards should be used in order to achieve the optimal information flow between different actors in the AEC industry. It is believed that integration and collaboration within an organization are important factors, which can be achieved through incentives and common goals. This argument is also supported by Gu and London (2010), whom states that a successful BIM implementation within a project team might be achieved through alteration in work practices as new integrated project requires improved collaboration and communication among the different disciplines. However, neither collaborative work nor BIM technology could possibly be standardized as the project conditions differs significantly depending on the project type, scope, client's BIM demands etc. Therefore, processes and work approaches should be tailored by the conditions at hand. Moreover, in order to bridge the gap between building practice and technology invention, closer collaboration between research institutes, universities and the construction sector are necessary (Sebastian, 2010). Bensalah et al., (2018) explains three levels of maturity of BIM as presented below:

Level 1 Used by one or more actors and includes the realization of the digital model but does not include the exchanges between the model automatically. Everyone updates their data individually and manually.

Level 2 In this level, each respective discipline's model are combined into a coordinated model. In level 2 project models, structured data, documentation and native file format (IFC) are to be delivered.

Level 3 This level is the ultimate and most efficient work procedure. In this level, every actor shares an unique model that allows intervention by all actors in real-time. In addition to "Level 2", the model is stored on a central server where all the changes are saved and available for everyone immediately.

2.1.1 BIM Implementation

When implementing BIM, significant changes will occur. Eastman et al. (2011) emphasize two significant changes that companies are facing when implementing BIM technology. The first major change is using a coordinated set of models during the construction/production phase. The second change is when a shared 3D model is used intensively as basis for all work processes and cooperation during the design phase. These transformations in technology and work processes require time and education investments within the subject.

According to Wondium et al. (2016), cooperation between the different parties is a game changer when implementing BIM within an organization. Wondium et al. (2016) states that collaboration between contractor and stakeholders is one of the main challenges and believe that changes in management are more challenging than in technology. This belief is also supported by Bryde et al. (2013) whom pinpoint changing roles among the stakeholders as a challenge. In order to achieve the potential benefits of BIM, stakeholders might need to change roles and work more cooperatively and in different teams. Another challenge when implementing BIM is the implementation cost that the organization or company must invest. BIM technology could only be successful if the BIM-users adapt and follow specific rules that suits the process. The learning process is time consuming and requires major human resources such as education and workshops.

In order to enable the integration of BIM, an understanding of success factors and risks with BIM implementation must be understood (Gao et al., 2016). These factors can be investigated both on individual, organisational and institutional levels. This is also supported by Eastman et al. (2011), whom emphasize the importance of considering every possible aspect of the company's business plan in order to avoid producing the same thing but in a different way. Before implementation, an overall understanding of the term BIM, related processes and a clear plan for the implementation process are required. Gao et al. (2016) believe that the process should be divided into steps or stages in order to make the implementation process more effective, where each step is dependent on the project conditions. Table 2.1 presents general steps that needs to be considered when implementing BIM, regardless of the AEC activity and the contractor's specific conditions (Eastman et al., 2011).

Table 2.1: The general steps to consider throughout the BIM implementation process by Eastman et al. (2011).

Step 1	BIM adoption plan provided by the top level managers, that includes all aspects of the company's business and an explanation of the impact that the proposed changes will have both internally and externally towards clients.
Step 2	Assign an internal team that consists of key managers to integrate and fulfill the plan along with time, cost and performance budgets.
Step 3	Start the integration by using the BIM technology on smaller pilot projects or on completed projects. When working with the pilot projects in parallel with existing systems.
Step 4	Educate and guide continued implementation of the BIM software together with team training. The senior managers need to be notified of the progress, issues that arose etc.
Step 5	Extend the BIM utilization into new projects. It is important to engage external members of the project in new collaborative manners that allows integration and sharing of information through the project model.
Step 6	Integrate BIM capabilities into the company's business concept and add these new business processes as contractual points towards clients and business partners.
Step 7	Periodically re-plan in order to reflect the benefits and issues that arose along the way. New goals that consider performance, time and cost, has to be set by the key managers. The company is now ready to further extend BIM facilitated changes to new departments and business units within the company.

2.1.2 BIM benefits throughout different project phases

Although the overall economic benefits of BIM are comprehensible in theory, BIM implementation in the construction sector has been met with scepticism, often by not investing in the technology. By using BIM during the design phase of the project cycle, document errors and rework can be reduced. Moreover, errors and time spent can be reduced in the design phase. In a study by Sacks, it is demonstrated that 3D-modeling has the potential to reduce the drafting cost by 80-84% (Gao et al., (2016). Another study by Sack and Barak found that the productivity gain from BIM modeling is estimated to approximately 15-41% of the hours required for construction documents.

Furthermore, Gao et al. (2016) pinpoint that BIM might be useful to streamline the operation and reduce the obstacles during the construction phase. BIM can provide powerful software for progress monitoring, which can be useful for quick and remote analyses of the building performance. During the construction phase, many changes are often made to the design due to previous unknown errors and omissions such as changes in material availability and client requirements. These changes or errors need to be resolved by the construction team onsite. For each change or error identified onsite, a procedure is started to determine the cause, address a solution and evaluate time and cost implications (Eastman et al., 2011). These procedures and resolutions might lead to legal disputes, additional costs and delays in the projects.

One of the major benefits of BIM is that the technology minimizes process related risks by preventing information loss, identifying safety risks onsite, decreasing resource and time for document exchanges between the enterprises as well as transitions between the construction stages. In Figure 2.1 below, the benefits of BIM in the different project phases are illustrated.

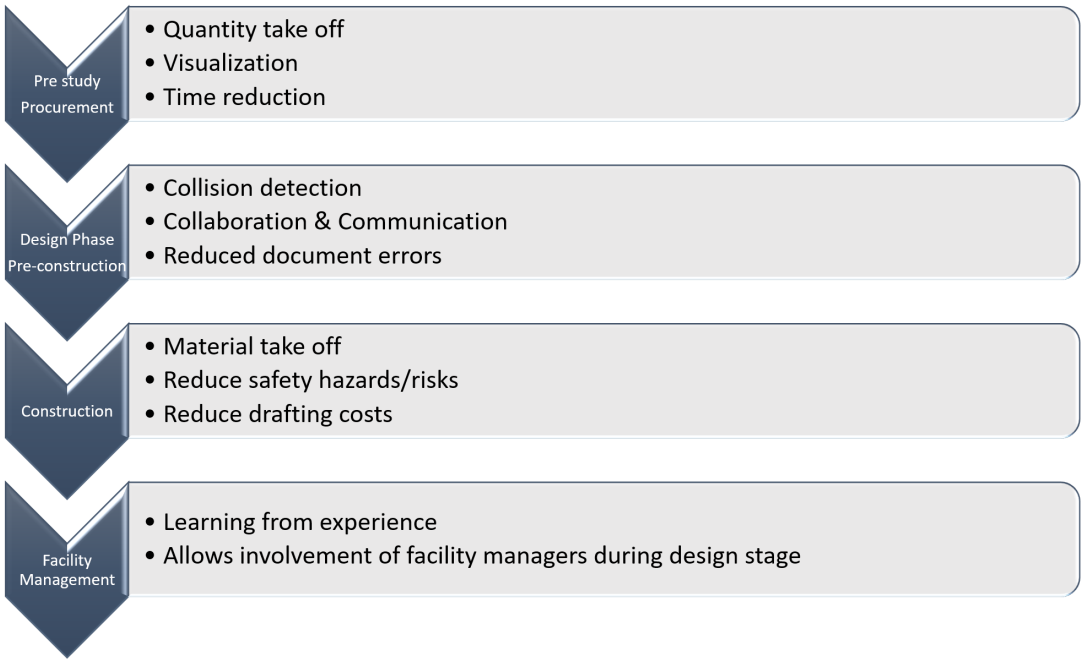

Figure 2.1: Benefits of BIM throughout different project phases.

During the tender phase, BIM is also useful since the coordinated model might contain detailed information about products and objects (Gao et al., 2016). This accelerates and simplifies the preparation of the tender documents.

When commissioning a project, final drawings are provided in order to reflect all project changes depending on the client requirements (Eastman et al., 2011). However, as the information provided to the client is often conveyed in traditional 2D format, the owner has to relay all relevant information to the facility management operation that is charged with maintaining the end product. This argument is also supported by Gao et al. (2016) whom state that beneficial possibilities within the

facility management and construction phase might be achieved as BIM can provide information that includes systems from all disciplines.

2.2 Procurement approaches

The rate of improvement from BIM implementation depends on the project phase and how well the project team cooperates in the coordinated project model. According to Eastman et al. (2011), the greatest challenge is found within the Design-Bid-Build (DBB) procurement approach, which corresponds to the Swedish AB contract, as the responsibilities for the design and construction phases are divided in separate contracts. As the contractor is not involved in the design phase, input from the production team is not included in the coordinated project model during the design process. DBB is therefore not estimated to be a time and cost efficient procurement approach when working with models in infrastructure projects.

Other procurement approaches such as Design-Build (DB), corresponding to the Swedish ABT contract, are more suitable when implementing BIM in a project. The DB procurement approach has been developed to combine the responsibility for design and construction into a single contract in order to simplify the project administration for the client (Eastman et al., 2011). The client signs contract directly with the contractor, providing the opportunity to develop an appropriate project strategy for the design phase that fulfill the client's requirements. When the project plan is approved, all modifications provided by the client are considered and implemented before the final budget is established. By allowing modifications in the earliest stages of the project, money and time otherwise spent on contract changes (ÄTA) can be significantly reduced.

In railway and road infrastructure projects provided by the government and authorities such as Swedish Transport Administration (STA), the DB procurement approach is often selected (Eadie and Graham, 2014). The major issue with the DB procurement approach in such projects is the lack of communication and cooperation between the contractor and subcontractors. Furthermore, the DB procurement approach often encourages a culture where contractors bid low and claim later due to the high competition and the Swedish Public Procurement Act (LOU) law.

2.2.1 Collaboration forms

Partnering, IPD and ECI are examples of collaboration forms often applied in combination with the procurement approach and BIM. Integrated project delivery (IPD) is a relatively new collaboration form developed in USA during the 21st century (Eastman et al., 2011). The collaboration form has gained popularity among BIM users as it promotes collaboration between different disciplines in the earliest stages of a project. Furthermore, as the project team uses the most appropriate collaborative tools at their disposal, IPD ensures that client requirements are met at minimum cost and time spent. With IPD, BIM implementation in the design phase can increase the knowledge of client demands and the accuracy of project cost estimations.

Additionally, IPD removes the need of document exchanges and associated delays.

Partnering is a collaboration form which lately has gained popularity in the Swedish AEC industry (Hallgren and Häggblad, 2017). It is believed that partnering is mostly suitable in complex projects with high uncertainty and long execution time. Partnering is characterized by bidding and evaluation of soft parameters such as competence, work experience, collaborative tools and workshops (Byggteknikförlaget, 2019). The collaboration form does not have an universal definition, which might cause misunderstandings and delays in the implementation process (Hallgren and Häggblad, 2017).

Early Contractor Involvement (ECI) delivery approach is characterized by allowing the contractor's skills and expertise in the early design phase to influence and aid the construction phase (Eadie and Graham, 2014). The collaboration approach is divided into a two-stage process with separate contracts for the design phase and the construction phase. This collaboration approach gives the ability to integrate a go/no go moment between stage 1 and 2, which makes the contractor exchangeable. Therefore, the collaboration form is preferable from a client perspective. Depending on during which phase the contractor is involved, the ECI implementation varies (Hallgren and Häggblad, 2017). In some cases, the contractor is involved in phase 1 at the client's request as they need advice during the development of the initial project idea. In other cases when the client only requires input regarding the pre-study, the contractor is involved in phase 2. Figure 2.2 demonstrates the ECI's impact on the project phases in comparison to the Design-Bid-Build and Design-Build procurement approaches.

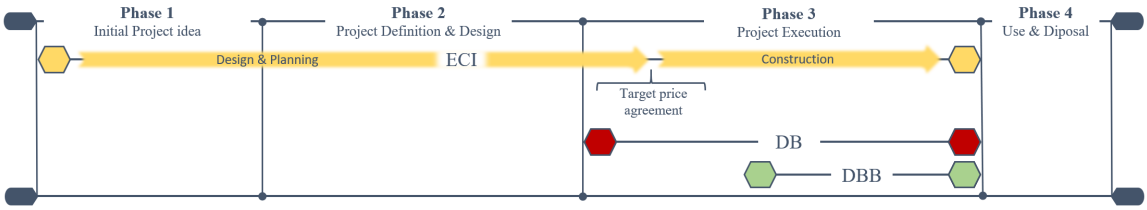

Figure 2.2: Self-illustrated chart over ECI, DBB and DB in the project life cycle.

2.2.2 LOD

The industry standard Level of development/detail (LOD) is a set of specifications which aid designers, clients and other stakeholders to, in a clear and effective way, determine and specify the contents of BIM in a project (United BIM, 2017). This industry standard was introduced in 2008 by the American Institute of Architects (AIA). LOD is specified in a range between 100 to 500, as explained in detail in Figure 2.3.

According to Weygant (2011), it is important to be aware of the project conditions and client requirements in order to know which level of detail to select. In order to avoid unnecessary information in the model, the BIM coordinator has to identify the end-user before creating an information database. Information that might be used in a model is information regarding e.g., specifications, identifications, dimensions, performance, sustainability, management and installations. The information in the model is often linked to a specific component such as windows, roof and walls. Moreover, different levels of detail are required depending on what the model is intended to be used for. If the model is used for calculation and one off pricing purposes, a higher level of detail is required. On the contrary, if visualization is the main purpose, a higher level of detail of surface areas is required instead (Weygant, 2011).

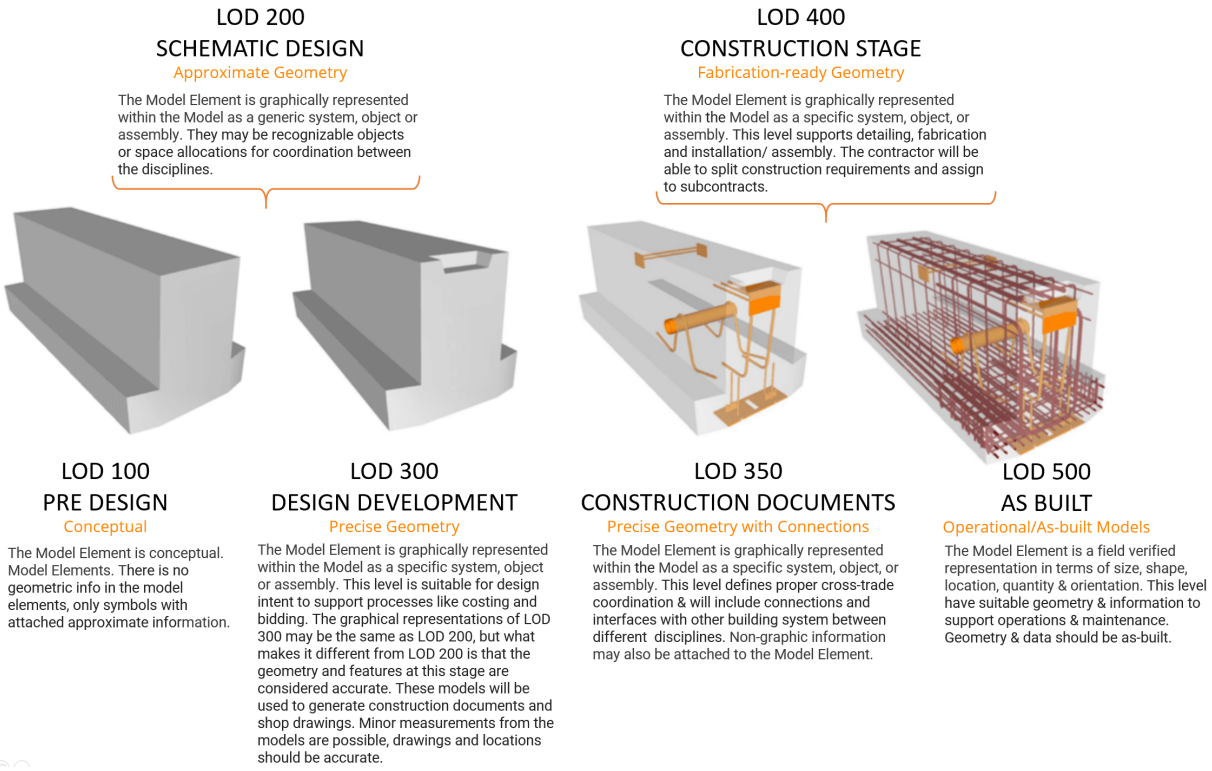

Figure 2.3: Level of development/detail, re-illustrated from MaineBIM (2020) and United BIM (2017).

2.3 BIM application within infrastructure projects

In this section, three cases from STA with BIM application are presented. Each case is presented by summarizing identified benefits and challenges.

Mälarbanan in Stockholm is one of the most trafficked stretches with 20 km long double-track railway between Tomteboda and Kallhäll (Trafikvekret, 2021). Due to congestion and delays, STA has obtained the mission to extend the double-track railway with two new tracks in order to ease the traffic. This project is one of the successful cases that has been using BIM technology throughout the project. Benefits and challenges for this case are presented in Table 2.2.

Table 2.2: Project Mälarbanan in Stockholm, Sweden (Bensalah et al., 2018).

Project	Mälarabanan
Client	STA (Trafikverket)
Company	Vectura
Delivery	2016
Benefits	During pre study and the design phase, integration of the facility organization and management system provided a better understanding of the railway facility as all actors could see the common 3D model in the early stages. Moreover, collaboration between the different disciplines was improved by using integrated project delivery (IPD). This improved the project quality, saved time and reduced project cost due to the more efficient work procedure. In addition, other benefits such as 3D simulation, quantity take-off, time planing and cost estimation was gained.
Challenges	The challenges with BIM implementation in this project was to coordinate all the disciplines to work in a coordinated model. The gained benefits would not have been achieved if this was not followed.
Reference	(Bensalah et al., 2018)

The Röforsbro project is another example of a successful case where BIM has been used. Beside all the benefits in the design-, production-, and facility management phases, the project model has provided a juridical definition in the procurement process. In order to avoid confusion regarding the amount of elements and element type in the model during the procurement process, special BIM demands were required in the design phase. When a model is used for procurement purposes, the contractor has the right to calculate on the cheapest solution if contradictory data exist in the model, according to the Swedish general building conditions (DB and DBB). The BIM maturity level in this project is equivalent to levels 2 and 3 defined by Bensalah et al. (2018) in chapter 2.1.1.

According to Malmkvist (2013), one challenging task during the project was to find an appropriate project Common Data Environment (CDE). The software Tekla was used but the software did not have a well developed CDE for infrastructure projects which became a major challenge in the project. Furthermore, the main economic disadvantage was the expensive software licenses, as the disciplines used several different softwares. A main condition during the design phase was therefore that the model-file had to work with different softwares. The project team further states that it was difficult to only work with free-viewer versions of softwares as the analyses could not be exported (Malkvist, 2013).

Table 2.3: Project Röforsbron in Arboga, Sweden (Malmkvist, 2013).

Project	Röforsbron
Client	STA (Trafikverket)
Company	WSP & Skanska AB
Delivery	2013
Benefits	The project model enhanced the information flow among the different parties by enabling information to be shared concurrently in the project. This made it even easier to provide as-built documents. Otherwise common alterations and additional work have been reduced as well as the production cost. An examination showed that many contractors perceived the model as more adaptable and flexible to work with than traditional drawings. The design team claims that the collaboration between the contractor, designers and production team increased the possibility of creative solutions at early stages. The coordinated project model has been used for tendering purposes between contractors and subcontractors. Overall, the construction team were positive about BIM in the project and claim that the work was significantly simplified.
Challenges	The challenges in this project have been e.g., to implement a new working procedure based on the BIM demands. It has been difficult to mange the documents and the coordinated project model in the facility management phase due to a lack of archiving routines. During the building permission process, the local municipality often requires complete 3D-models if no 2D-drawings are provided. In this case, the municipality made an exception and approved 2D-views from the model. Accommodated drawings and 2D-views were provided due to difficulties with measurements and quantity take off.
Reference	(Malmkvist, 2013)

Another project worth mentioning is the railway project East Link (Ostlänken) between Järna and Lindköpning in sweden. The project consisted of 30 disciplines that used over 23 different software applications. The project was initially planned to conduct a traditional BIM review, but this method is time consuming and would increase miscommunication and misinterpretation between the disciplines. Therefore, the iTwin solution was proposed as a pilot project for this six-year-long project. Initially, the design team were sceptical about a new procedure for the review process, but with COVID-19 conditions they had to reevaluate their collaboration and their coordination model to enable a more effective and remote design review process.

Furthermore, the project was announced as 2021 Founders' Honorees during the global conference "Bentley Year in Infrastructure and going digital awards" for using, integrating and collaborating through the platform iTwin (Bentley, 2021). Both AFRY and Tyréns were awarded the badge of honour "Digital Adaption, 2021" for the advancements they have made by "going digital" and advancing the infrastructure profession.

Table 2.4: Project East Link in Stockholm, Sweden (Bentley, 2021).

Project	East Link (Ostlänken)
Client	STA (Trafikverket)
Company	AFRY & Tyréns
Delivery	Estimated to be fully operational by 2035
Benefits	The project team selected the Bentley iTwin platform to facilitate and streamline the review process. The platform simplified the transition to a BIM working procedure and increased the model availability by approximately 75%. Furthermore, the review steps were reduced by 50%, which made the review process much easier, see Figure 2.4. Besides the award and integration of new tools, using the digital twin solution saved 33% in design review time. The review cost was also reduced by 21% which amounts to approximately EUR 20,000 (Bentley, 2021)
Challenges	Since the iTwin platform was used as a pilot project by the design team, it has been a great challenge to avoid contractual changes towards the client. Furthermore, the team was very aware to not interrupt the current process for the design team and not impact the project time schedule as it was very compressed. The main technical challenge was storage of project data. The project was compelled by contract to work and store data on the client's CDE ProjectWise, which was an on-premises solution.
Reference	(Trafikverket, 2019), (Bentley, 2021) & (Ramström and Haas, 2022)

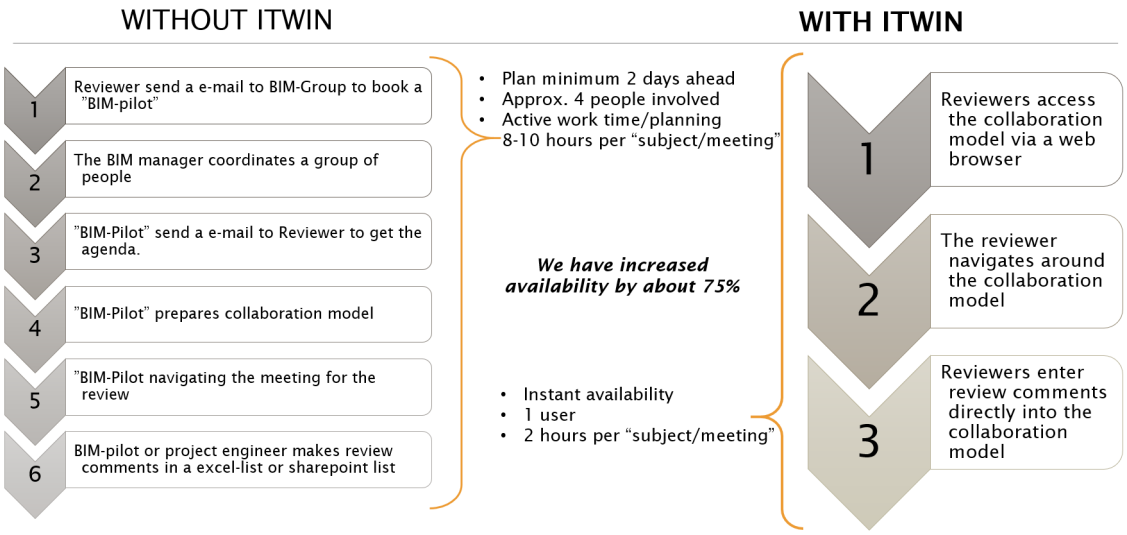

Figure 2.4: Design review steps (for non designers) with and without iTwin by Ramström and Haas (2022).

3

Context of the study

This chapter provides necessary information and data regarding the studied company. The working procedure within the company and how it is related to the clients will be explained briefly in order to understand the context of this study. Moreover, the infrastructure public client STA will also be introduced.

3.1 AFRY

AFRY, also known as ÅF, is one of the largest international consultant companies. The company started in February 1895 in Malmö as Sweden's first industrial association to take care of the interests of the owners of steam generators and other pressure vessels, under the name "The Southern Swedish Steam Generator Association" (AFRY History, 2021). AFRY has been a part of several major technological shifts over the years such as electricity, automation and digitalization. The company changed name during 2019 when ÅF acquired Pöyry PLC and is now one combined company under the new brand name AFRY.

3.1.1 Transportation Sweden

Since this thesis is conducted in collaboration with AFRY, it is important to understand the organization and work structure within the company and the studied business area. The business area Transportation Sweden belongs to the division infrastructure, consists of different business sections and exists in fifteen countries all over Europe (AFRY, 2021). The business area consists of business units, focusing on different areas e.g., rail, road, bridge design, geo engineering and traffic as illustrated in Figure 3.1. As mentioned in chapter 1, this study focuses on employees working with BIM and within infrastructure projects. The blue marked squares in the organization plan in Figure 3.1, demonstrate the units from where this study has been conducted.

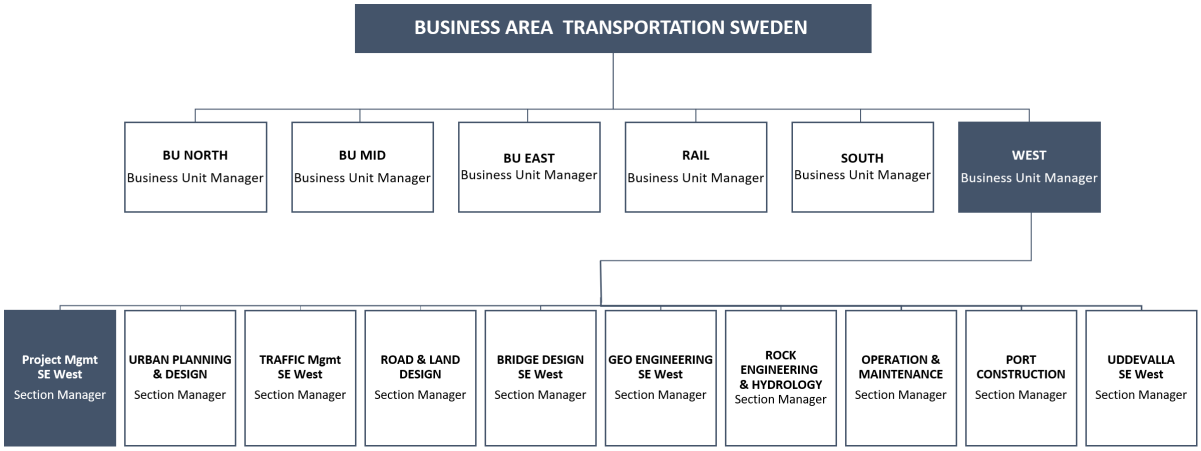

Figure 3.1: Structure for the business area Transportation, Sweden (AFRY, 2022)

3.1.2 Working procedure at Transportation Sweden

The current working procedure at Transportation Sweden for CAD-, BIM-, VDC-work is presented in Figure 3.2. The business area primarily works with infrastructure and railway projects, where the project process is divided into two phases, namely the sales phase and the delivery phase. The sales phase consists of lead, prospect, bid project, contract negotiations and formalize/handover contract. The delivery phase consists of planning, execution and closing. Currently, the BIM work

is often considered during the project start up at the beginning of the delivery phase. The BIM requirements are therefore considered and provided in the start up phase, which increases the information flow before the contractor can initiate the execution phase.

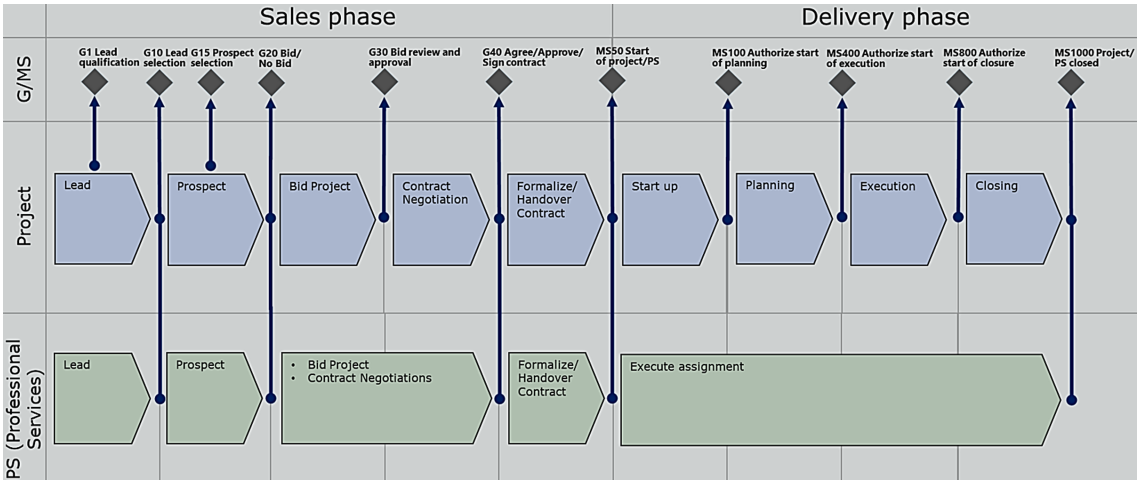

Figure 3.2: Sales and Project model (Helin, 2022)

When the CAD/BIM consultants get stuck in the projects and need help, the following support process is available, see Figure 3.3. The designers can either contact the different help networks or ask their colleagues. This is a long and time consuming process for CAD/BIM consultants to access. According to AFRY's development plan, BIM assessment approach, the support process will be considered and reviewed in order to improve it (AFRY RAIL, 2022).

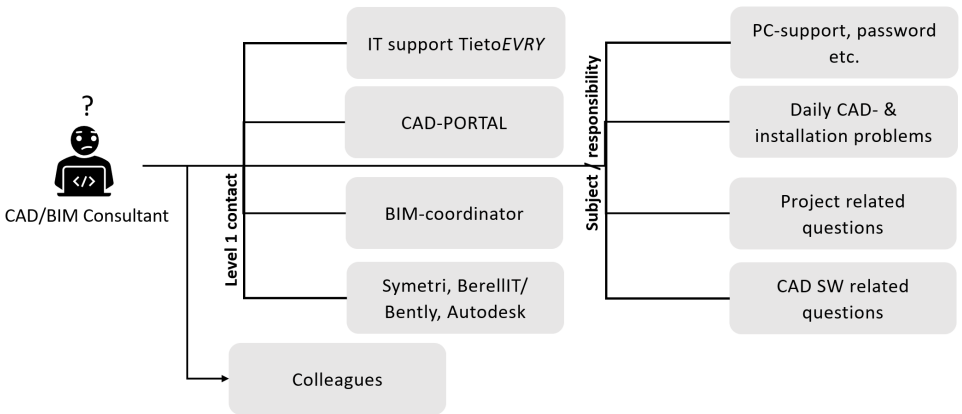

Figure 3.3: CAD & BIM support process, re-illustrated from AFRY RAIL (2022)

3.2 STA

The Swedish Transport Administration (STA) is a government agency with the aim to create and provide a safe and national transport infrastructure. STA acts like a passive client, which means that they want all projects to be designed and executed by external enterprises (Trafikverket, 2021). STA is one of the largest clients and collaborative partners with AFRY. The work procedure and BIM conditions at the studied business area are always based on STA's requirements in the projects.

STA has developed a BIM staircase in order to simplify their demands towards their suppliers. According to the STA's BIM staircase, suppliers were working with a maturity level between 0 and 1 during 2015 at the same time as STA worked to develop requirements regarding level 2 towards their suppliers (Trafikverket, 2015). At this moment suppliers such as AFRY are often working within level 2. However, the STA are planning to gradually integrate new demands regarding level 3 in their contract conditions.

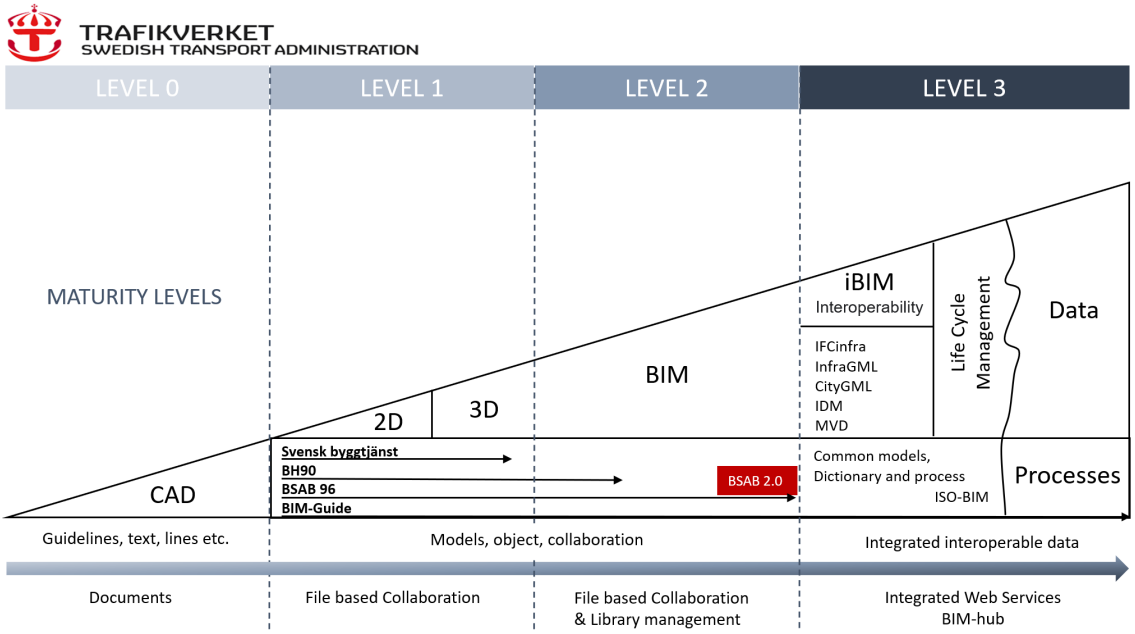

Figure 3.4: The STA's BIM staircase, re-illustrated (Trafikverket, 2015)

According to an interview conducted by Hallgren and Häggblad (2017) with a BIM strategist at STA, level 2 is currently the stage they works at. Moreover, the BIM strategist pinpointed that the requirements are not specified and that they are left for interpretation by the suppliers which in turn results in unusable models for STA. An example regarding the maturity level in the projects can be described as following in the STA's mission description. See appendix F for the entire description.

"Subject area models must at least state what has previously been reported on drawings, maps and pictures as well as other technical and environmental conditions."

"The LOD regarding geometric accounting of objects in 3D must correspond to the content and purpose of the assignment type."

- Trafikverket (2021)

Furthermore, the BIM strategist states that demanding too many conditions in a project might prevent the service providers freedom of choosing an appropriate working procedure and might decrease innovation possibilities (Hallgren and Häggblad, 2017). The BIM strategist also mentions that one main BIM challenge in the AEC industry is the lack of a common classification system. However, a new digital classification system called CoClass has been developed by specialists in the industry in order to investigate and face this challenge. The CoClass system includes information through the project's entire life cycle and will be an important communication tool between all actors.

3.2.1 Current situation description

The STA has recently published a report regarding digitization within the infrastructure industry with the aim to identify and publish their vision and future development plans. The report is established by Mats Karlsson at STA and presents and describes the current situation regarding BIM at STA (Karlsson, 2021). In the report, changes in the contracts are suggested with the aim to facilitate and aid the industry's BIM development. The main purpose of the report is to enable an integrated digital working procedure for the upcoming versions of DB and DBB with the industry's actors and service providers. The IT-tools that are used in the AEC industry today have the capacity to manage almost every part in level 3 in the BIM staircase. The internal projects with the consultants are executed in the first half of level 3 but the delivery methods between different phases such as e.g., production, design, tendering and facility management are in the best case in level 1 according the report from STA.

Furthermore, the contract aspects have been summarized as following. The current DB and DBB procurement approach does not address or demand any kind of digital working procedure (Karlsson, 2021). This means, per definition, that the maturity BIM level are 0 in the BIM staircase. In order to address this, substantial changes to the Swedish procurement approaches DB and DBB are necessary.

4
Methodology

This chapter aims to present the research approach and methodology for the thesis. The chosen method for conducting the questionnaire survey and interview study will be argued for and explained.

4.1 Research approach & method selection

There are primarily three main research approaches that can be used when conducting academic reports, namely the deductive, inductive and abductive research approaches. The deductive approach aims to test an existing theory where the reasoning moves from general observations to a specific observation, whilst the inductive approach aims to develop a theory and move from specific observations to generalization (Bell et al., 2019). According to Streefkerk (2019), the inductive research approach is appropriate to apply when there is a lack of literature on a topic. The benefit of these approaches are that they can be combined in a larger study. In addition, an abductive research approach, also called systematic combining, is a nonlinear path-dependent process with a mix of deductive and inductive research approaches (Dubois and Gadde, 2002). This process is based on going back and forth between the case study and theory in order to define the theoretical framework and provide analysis and recommendations.

To carry out this study, an abductive method approach has been applied, which includes both qualitative and quantitative data. A qualitative research approach relies on observations and understandings of different perspectives (Bell et al., 2019). Examples of qualitative research approaches are interviews performed as notes, audio or video recording and analyses of text documents. A Qualitative research approach is more useful for identifying and characterising data from e.g., experiments, official statistics and questionnaires with focus on measuring a phenomena. The difference between qualitative and quantitative method approaches can be explained as the way we measure and view the collected data.

In order to collect data for the investigations in this study, a questionnaire survey and an interview study have been conducted, see the illustrated thesis structure and content in Figure 4.1. In essence, the thesis consists of the following: literature study, pre-study to approve the problem formulation, questionnaire survey, interview study, analyses, discussions and conclusions.

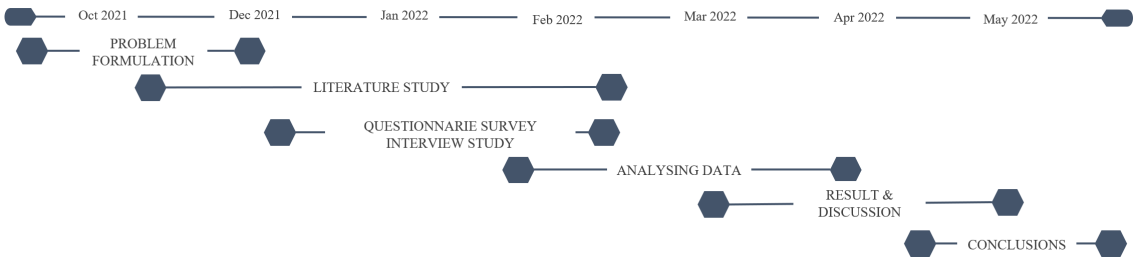

Figure 4.1: Structure and content of the thesis.

4.2 Questionnaire Survey

Questionnaire surveys are often associated with samplings that represent a wider population or organization (Bell et al., 2019). Samplings are important to consider in order to avoid biased data (Bhandari, 2021). Furthermore, questionnaire surveys often aim to generalize the results of an studied organization. A stratified sampling method has been applied to ensure that the right group is captured for the questionnaire. Moreover, basic instruction and explanation have been included in order to outline the purpose for the participants. For different illustrations by McCombes (2021), Thomas and Laura (2021) see Appendix E - Samplings.

4.2.1 Preparation for the questionnaire survey

When preparing for the questionnaire survey, a structured survey with a combination of closed and open-ended questions was chosen. In order to simplify and enhance the analyses of the collected data, the survey questions have been examined by professionals and my supervisor at AFRY. Moreover, the questionnaire survey consists of two sections with the aim to measure different concepts, were the sections are clearly defined. The amount of closed questions has been systematically chosen in the survey to reduce the execution time for the participants and also to be able to consider correlations. The questionnaire survey was sent out to 45 section managers that forwarded the survey to their employees. The amount of possible respondents was approximately 150-200 within Transportation Sweden, whom in some context work with BIM and digitization at AFRY.

4.2.2 Analysing the results

Different statistical methods can be used when analysing the data of a questionnaire survey such as descriptive statistics, pie charts, histograms, chi-square test and correlations. The design of the questionnaires was based on open-ended questions, multiple-choice questions, closed questions and Net Promoter Score (NPS). NPS questions is a metric used in customer experience programs and measures the loyalty of customers to a company. NPS scores are measured with a single question and the result is not expressed in percentage but as an absolute number between -100 and +100, where a higher score is desirable.

Furthermore, a combination of several statistical methods is used depending on the received data. The results are also presented through graphical charts such as tables, indicators and histograms. Moreover the chi-square method is used when analysing the closed questions such as e.g., "Yes/No", gender, age, education and work experience in order to find correlations between different questions.

4.3 Interview study

This thesis is based on both qualitative and quantitative research approaches. The interview study is an important and necessary part in this study as it complement the questionnaire survey. In total, seven employees with different background, position, age and gender were interviewed. Stratified and cluster samplings have been used for the interview study where the employees were divided into clusters depending their position, work experience and role. Some were then randomly selected and asked to participate in the interview study. Random selection from the clusters allows simple sampling that supports the validity of the results (Thomas, 2020). The interviews in this study are qualitative and semi-structured to optimize the ability of limitless expressions among the interviewees.

4.3.1 Preparation of the interview questions

An interview can be divided into two categories, namely open-ended and closed questions. The closed questions aim to provide specific answers to a topic where the focus is on fact and not on impressions (Bhandari, 2021). The open-ended questions aims to bring out the interviewees point on view on the topic and allow the interviewee to give an answer based on their own experience. For this study, a combination of open-ended and closed questions have been used. The interview questions were well prepared beforehand and small changes have been made during the procedure in order to adapt the questions to each interviewee depending on their qualifications. The interview structure starts with closed questions in order to receive personal information about the interviewee such as education, role, work experience and general BIM knowledge. The interview continues with open-ended questions in order to utilize the interviewees' knowledge to describe and contribute to the research questions for this study.

4.3.2 Analysing the results

Several descriptive and qualitative methods can be used when analysing the results of an interview study. Content analysis and thematic analysis which are the most common methods are appropriate to be applied when the aim is to achieve a lower level of interpretation rather than a more accurate response (Vaismoradi et al., 2016). Thematic analysis, on the other hand, is an approach used to understand aspects of a phenomenon, described frequently or in depth by the participants.

The interview study aims to provide the participants' general opinion, description and interpretation of the BIM subject, the implementation of BIM and further improvements regarding BIM within the company. Therefore, it has been important to chose appropriate approaches for analysis to highlight suggestions, improvement factors and future research questions within the subject. In this study, a combination of thematic and content analysis has been applied in order to provide both analytical and conceptual results.

4.4 Research Ethics

According to NSPE "Code of Ethics for Engineers" (2019) engineers have a direct and vital societal impact on the quality of life for people and therefore have to perform in a professional manner. The services provided by engineers therefore require honesty, equity, impartiality and expectation to exhibit the highest standard of integrity (NSPE, 2019).

As a part of the research ethics constitute, it is important that ethics are considered throughout the entire thesis process. The main principle considered during the master thesis processes, especially during the interview sessions, were honesty in the way of performing and behaving. Prior to the interviews, the interviewees were informed that they would be recorded and urged to speak and answer truthfully. Furthermore, the interviewees were also informed that they would remain anonymous and that company sensitive details would be omitted. Moreover, efforts were made to ensure that the interview study and questionnaire survey were as objective and generalized as possible to avoid the risk of back-tracing any responses to a specific respondent or interviewee. Since the master thesis aims to benefit the company, the report has been examined by supervisor and digital manager Peter Bolt at AFRY to ensure anonymity of the participants and protection of any sensitive company data or information.

Lastly, to protect the environment from needless paper consumption, the questionnaire survey was created in Office 365 in a digital environment and was digitally sent out by email with a link to access the survey.

5

Results and Analysis

This chapter will provide and present the results from the conducted interview study and the questionnaire survey. Furthermore, the results will be systematically analyzed in order to simplify and clarify the collected data.

5.1 Questionnaire Survey

The questionnaire survey was sent out to eight business units within the studied business area at AFRY, which consist of approximately 45 section managers and more than 200 employees. Out of approximately 150-200 possible respondents, 65 answers were received. The results show that the age, role, education and work experience among the respondents are relatively mixed, which is beneficial as it diversifies the results. However, 66% out of the participants were designers within disciplines such as e.g., rail, road and bridge design. Among the respondents, there were also project managers, architects, geotechnical, BIM coordinators, data coordinators and BIM strategists. 34% of the participants have a Bachelor's degree and 27% a Master of Science in Engineering. The remaining 39% have other education such as polytechnic, high school or equivalent. Moreover, the majority of the participants have more than 5 years of work experience which indicates that the responses were given by experienced professionals in the sector.

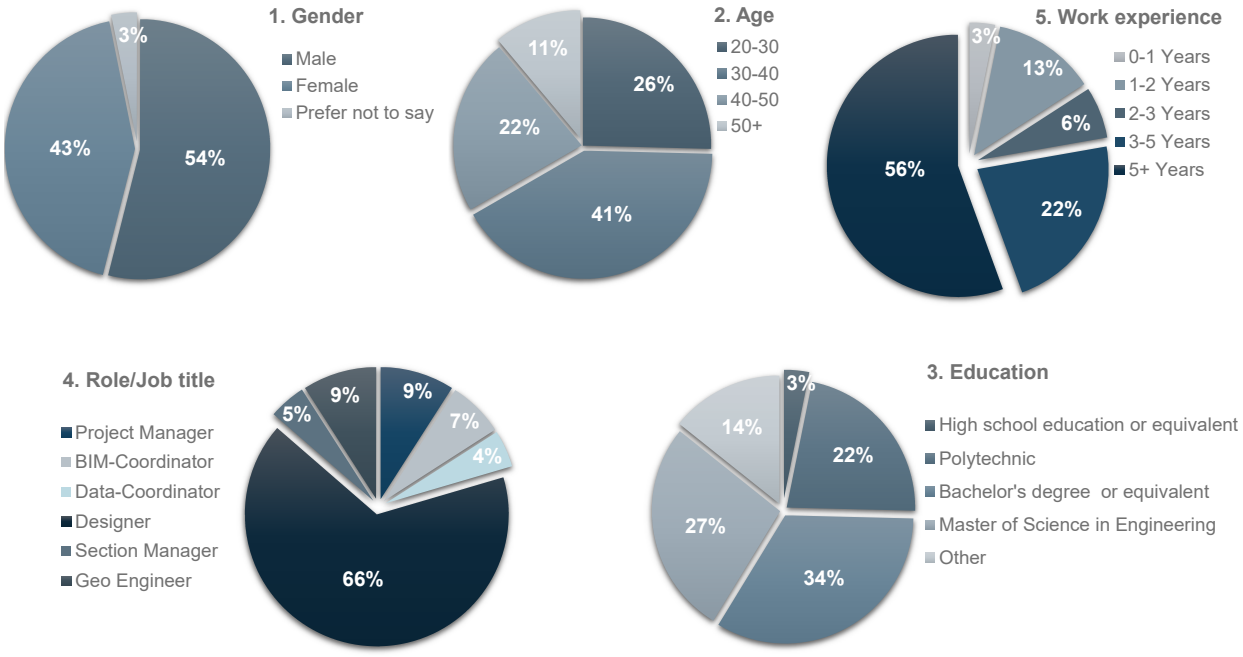

Figure 5.1: Responses from questions 1-5 in the questionnaire survey.

5.1.1 BIM education and competence

The familiarity and perception of the term BIM were investigated. The results establish that 94% of the participants were familiar with the term, 5% were not and 1% were unsure about the actual meaning of the term BIM. Among the 94% familiar with the term, BIM was defined as 3D-modeling but also as a working process and a platform that gathers information from different disciplines. Some of the answers will be presented below.

"Design in 3D, a common working procedure."
"BIM is when we use a 3D model for visualization purposes in the projects."
"Information flow within the project."
"BIM is a coordination tool for me."
"Collection of data in a structured manner."

- Anonymous answers from question 11

Among the respondents, 42% have not received any education or courses in CAD/BIM neither internally nor externally. Among those whom have received BIM education, 26% were through internal educations and 32% through external educations. 82% of the respondents that have received any kind of education are interested in further education, while 12% are unsure and 6% not interested. Of the participants that have not received any kind of education or courses, 85% are interested and willing to take CAD/BIM courses while 15% are not interested at all.

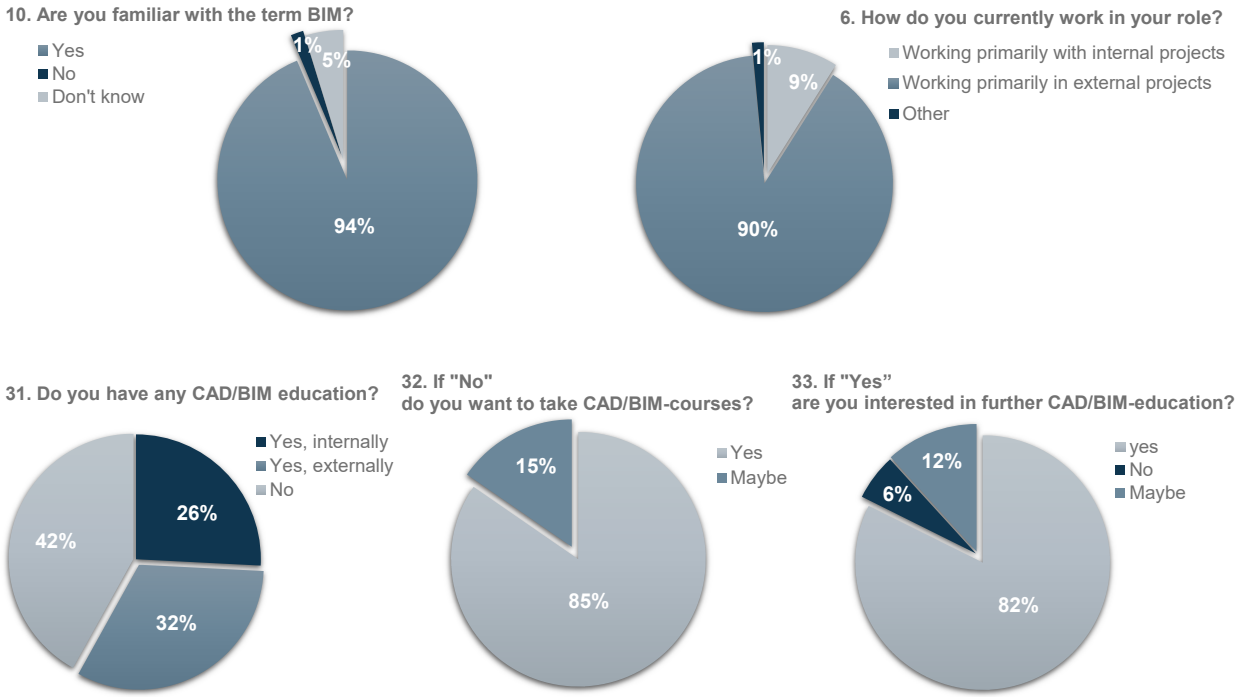

Figure 5.2: Responses from questions 6, 10 and 31-33 in the questionnaire survey.

The questionnaire survey establishes that the majority of the respondents are working primarily in external projects and only 9% works in internal projects. Furthermore, the results shows that only 8% of the designers are designing solely in 3D. 48% are flexible and design in both 2D and 3D, whilst 25% design only in 2D. Among the 25% of designers that only work in 2D, 59% are willing to gradually proceed into 3D whilst 23% do not feel comfortable with 3D modeling.

In order to identify the reasons behind why some of the employees do not support a transition from 2D to 3D, an alternative question was prepared in the questionnaire survey. A selection of the answers are presented below. The main reasons point at specific cases, sub-operations and an overall lack of knowledge within the subject.

"I do not think that 3D-modeling is efficient when working with traffic signals in railway projects. We can not use the BIM model to provide the same information we have in our drawings and it causes additional work if we choose BIM in our case. Furthermore, the response we receive from STA in our project demonstrate that even they do not really recognize the benefits of the BIM-model."

"I do not see the point of designing in 3D since my job is to provide circuit layouts only. I am afraid that it will take more time to do geographical models in 3D than 2D. In my case, it would only be time consuming to design in 3D."

"I think it is time consuming and complicated. Furthermore, I believe that we do not need it because the workers at construction site will never trust and use a 3D-model as construction documents."

- Anonymous answers from question 16

To find out how much time the designers are spending to redo their models or other work when designing, specific open-ended and multiple-choice questions were chosen in the survey. The results show that 19% of the participants are spending between 8-10 hours/week on issues or redoing their work. 22% answered 5-7 hours/week and the remaining 59% answered 0-4 hours/week. The main causes are found to be bugs because of inefficient work procedures and routines.

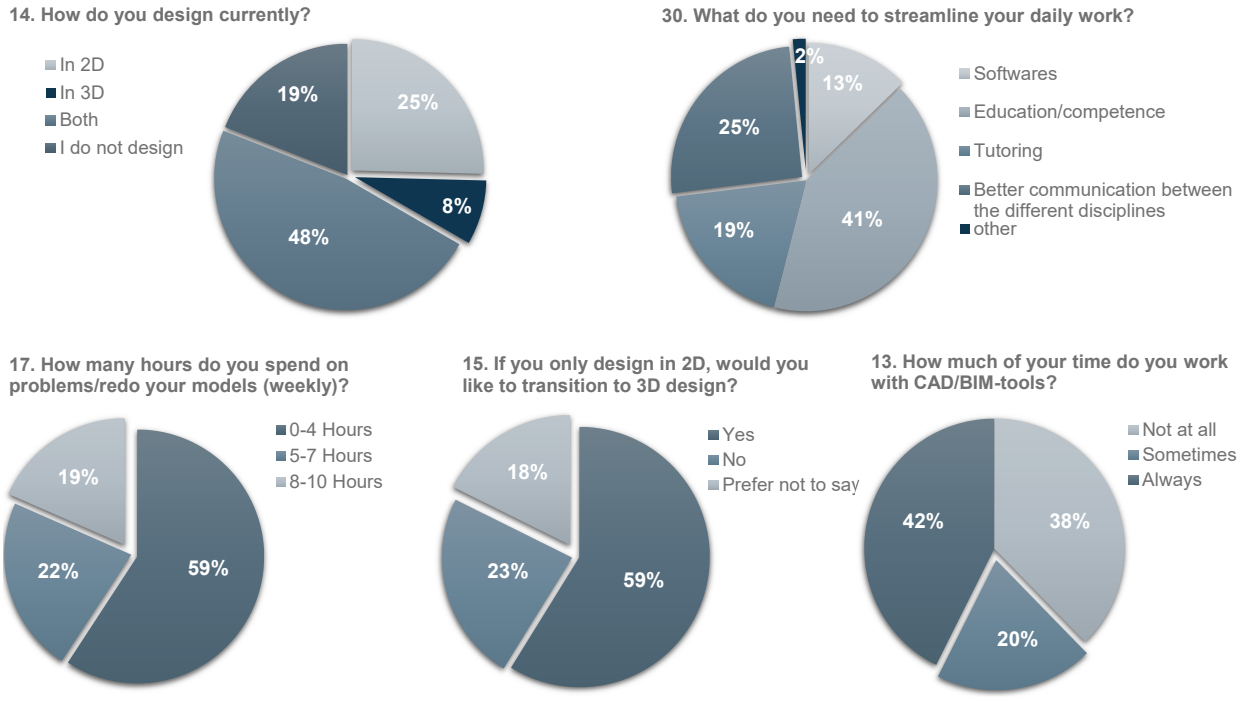

Figure 5.3: Responses from questions 17, 30 and 13-15 in the questionnaire survey.

5.1.2 Utilization of BIM in everyday work

The second part of the questionnaire survey consists of several detailed open-ended questions about utilization of BIM, which aims to establish how the employees are working with different software and what they are suggesting as improvement factors. Furthermore, solutions to issues the employees wrestle with on a daily basis will be highlighted.

One of the most common answers regarding obstacles when working with BIM, was that the client does not require any BIM demands. Further restricting factors are found to be a lack of availability of appropriate education among the employees or that BIM is not used in current projects. The majority of the respondents also think that BIM is most efficient and beneficial in the design and production phases. 41% of the participants point at a lack of education and knowledge within the subject as a restricting factor in their everyday work. Moreover, 25% believe that miscommunication between different disciplines might restrict the efficiency in the everyday work. Furthermore, 19% state that they are not receiving great tutoring, whilst 13% indicates the lack of appropriate software as a restricting factor to streamline their work on a daily basis.

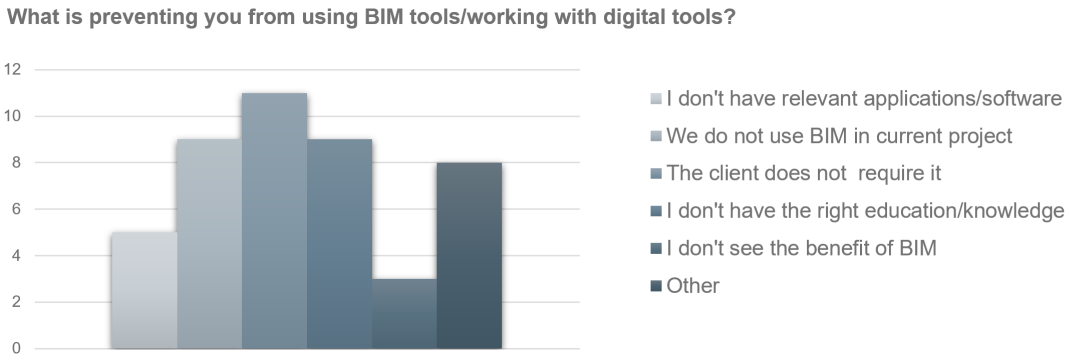

Figure 5.4: Responses from question 29 in the questionnaire survey.

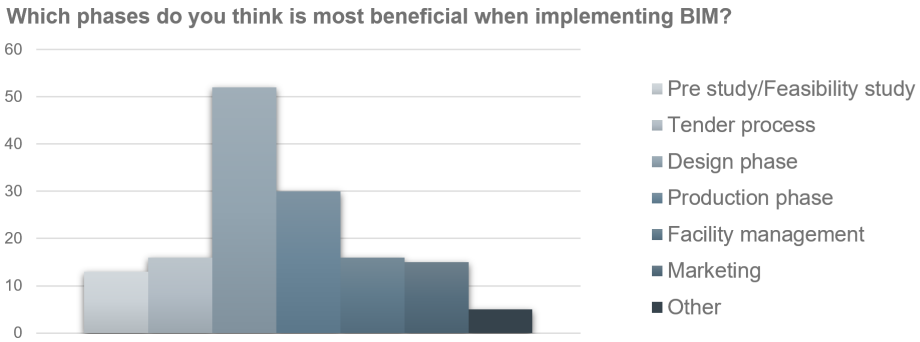

Figure 5.5: Responses from question 12 in the questionnaire survey.

Furthermore, there were several open-ended questions about the daily BIM work and how it possibly can be streamlined. Among the suggestions for improvement factors, many answers highlight technical improvements such as e.g., integrating plug-ins for

CAD applications, modeling by parameters, automatically updated tools and pipe specs.

Other improvement factors such as e.g., straight forward routines regarding 3D modeling, well developed templates, smoother collaboration between the different disciplines, increase of landscape designers with 3D skills and developed guidelines for creating drawings from 3D models have also been brought up. Further suggestions regarding automation of different tasks in the daily work have been obtained. Drawing management is one of the pinpointed improvement suggestions from the respondents. The suggestions also highlight different processes that can be automatized such as providing quantity take off lists and stamps of approval on the construction documents. Another respondent states:

"The promis-e application with the rail signaling has good opportunities for automation but bugs and lack of internal development might slow down the usage of it".

It is believed that drawing execution is a huge improvement opportunity if 2D drawings can be automatically produced from the 3D model. Moreover, the participants were able to express their thoughts freely about the development of the current framework and other improvement factors that might not have been covered by the closed questions. These results and expressions are presented in Appendix C.

5.1.3 The client perception

In order to provide an overall picture of BIM within the studied business area, it is important to consider the employees perception of the client's BIM needs and attitude. The result shows that 42% of the respondents in the questionnaire survey state that they generally have difficulties interpreting the client's requirements. Furthermore, according to the range in Figure 5.6 that measures the familiarity of the client's mission description regarding 3D modeling and LOD, 39% of the respondents selected a range between 0-5. Moreover, a follow up question demonstrates that this is mainly caused by unclear BIM demands in the client's mission description. Moreover, 21% do not know where to find the clients BIM-conditions and 18% have selected a lack of time as a reason for not being well aware of the client's BIM demands.

In addition, an open-ended question was asked about restricting factors, that according to the respondents impair the quality and in some cases extend the delivery time in projects. The most frequent answers were; "lack of well developed templates and routines", "lack of time and resources for reviewing the models before delivery", "lack of review routines", "encouragement to collaboration among colleagues", "high work load, which reduces the time for quality assurance in projects", "the disciplines' estimated time schedule in the projects is often too short".

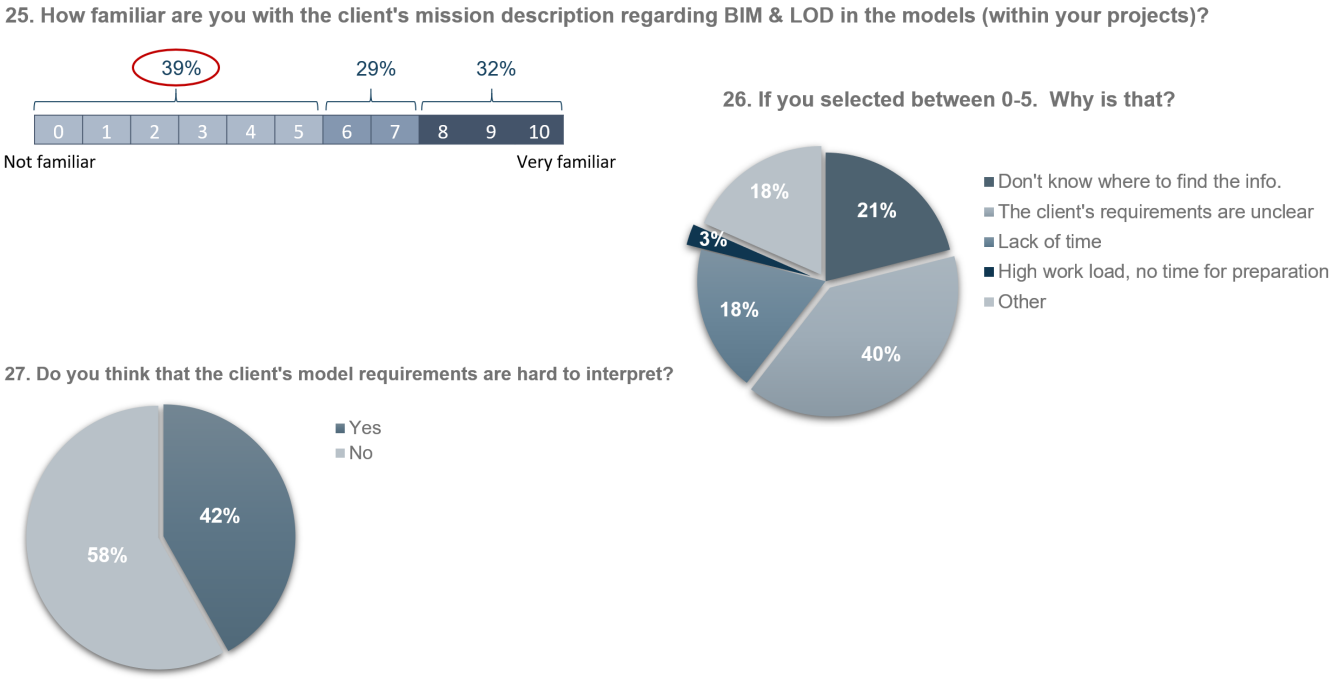

Figure 5.6: Responses from questions 25-26 & 27 in the questionnaire survey.

In addition, participants were also asked an open-ended question about how they validate and ensure that the products are correct before they are delivered to the client. The most frequent answers are; usage of checklists, internal reviews and self-monitoring routines. Some of the respondents also mentioned that they are

asking their colleagues to "look over" the documents but that this is not enough and further improvements should be developed and implemented in the review phase. The respondents were also asked about the type of projects and phases they are usually working within. The result shows that the majority of the participants are working in projects with both turnkey contracts (DB) and traditional contract (DBB) which is an amount of 38 responses. Secondly, DBB contract were selected by 10 responses. Furthermore, follow-up questions were asked about the specific procurement approaches in order to identify which phase is most common within the selected procurement approaches and in which project phases the challenges occurs. In an early stage when working with *"construction documents"*, was the most frequent answer among participants working in DB projects. In second place *"procurement process/tendering"* phase was chosen within DB projects. Participants working within DBB projects selected phases where *"project planning document"* and *"construction documents"* are provided.

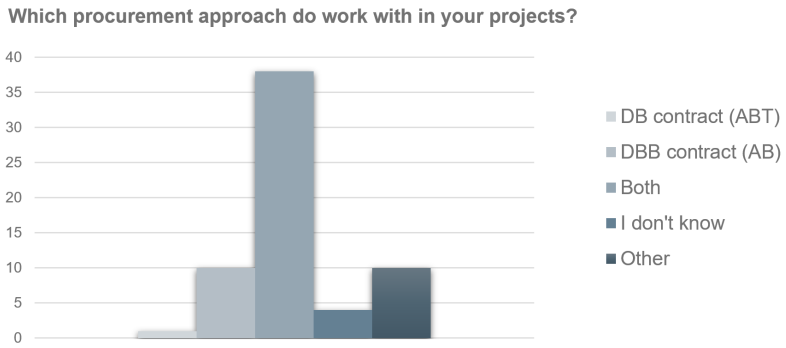

Figure 5.7: Responses from question 7 in the questionnaire survey.

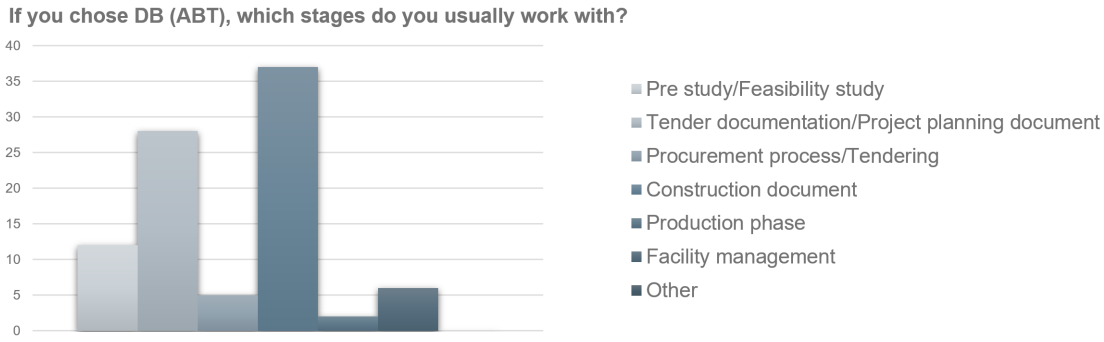

Figure 5.8: Responses from question 8 in the questionnaire survey.

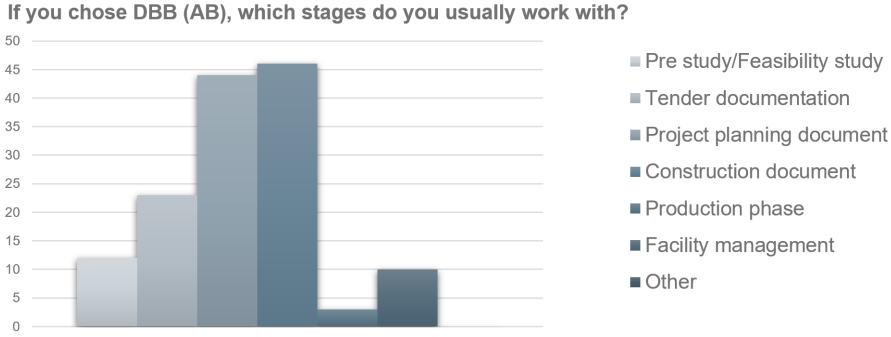

Figure 5.9: Responses from question 9 in the questionnaire survey.

5.1.4 Correlations

Findings from the questionnaire survey show correlations between age and education. The younger participants have higher university degree, whilst older employees have more work experience but only a few of them having a professional or bachelor's degree. The digital environment and BIM technology are more embraced by the younger employees. The overall perception is that older employees do not trust BIM technology as they often think the method is complicated and do not see the benefits of it. This results in a lower knowledge of BIM among the older participants and indicates that participants with higher degree of education have a positive view of the BIM implementation than the ones with a lower degree of education.

There are also correlations between design method, age and work experience. The older designers are working mostly in 2D whilst the younger participants work mostly in 3D. The older designers that only design in 2D in general have a negative attitude towards gradually transition to 3D, whilst the younger designers are positive and some of them are already working in 3D. Further correlations can also be found between gender and the attitude towards transitioning to 3D. The results demonstrate that females are more positive and supportive regarding gradually transitioning from 2D to 3D design. In addition, there were slightly more male than female, with male accounting for 54% and female for 43% of the participants. Although the percentage of male and female is relatively equal, there are divided opinions regarding transition to 3D depending on gender among the 2D-designers, accounting to 25% in total 65 respondents. However, this result could be a coincidence due to the limited amount of participants in the questionnaire survey.

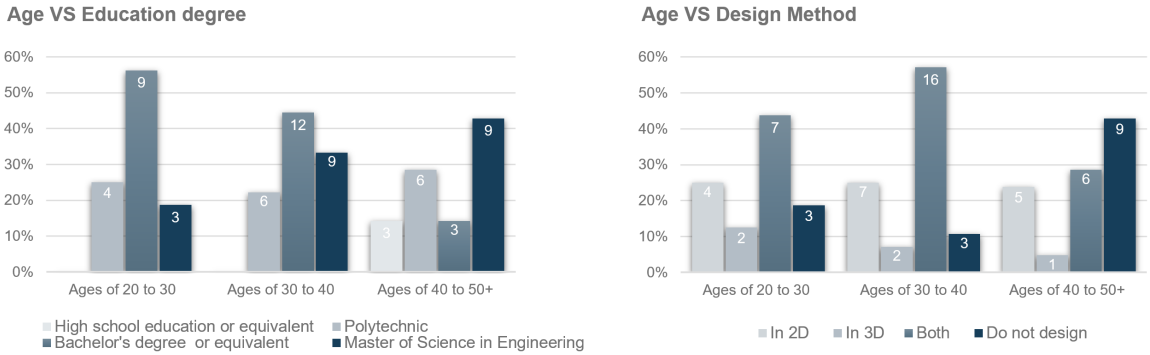

Figure 5.10: Correlations between questions 2-3 and 2-14 in the questionnaire.

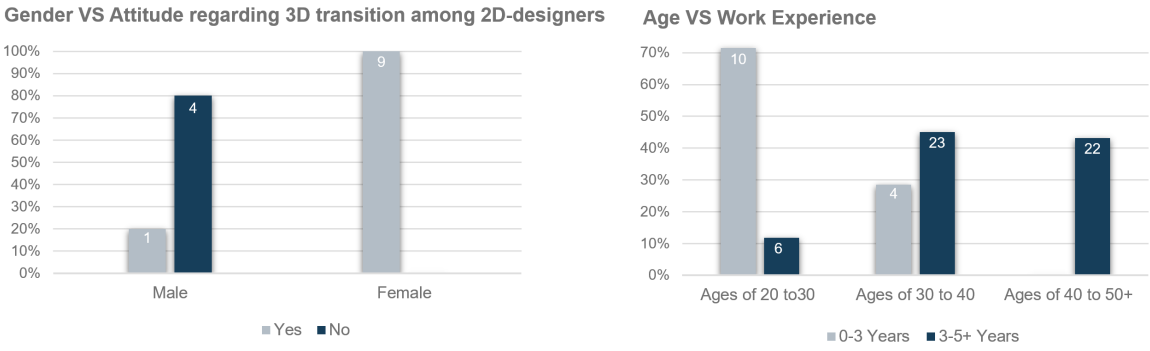

Figure 5.11: Correlations between questions 1-15 and 2-5 in the questionnaire.

The results reveal that only 20% of male respondents (2D-designers) support a gradual transition from 2D to 3D, whilst 100% of the female respondents (2D-designers) support 3D transition. In other words, 80% of the male 2D-designers do not support a gradual transition from 2D to 3D.

Further correlations have been shown in the results between the working method, error time, age and the usage of the available CAD-object library in the projects depending on the design method. It is clear that participants aged 20-30 years are designing mostly in 3D whilst respondents aged 30 to 50+ years are either designing in both 2D and 3D or do not design at all. Furthermore, error time and restricting factors on a daily basis are frequent among participants working in both 2D and 3D, accounting for 59%. Moreover, the amount of error time (7-10 hours/week) are higher among the participants designing in 2D, accounting for 26% in comparison to 3D, accounting for 9%. Generally, the amount of error time is lower among designers working in 3D compare to 2D or those who design in both 2D and 3D.

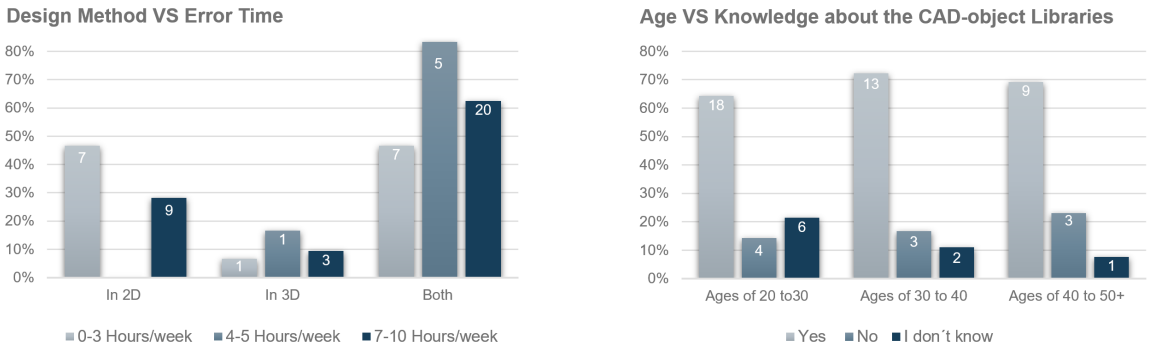

Figure 5.12: Correlation between questions 14-17 and 2-19 in the questionnaire.

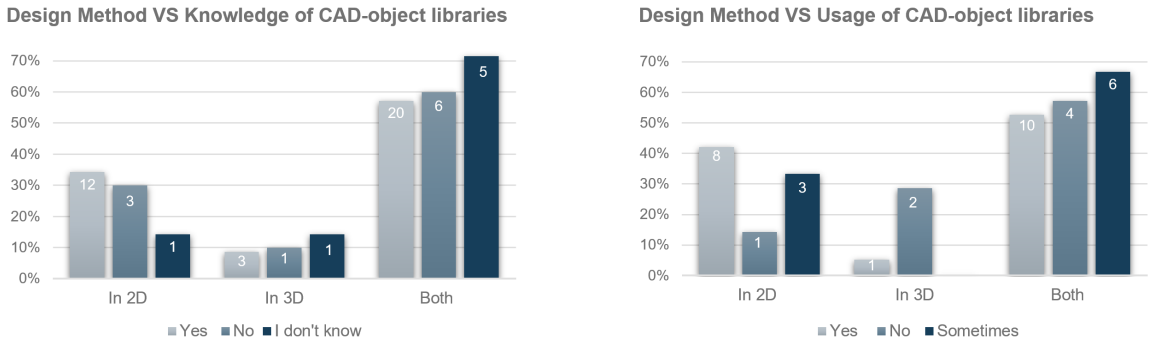

Figure 5.13: Correlation between questions 14-19 and 14-20 in the questionnaire.

The knowledge of the internal CAD-object libraries are slightly common among the participants of different ages. However, the knowledge and usage of the CAD-object libraries are more common among designers working in 2D accounting for 29% and 40%. Additionally, the most common design method is a combination of both 2D and 3D, which provide obviously highest rate in both knowledge and usage of CAD-object libraries. However, among the combined design method users,

50% of the participants with the knowledge of the CAD-object libraries actually use the libraries. 24% of the respondents are using the current libraries occasionally as the content is lacking and needs to be developed. 9% states that the content is not usable whilst 4% do not know how to use it at all. The remaining 17% gives other reasons for not using the libraries, some of the expressions are presented below.

"There are only a few of them e.g., railings and curbsides in the projects. I do not know of any AFRY specific libraries. The available objects are the only ones we have in Novapoint".

"The libraries are often in 2D and it requires additional work to import them in 3D."

"In our section the libraries are in 3D and we only design in 2D."

"I do not design but know that we have different templates."

- Anonymous answers from question 20

5.2 Interview Study

This chapter will present the results from the interview study which consist of 7 interviews, conducted among different employees with different backgrounds, ages and roles, within the studied business area Transportation Sweden. The most interesting answers will be selected and presented in this chapter. The complete interview questions and layout are attached in Appendix A. In Table 5.1, the interviewees are presented based on their role, age and work experience.

Interviewee	Position/Role	Age	Work Experience
Interviewee A	Project Manager	35+	15+
Interviewee B	Section Manager/Project Manager	35+	15+
Interviewee C	Section Manager	40+	20+
Interviewee D	BIM Coordinator	30+	5+
Interviewee E	BIM Coordinator/BIM Strategist	25+	5+
Interviewee F	BIM Coordinator/BIM Strategist	25+	5+
Interviewee G	BIM Coordinator/Road Designer	25+	5+

Table 5.1: Presentation of the interviewees.

5.2.1 BIM Awareness and LOD

The majority of the interviewees were aware of the term BIM and defined it as a process and work procedure. Among the section and project managers, BIM was related to review-able 3D-object or model based design. Furthermore, everyone agreed and mentioned that the level of development/detail (LOD) in BIM models at Transportation Sweden depends on the project but that in general there is potential for improvement.

"It depends totally on the type and scope of the projects. I would say that LOD in the major projects have a good level due to the budget and time we have in comparison with the smaller projects. However, we do not have general routines or framework when it comes to BIM determination levels within our projects, which I believe we need to develop and establish."

- Interviewee E

There were divided opinions about which procurement approach and project type are most suitable for BIM projects. The general view was that in major projects, where money and time are not an issue, the potential of BIM implementation is higher. Consideration of the projects complexity was also mentioned as a determining factor for BIM implementation according to interviewees D and E. A few other participants believe that the projects' scope or procurement approach is not determining and that BIM is applicable irrespectively. Interviewees C, D, E and G shared the same perception regarding BIM implementation in major projects. The majority of the interviewees had difficulties to pick or suggest the right procurement

approach and only three of them could give a straight answer. Interviewees B and E sees the DBB procurement approach as most suitable when using BIM, whilst interviewee F think BIM is suitable with the DB procurement approach.

"Design build (DB) contract is more appropriate when using BIM in my opinion. When using an DBB approach, we are not able to control how BIM will be used, therefore it is risky to use BIM in this procurement approach. In DB contract we know the demands of BIM and often know how to work with it in order to fulfill the client's demands. This is more difficult when using DBB approach."

- Interviewee F

"The procurement approach is absolutely a determining factor on the projects regarding utilization of BIM. I think we usually think that in a project with DB procurement approach the BIM Implementation is easier. I believe that it is actually the opposite since we still are in a position where the design team and the entrepreneurs is confident to fall back in old performance and do not dare to apply BIM in a DB contract when it is a fixed price. Therefore a DBB procurement approach is more suitable when implementing BIM in a project."

- Interviewee B

Regardning the various benefits of BIM implementation, a majority of the interviewees highlighted that most benefits are a direct result of 3D visualization and a simplified work procedure, specially during the design phase. Through 3D visualisation, misunderstandings and faulty information between the different disciplines can be reduced.

"The structure in our projects, that we have control of the data, trace-ability of the work, history, that we can follow the project development and progress. If we do not use this methods and software, it can be very messy, miscommunication occurs and data can be lost. A very important task in our job is the delivery phase. High quality of our products and services cannot be achieved if we do not use the document managing systems we use today."

- Interviewee E

"We provide a better picture a of the project when we visualize everything in 3D. The communication is simplified and reduces misunderstandings between the different parties."

- Interviewee G

5.2.2 BIM Challenges

Regarding BIM challenges, many interesting and different answers were given. In interviews with interviewees C and G, the client was brought up a as a significant restricting factor in BIM implementation. The interviewees claim that it is difficult to make the client understand the benefits, specifically the profits of BIM. Therefore, consultants end up in a situation were they need to motivate their work and educate the client on the subject. Interviewee C claims that it is the major clients that often need to be convinced rather than the minor clients and implies that decision makers within the major client's organization often only see the economic consequences when implementing BIM in a project. Furthermore, other challenges such as e.g., collaboration within and between different organizations and teams were mentioned. The cause of unsuccessful collaboration is claimed to be a lack of routines for communication among the disciplines within a project. Additionally, challenges with education and technical issues were brought up by interviewee F.

"Education within the subject and software knowledge is a big challenge. We also have technical challenges such as lack of necessary software, or sometimes lack of well developed functions within the software."

- Interviewee F

Furthermore, challenges regarding the implementation of BIM were also mentioned. Interviewee F specifically pinpointed difficulties with BIM implementation in ongoing projects. It is argued that in order to implement BIM in a later project phase such as e.g., the production phase, changes in existing working procedures are required. Interviewee F also claims that it is difficult to establish an appropriate maturity degree in ongoing projects. This claim is also supported by interviewee A, who states that different work procedures and new methods are required in order to achieve AFRY's BIM vision and goals.

"There are local cultures within the different disciplines which make it very hard to convince each respective discipline to impose a new working procedure in an ongoing project."

- Interviewee A

In the interview with interviewee D, challenges caused by misinterpretation of the client's requirements are mentioned. These challenges specifically occur in the design phase of a project and stem from a lack of preparation or an incorrect interpretation of the client's mission description. Interviewee D believes that the project manager should be responsible for explaining and guiding the designers to use the right method from the project start up.

"One recurring problem that often occurs during the design phase is that the designers are doing their work wrong at the first place and needs to redo it later. I mean those who are usually working in 2D, are often not familiar with the clients requirements regarding BIM and realize that they have to deliver a 3D-model to the client very late in the project. This puts high pressure on the project team as they have to provide the 3D-model just before delivery."

- Interviewee D

Furthermore, interviewee D states that by considering BIM as a separate discipline in a project, the client makes a critical mistake. It is explained that this is a recurring problem and argued that BIM must be demanded and integrated within each respective discipline in order to create the coordinated project model and use BIM as intended. By considering BIM as a separate discipline, other actors within the project expect the BIM coordinators to solve all the problems in the coordinated project model. In order to fulfill and achieve the client's requirements, the different disciplines have to design with the BIM demands kept in mind during the entire design phase.

"I think the responsibility for making the clients mission description clear should lay on project manager. The BIM demands should be explained in order to make the other disciplines understand that the BIM requirements are applied to the whole project and that BIM is not a separate discipline."

- Interviewee D

This argument is also supported by interviewee B who states that the BIM and data coordinators need a larger mandate or involvement at the project start up to establish the project conditions. This is necessary in order to avoid any major impositions before the project delivery.

"In my opinion BIM and data coordinators should be a part of the project management team, or lets say a complement to the project manager. They should not be considered as a discipline but rather as a part of the project management team that have the same mandate as the project manager. The BIM coordinator should also be involved before the design phase in order to establish the conditions for the project"

- Interviewee B

5.2.3 Digital Environment

The interview study also consists of questions about AFRY's digital environment. In the study, it is established that only one of the seven interviewees, interviewee F, has experience of so called "drawing free" projects, where the project has been entirely executed in 3D. The project is briefly outlined in Chapter 2.2. Interviewee F was overall satisfied with the success of the digital work methods implemented but argue that the information level (LOD) in the coordinated project model could have been increased. However, interviewee F believes that traditional 2D drawings should not be replaced by a 3D model, but rather be complemented.

Moreover, the lack of routines and a common BIM framework within AFRY were emphasized. According to the majority of the interviewees, there is no common BIM framework or guideline available to follow currently. The interviewees claim that clear directives and general BIM guidelines are necessary to implement BIM successfully. Furthermore, the interviewees shed light on the fact that, without a lack of routines and BIM guidelines, consultants often have to resort to self-made frameworks based on experience. This is at the risk of unintentionally excluding valuable knowledge and experience from others, hindering the overall development within the company.

"We need routines. I mean we have done excellent work within different projects all over the country but it is almost like What happens in the project, stays in the project. In other words, we need to gather all the fantastic work and experience, create common guidelines and apply them in future projects."

- Interviewee A

5.2.4 BIM in the studied organization

As the infrastructure industry is undergoing digital changes the studied business area Transportation Sweden has been actively committed to the digital evolution. The studied business area has a development plan called BIM assessment approach, which aims to improve and streamline the workflow within their projects (AFRY Rail Digitalization, 2021). The development plan consists of four stages, namely inventory, maturity assessment, analysis/strategy, implementation/education and is sustained by different disciplines through workshops, meetings, networks etc. This development plan is managed by experienced key managers at AFRY and is an ongoing investigation within the company.

In order to provide accurate information for this study and increase a better understanding of the company's working procedure, data from different workshops, network meetings and business plans have been collected and analyzed. The best current practices have been determined during a workshop conducted with BIM and data coordinators from different regions in Sweden. Figure 5.14 demonstrates the identified best practises along with their pros and cons, as concluded during the workshop.

Field	Pros	Cons/How to proceed
Geo Calculation & GIS	• Great in early stages • Overall project	• Implement them in other projects? • How to take the info from early stages to design?
iTwin Collaboration	• Mass report • Time for review • iTwin - collaboration with Microsoft/Bentley • Increasing the communication in the Project	• Do we save time & improve quality? • Is there a risk with too high resolutions/information in the model • How to make sure we can reuse best practice • High price - only for big projects? • Risk of overestimating the model (wrong data input, manual effort)
4D & Automation	• Automation • Increased efficiency • Easy to change and use afterwards • Combine with Geokalkyl • Reduce errors during modeling	• Expert use (Trust of use) • Which are the weaknesses / being aware about
Unreal Engine Visualization	• High quality rendering • Accessible information possible • Free for use • Accessible via web • Use of FME for transformation • Performance • It is scalable on global level	• How to make it accessible for everyone • How to use it to win more projects
Quadri	• Certain level of BIM standard even if customer doesn´t want it • Everything is in one place • Connectors to many software tools (Civil3D)	• Closed BIM
ProjectWise	• Automated imports of meta data • Improve quality of data • Focusing on the whole project	• Lack of integration
Create guardrails with Dynamo & Civil3D	• Automized workflow for creating guardrails • Quick creation • Easy to use	• These workflows should be in Autodesk products already implemented • Maintenance on scripts to keep up with • Dynamo/Civil3D versions. • Depended on Special Competence

Figure 5.14: Best Practices shared on BIM workshop conducted autumn 2021.

6
Discussion

In this chapter, discussion and analyses based on the empirical findings, the interview study, the questionnaire survey and correlations to the theoretical framework in previous chapters will be presented. Further analyses will be done based on the previous analyses conducted partly in the Chapter 5. Furthermore, the author's thoughts and interpretations of the subject are also included in this chapter.

6.1 BIM knowledge and usage in everyday work

According to the literature review, BIM is defined as more than just a software. This definition is aligned with the description from the interview study and questionnaire survey. 94% of the respondents in the questionnaire survey state that they are familiar with the term BIM. In summary, the respondents describe the technology as a framework in a digital environment where collaboration and visualization are the main success factor for information flow throughout a project. In Chapter 3.1, AFRY's work procedure, organization and support system are explained with the aim to get an overall view of how the company is working with BIM on a daily basis. The support, sale and delivery systems can be improved and adapted to facilitate BIM implementation in projects. For instance, the BIM requirements should be brought up in the sales phase in order to achieve a smoother transition of the BIM services into the delivery phase, see Figure 3.2, Chapter 3.1.2. The support system can also be improved by adding a common and general BIM standard with the aim to eliminate recurring issues such as non updated templates, scripts and checklists. This has also been emphasized by the participants both in the interview study and questionnaire survey.

From the results, it is evident that there exist numerous experienced employees within the sector with innovative ideas and solutions to existing problems. Still, many leading companies within the sector does not utilize nor consider these ideas and solutions. To avoid this, someone within the companies should be assigned and responsible to gather, summarize and implement such ideas and solutions. This is absolutely necessary and a possible success factor when implementing BIM in infrastructure projects.

6.1.1 Quality and validation before delivery

One of the most important phases when working with BIM is the delivery phase. During this phase, there are numerous documents and drawings that must be reviewed to ensure that they align with the client's mission description and requirements. In order to identify the risk and improvement factors, there were several questions in the questionnaire survey regarding validation and quality. The results demonstrate that AFRY, as a service provider, is working heavily with delivery routines and document reviews before delivery. The main set up factor is often a lack of review time in the project time schedule. It is therefore very important to consider review time during the tender stage of a project. Furthermore, idle software, lack of support from colleagues, IT-bugs, lack of updated templates, high workload, non developed object library both in 2D and 3D are other restricting factors that have a negative impact on the product/service delivery. Regarding the software issues, the collected data from the workshop in Figure 5.14, Chapter 5.2.4 highlights the specific issues, solutions and improvement factors of each respective software.

The most frequently used method for ensuring and reviewing documents before delivery is through checklists according to the questionnaire survey. This is very interesting as the interview study also pinpoints a lack of well developed checklists and templates. As the usage of checklists is highly frequent in the review phase, more effort should be taking to streamline the review process. This can be achieved by e.g., taking advantage of best practices from various projects in the company and reusing this information.

Findings from the interview study and questionnaire survey indicate a lack of willingness from other colleagues or team members to interact and collaborate with each other. Furthermore, the findings suggest that this could be caused by an inadequate group dynamic within the organization. In order to enhance the collaboration between employees, encouragement should be considered. This can be applied in combination with workshops such as DISC (Dominance, Influence, Steadiness, Compliance) personality tests to gain insights and build better and stronger relationships within the project teams.

6.1.2 BIM maturity level and LOD

There were divided opinion regarding the maturity level of BIM within the business area Transportation Sweden. The overall perception is that the maturity level of BIM is dependent on the project's BIM conditions. Education and knowledge in the subject are other causes which decreases the maturity level internally. This has also been confirmed in the questionnaire survey. The interview study enlightens specific restricting factors such as a lack of e.g., internal frameworks, role descriptions, well developed templates and scripts. These restricting factors cause delays in the BIM implementation process and might decrease the BIM maturity level in a project. Furthermore, due to these restricting factors, different divisions within the studied business area obtain different maturity levels depending on the "in house" knowledge and competence. Findings from the literature review establish three maturity levels of BIM as defined by Bensaleh et al., (2018). By comparing the results from the interview study and questionnaire survey, the studied business area generally seems to be between levels 1 and 2 depending on the factors mentioned above.

A determining factor when working with BIM is the level of development/detail (LOD) of the coordinated model. According to the literature review, one of the key factors when deciding the LOD in projects is to be aware of the client's BIM requirements (Weygant, 2011). It is therefore important that the client's requirements are clarified and understood by everyone in the project. Furthermore, the questionnaire survey demonstrates that the participants have difficulties with interpreting the client's requirements. According to 42%, the client's requirements are difficult to interpret. This is due to unclear BIM demands in the client's mission description. This claim is also confirmed by a BIM strategist at STA who states and accuses STA for not being more specific in their mission descriptions. The unclear BIM demands risks being misinterpreted, which could result in faulty and unusable models for the

end-users. The main causes for the unclear BIM demands are found to be ignorance and a overall lack of knowledge of BIM among the clients. If the clients does not understand BIM and its information that follows, it will be difficult to shape and describe their BIM demands. Additionally, the interview study highlights an interesting factor regarding this issue, which is that BIM usually is considered as a discipline by the client instead of a forced demand on each respective discipline. This creates confusion within the project team which in turn causes misunderstandings between the designers and the BIM coordinator for instance. Furthermore, the different disciplines might not consider BIM model requirements during the design phase, thereby forcing responsibility on the BIM coordinator to achieve the model requirements. This issue can be solved by giving the project manager main responsibility to clarify the BIM conditions before project start up. By doing this, the workflow can be streamlined and good collaboration during the project process will be achieved.

The East Link project, described in Chapter 2.3, is one of the successful BIM projects by AFRY and Tyréns. However, according to the conducted interview study, the LOD in this project could have been increased. Additionally, a combined 3D model with 2D drawings is recommended in larger infrastructure projects in order to achieve optimal efficiency. As information such as e.g., electrical construction drawings regarding wiring or construction details might be hard to illustrate in a 3D model, a combination of a 3D model and 2D drawings can be beneficial.

The interview study highlights a reccurring mistake related to misinterpretations of the client's mission description during the design phase. It is common that the designers are not aware of the BIM requirements and often realize that they have to deliver a 3D model at the end of a project. This mistake might lead to significant delays and economical consequences. However, this could be solved by giving the BIM & Data coordinators a wider mandate regarding the project's framework by including them in the project start up. Furthermore, when including the BIM & Data coordinators earlier in the projects, they can guide the project team in the right direction. Therefore, BIM & Data coordinators should be considered as a part of the project management team and not as a discipline or support function.

6.2 Implementation challenges and solutions

Eastman et al. (2011) outline two significant changes a company face during BIM implementation within an organization or a project. The design and construction phases will be most affected by the implementation process as the coordinated set of 3D-models will be used as basis of all design and construction work. To achieve this extensive transformation, time and education are required. The management challenges might therefore be more difficult to overcome than the technical challenges according to Eastman et al. (2011). Furthermore, according to Bryde et al. (2013), role changes within the project team must be made in order to achieve the potential benefits of BIM. In addition, the interview study confirms these statements as the interviewees believe that it is more challenging to implement BIM in later stages such as e.g., the design- or construction phase. This is due to the local cultures within different disciplines that might be hard to change in ongoing projects where i.e., the project team needs to be convinced to follow a new work procedure.

The lack of routines and a common BIM maturity level within the company were lifted as the main reasons for delays in BIM implementation in projects. Larger consultant companies such as AFRY have an extensive library of previously held successful projects, with methods and frameworks that could be learned from and reused. The absolute optimal solution would be to take advantage of the previous project's success factors, digital solutions and frameworks etc., and apply them in current and future projects. By establishing a common AFRY framework, the work and information flow will be simplified for the employees. This framework should be forced and motivated by AFRY regardless of the client's demands.

Well, it feels like AFRY is not taking the BIM implementation and evolution seriously. I mean it feels like they know that we need to improve BIM in the company but no one knows what actually goes on at the ground level where the BIM coordinators and designer are working. The focus is more on the client's BIM demands, but we ourselves within AFRY does not have framework to follow. We should have our own standards for BIM models regardless of the client's demands.

- Interviewee D

Education within the BIM subject and software is necessary for the project team. This requires economic investment in the project organization which might slow down the BIM implementation process (Bryde et al., 2013). This is a major issue in the consultant industry as the business mentality is about selling services per hour. Furthermore, this means that it will be almost impossible to invest in the implementation process internally if the clients are unwilling to cover the education and implementation costs. This issue is also mentioned in the questionnaire survey as the participants pinpoint a lack of appropriate education/competence as a preventing factor for working more digitally. This confirms that the consultant companies in the infrastructure industry does not invest enough in education within BIM technology.
In the interview study, the interviewees highlight the fact that they, on a daily basis,

have to convince the clients to choose BIM as a work procedure. Furthermore, it is stated that it is very challenging to prove the benefits of BIM from a short term perspective. This is due to the fact that the benefits of BIM are most noticeable and profitable in the long term,

According to the development plan at AFRY, a group of BIM strategists together with a digital manager have recently been tasked to investigate, evaluate and improve upon the current working procedure within the business area Transportation Sweden. By analysing the implementation step-stair introduced by Eastman et al. (2011), it is evident that AFRY is between steps 2 and 3 in the implementation process.

6.2.1 Contract impact on BIM implementation

The empirical findings demonstrate several diverse factors for an appropriate procurement approach when using BIM in infrastructure projects. There are two procurement approaches and three collaboration forms presented in the theory which demonstrate that the IPD collaboration approach has gained popularity and acceptance among BIM users over the past few years (Eastman et al., 2011). BIM users prefer this approach as the management strategy gives them the mandate to control BIM conditions throughout the project. Partnering and Early Contractor Involvement (ECI) are equivalent collaboration approaches to IPD and are most commonly applied in Sweden. These collaboration approaches might be beneficial for BIM users as one of the main characterizations of these approaches is the collaboration between different actors.

Findings from the literature review confirms that Design Build (DB) contract is often chosen by the major clients for projects that are more straightforward such as railway and road. When working with infrastructure projects, DB procurement approach simplifies the execution phase for the client as the design and construction phases are combined into a single contract. Furthermore, a DB contract gives the service provider freedom to chose an appropriate software and- a working method which might increase the product quality and save both time and money in the project. However, the DB procurement approach often creates a culture among the contractors where the contractor tends to bid low for a project. This often causes significant contract changes (ÄTA) during the later stages of the project, which in turn could severely damage the relationships between the different actors involved (Eadie and Graham, 2014). By analyzing the findings, it is established that the most suitable procurement approach, beneficial for BIM users, clients and contractors, is the DB procurement approach combined with a collaboration form such as e.g., ECI or partnering. By demanding a collaboration form in the contract, cooperation and optimal efficiency regarding information flow in a digital environment can be achieved.

The interview study, on the other hand, shows divided opinion regarding a suitable procurement approach for infrastructure projects. Some interviewees do not think that the procurement approach have any impact on BIM utilization in projects, whilst others think that the procurement approach is incredibly important and a determining factor for BIM utilization. Correlations were found between the interviewees' roles and their respective answers, where e.g., BIM & data coordinators whom often work in projects with a DBB contract believe that the DBB procurement approach is the most suitable approach for BIM utilization in projects. In contrast, section and project managers disagree and argue that a DB procurement approach is most suitable for BIM utilization. The main argument against a DB procurement approach, which often constitutes a fixed price contract, is that the contractors are unwilling to risk the possibility of economic consequences by implementing BIM when the client does not demand it. Furthermore, as contractors in a DB procurement approach often hire consultants to provide construction documents and drawings, the implementation of a BIM working procedure among consultants

and designers is hindered. In a DBB procurement approach on the other hand, the client selects the working procedure by e.g., requiring BIM implementation in their projects.

In the interview study and questionnaire survey, the client's significant influence on BIM implementation is highlighted. With this in mind, STA, which is the largest client within the Swedish infrastructure industry, has a determining role in the development and implementation of a BIM work procedure. In their BIM implementation plan, STA recognizes their significance in the development and implementation of BIM (Karlsson, 2021). STA believes that the technical tools for BIM implementation already exist within the industry and that the implementation process is hindered by the contract conditions. To address this, changes in the contract contents of the DBB and DB procurement approaches are required. The published report by STA consists of a detailed integration plan that describes how STA might proceed by implementing changes in the contract contents to aid the BIM working procedure both internally and externally.

In order to find correlations between theory and reality, the questionnaire survey has been reviewed. Unfortunately, there is no specific question regarding the most suitable procurement approach. However, there are some correlations between the most common contract type and the project phases among the respondents. The bars in Figure 6.1, demonstrate that the design and production phases are believed to be the most beneficial phases for BIM utilization.

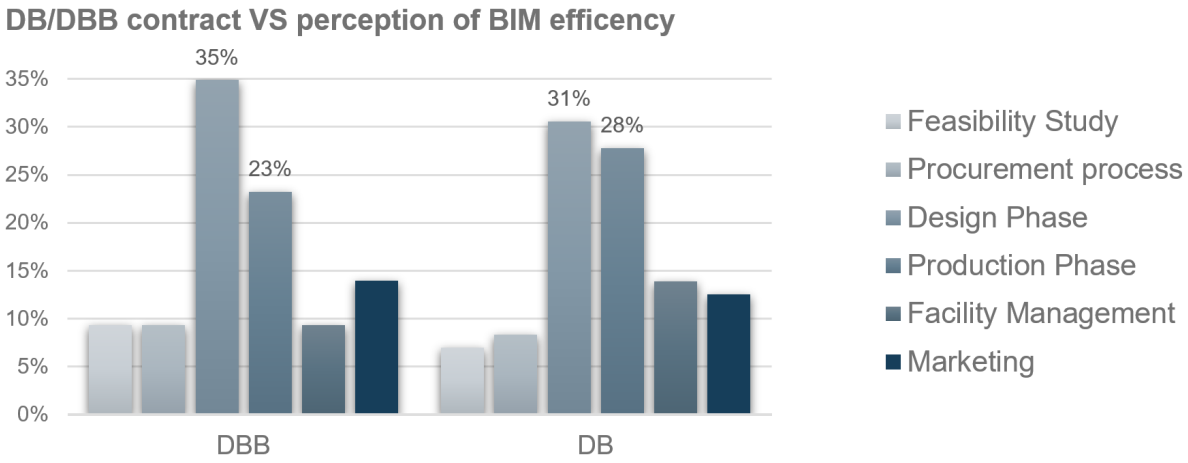

Figure 6.1: Correlation between questions 7 and 12 in the questionnaire survey.

Furthermore, the most common project phase versus procurement approach has also been analyzed. The result shows two interesting things as demonstrated in Figure 6.2.

Firstly, the majority of the participants working in projects with a DBB contract are connected to the phase where tender and construction documents are provided, accounting for 31% and 33%. Secondly, the respondents working in projects with a DB contract are also mostly connected to the design phase, accounting for 31%. However, the amount of project planing documents and tender documentation are equal, accounting for 25% each, see Figure 6.2.

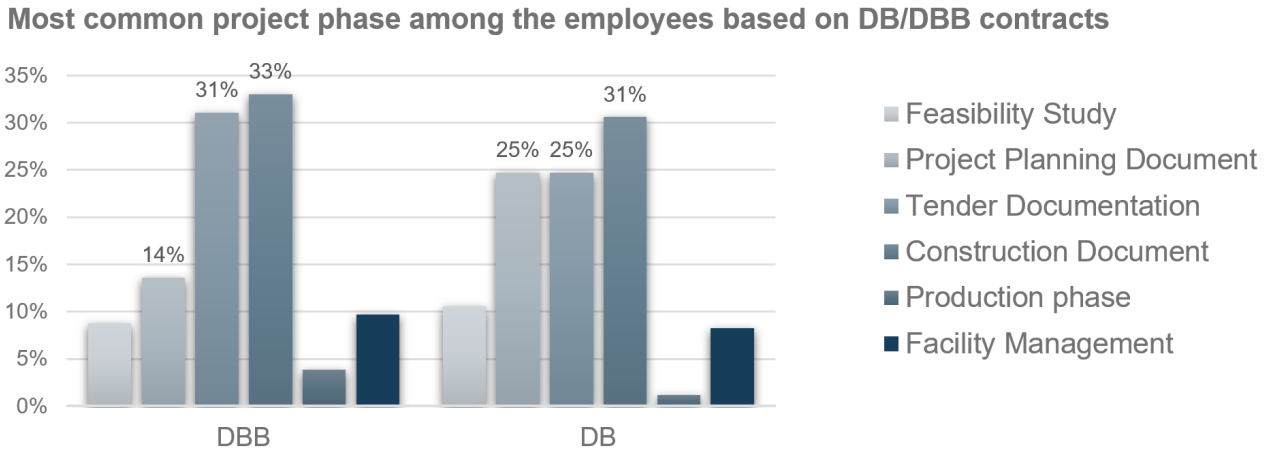

Figure 6.2: Correlation between questions 7 and 8-9 in the questionnaire survey.

7
Conclusion

In the following chapter, the research questions will be answered based on the analysis and discussion from the previous chapters. Additional research conclusions, recommendations for AFRY and suggestions for further research will also be presented.

7.1 Answering the research questions

What is the BIM maturity level at AFRY and what are the challenges when working with BIM in infrastructure projects?

The study establishes that the BIM maturity level at AFRY is between levels 1 and 2 according to the definition of the BIM maturity levels by Bensalah et al., (2018). Generally, this is due to the fact that the BIM maturity level in the projects is determined based on the client's requirements. Conclusively, if the clients raise their project BIM demands, AFRY would have the possibility to increase the BIM maturity level to 2 and 3. AFRY could also increase the maturity level by establishing a general BIM framework within the company, but at the risk of economic consequences if the clients are unwilling to invest in the additional work that follows.

The challenges with BIM varies depending on the project and are therefore hard to accurately identify. Findings from the interview study and questionnaire survey establish that the main challenge within the studied business area at AFRY is the lack of a common BIM framework, which can be described as a general BIM working procedure that is appropriate and applicable for infrastructure projects regardless of the client's BIM demands. Furthermore, other challenges consist of a lack of collaborative skills and knowledge regarding 2D and 3D models within AFRY's project management team. Moreover, there is a lack of overall knowledge in the BIM subject which causes confusion and slows down the BIM implementation process. From a consultant perspective, STA is pointed out as one of the main setbacks for BIM implementation, which means that STA needs to set higher demands on BIM utilization through contractual changes. However, the findings demonstrate that the industry's clients, consultants and contractors are aware of this issues and that they are working to solve it in the near future.

For which procurement approach is BIM most suitable?

It is difficult to pinpoint one specific procurement approach for BIM implementation in a project, as the theory and findings from the interview study differs. Generally, findings from the literature review establish the DB procurement approach as most suitable for BIM projects. On the contrary, findings from the interview study highlight the economic consequences by choosing the DB procurement approach from a consultant perspective. The consultants are dependent on the financial investment of the clients for BIM education and innovation projects internally. However, the client needs to change the BIM demands in their contracts with the aim to simplify the BIM procedure, as they have a position of power in the industry. Since the DB and DBB contracts are not adjusted with BIM conditions at this moment, it is easier to implement BIM in a DB contract as the contractors have the main responsibility for the project and can therefore freely chose the design and execution methods. In complex infrastructure projects, it can actually be beneficial to add a collaboration form in the contract such as partnering or ECI in order to increase the collaboration and take advantage of information exchanges between the client,

contractor and consultants. The ECI method for instance enables involvement of the construction team in the design phase. This might yield exchanges in experience and increase the overall quality of the project execution.

How can the workflow be streamlined within infrastructure projects?

The study demonstrates several key factors that could aid and streamline the workflow within infrastructure projects. Well developed and updated templates, guidelines and checklists are huge factors for increasing the efficiency in the projects. Moreover, the sense of encouragement and motivation in the project team to work in the same direction and towards a common goal will also streamline the workflow. However, streamlining the workflow could be biased depending on what the company wants to achieve. The accurate question should therefore be what the aim is with an efficient workflow and what the company actually wants to achieve. Is the goal to be the best service provider in the industry in long term or is it to earn more money in short term? From a consultant perspective, usually the focus is on the amount of hours the company possibly can sell in a project. Moreover, in the end, the total end-price of a project is what matters and if an efficient framework is used to promote the company, in long term, this would cover both marketing and financial issues.

7.2 Further research

In this study, the main focus has been on the consultants role for BIM implementation in the infrastructure industry. For consultants in the infrastructure industry, the client can be authorities, agencies, municipalities etc. Depending on the project and contract type, sometimes the contractor might be the consultant's client. It would be interesting to further investigate if the BIM implementation and application differs depending on the type of client the consultant is dealing with.

Based on the findings in this study, it is shown that the attitude and mindset regarding BIM implementation varies depending on age, education and in some cases gender. The result from the questionnaire survey demonstrate different attitudes towards BIM implementation and a transition from 2D to 3D depending on gender. Due to the limited participants in this study, the result regarding gender versus attitude towards a transition from 2D to 3D might not be fully representative. It would therefore, be interesting to further investigate if gender has a determining impact on the overall attitude towards BIM and 3D transition.

7.3 Improvement suggestions & recommendations

The possibilities and benefits when working with model-based projects are numerous. This study confirms the benefits of BIM if it is implemented and utilized in the right way. Based on the findings in this study, several improvement suggestions and recommendations are provided for the BIM implementation within the studied business area and other consultant companies:

- In order to avoid misinterpretations of the client's BIM demands, the project manager should be responsible for clarifying the BIM conditions and establish a common framework, involving all disciplines, before project start up.

- Because of the unclear contractual BIM demands by the clients, the service provider needs to establish their own BIM standard for in house use. This must be made regardless of the client's BIM demands and can be achieved by establishing a BIM manual for instance.

- Consider the BIM & Data coordinators as a part of the project management team. Involve them in the sales phase and before project start up in order to set relative BIM conditions and guide the disciplines to use the right methods throughout the entire project.

- Develop and complement the current checklists, templates and routines in order to streamline the delivery phase and improve the validation and quality of the products and services.

- Offer and encourage the employees to enroll in appropriate courses in order to increase the knowledge and strengthen the skills within different disciplines.

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A

Appendix - Interview study

INTRODUCTION
This interview is a part of the Master Thesis at the program Design and Construction Project Management at Chalmers. The interview is complete anonymous and the answers will be used to investigate and identify the problem with BIM implementation within Infrastructure projects and AFRY Transportation.

The interview is divided in two part. The first section is about you and your background. Part two is specified and bias questions about BIM implementation and the challenges as well as benefits working with BIM. Is it ok to record this interview?

Part 1 - Who are you?
1. Name
2. Age
3. Background, experience, education etc?
4. Current role, job?

Part 2. Field specified questions
1. What is your definition of BIM?

2. Are you self-learned or got any education for your current daily job?
    a. Do you think that the education was suitable/useful for your current job?
    b. Would you like to take more course in BIM?

3. How would you describe current lever of BIM at ARFY Transportation?

4. Does the BIM ambition goes hand in hand with the level you have at the company?

5. Do you work with BIM/digital tools on your current projects?

If yes:
    a. How do you use it
    b. Which software?
    c. Do you draw in 3D/2D?
    d. What is the greatest advantages you get from BIM in your daily work?
    e. What is the most challenges when using BIM?

f. What would you suggest in order to improve the challenges?
g. Are you for or against BIM utilization?
h. What is your suggestion for implementation BIM, where should AFRY start?
i. Within which construction phase do you think that BIM is most beneficial?

If No:
j. Why is that?
k. Do you want to work more digitally?

6. Have you ever been working in a project that is completely digital (in other words, blueprints free)?

7. What information do you need in order to work more digitally in your projects?

8. How does the communication works among the different parties?
a. Could this communication been done with 3D-models through visualization?
b. Do you find any lack of communication in your projects? What is the reason of these misunderstandings?

9. How would you identify the risks and possibilities working with model-based infrastructure projects at AFRY Transportation?

10. Which procurement type is most suitable for BIM projects?

11. How can the daily workflow be streamlined?

12. How would you describe current level of BIM and LOD at ARFY Transportation?

13. Other thoughts?

B

Appendix - Questionnaire survey

BIM- & Digitalization within AFRY Transportation

This questionnaire survey is a part of a Master Thesis, within the Master program Design & Construction Project Management at Chalmers University of Technology, aiming to investigate BIM implementation within Infrastructure projects.

The result will be used in order to get a perception of how the employees at AFRY Transportation is working with BIM in the projects and how they can contribute as well as improve the BIM and digitization work in their everyday work. The result will also be used internal for the BIM strategy work carried out by Peter Bolt Digital Manager and Martin Haas, BIM strategist at Rail at AFRY Transportation.

The survey is divided in two parts, consist of 25-35 questions (depending on your answers) and takes approximately 10 min to accomplish.
Part 1 - Questions about you
Part 2 - How do you work and want to work digitally/with BIM

OBS!
The survey is anonymous, the answers is not possible to linked back to the respondents. By accomplishing this survey, you give your permission of using the data in the study.

Please feel free to contact me if you want to elaborate the questions or have any improvement points on the survey/questions.
Shakrin.ahmed@afry.com
076-277 21 20

Thank you for participating!

Part 1 - Who are you

1. Gender *

- ◯ Man
- ◯ Woman
- ◯ Prefer not to say

2. Age *

- ◯ 20-30
- ◯ 30-40
- ◯ 40-50
- ◯ 50+

3. Education *

- ◯ High school education or equivalent
- ◯ Polytechnic
- ◯ Bachelor's degree (3 years) or equivalent
- ◯ Master of Science in Engineering
- ◯ [ ] Other

4. Role/Job title *

[ ]

5. Work experience (in the construction industry) *

- ○ 0-1 year
- ○ 1-2 years
- ○ 2-3 years
- ○ 3-5 years
- ○ More than 5 years

6. How to you work currently in your role? *

- ☐ Working primarily with internal projects/development issues at AFRY
- ☐ Working primarily in external projects
- ☐ [ ]

Other

7. Which procurement approach or contract type do you have in your projects? (Fill in other if you work in very early stages, eg feasibility study, pre-study etc.) *

- ○ Turkey contract or DB approach (ABT06)
- ○ Traditional contract/ DBB (AB04)
- ○ Both
- ○ I don't know
- ○ [ ]

Other

8. If you chose DB (ABT06) - which stages are you usually working within?

- [ ] Pre study/Feasibility study
- [ ] Tender documentation/Project planning document
- [ ] Procurement process/ Tendering
- [ ] Construction document
- [ ] Production phase
- [ ] Facility management
- [ ] Other

9. If you chose DBB (ABT06) - which stages are you usually working within?

- [ ] Pre study/Feasibility study
- [ ] Tender documentation
- [ ] Project planning document
- [ ] Construction document
- [ ] Production phase
- [ ] Facility management
- [ ] Other

Part 2 - BIM

10. Are you familiar with the term BIM? *

- ○ Yes
- ○ No
- ○ Don't know

11. How would you define BIM (Building Information Modeling)?

12. Which phases/stages do you think is most beneficial for implementing? *

- ☐ Pre study/Feasibility study
- ☐ Tender process
- ☐ Design phase
- ☐ Production phase
- ☐ Facility management
- ☐ Marketing
- ☐ Other

13. How much of your time do you work with CAD / BIM-tools? *

0	1	2	3	4	5	6	7	8	9	10

0% 100%

14. How do you design currently? *

- ◯ In 2D
- ◯ In 3D
- ◯ Both
- ◯ I do not design

15. If you only design in 2D, would you like to transfer to 3D?

- ◯ Yes
- ◯ No
- ◯ Prefer not to say

16. If NO, please explain why?

17. How many hours do you spend on "problems/redesigning your models" (weekly)? *

0	1	2	3	4	5	6	7	8	9	10

0h 10h

18. if you selected between 5-10, please explain the issues?

19. Do you have CAD-object library to use for you projects? *

- ◯ Yes
- ◯ No
- ◯ I don't know

20. If YES, do you use the CAD-object library?

- ☐ Yes
- ☐ No, I don't know how to use it
- ☐ No, The content is not useable
- ☐ Sometimes, the content is too bad and needs to be improved
- ☐ Other

21. Do you have ideas / suggestions for areas that could be fully /partially automated in order to simplify your daily work? *

22. Do you have any ideas/suggestions of how we can work more effective within your technique field? *

23. What do you currently missing that according to YOU deteriorates the quality or/and extend the delivery time in your projects? *

24. How do you validate/ensure that the data/documents/models you deliver are correct? *

25. How well are you familiar with the client's mission description (within your projects) regarding models and LOD in the models etc.? *

0	1	2	3	4	5	6	7	8	9	10

Ingen aning — Har 100% koll

26. If you selected between 0-5. Why is that?

- [ ] I don't know where i can find the infromation
- [ ] The client's requirements are unclear
- [ ] I don't have the time to prepare, lack of time
- [ ] Have too many project, the time for preparation doesn't exist
- [ ] Other

27. Do you think that the client's model-requirements are hard to interpret? *

- ( ) Yes
- ( ) No

28. If "YES", please try to explain why?

29. What is preventing you from using BIM-tools/work more digitally?

- [ ] I do not have relevant applications / software
- [ ] We do not use BIM in current projects
- [ ] The client do not demand to use BIM-models
- [ ] I don't have the right education/knowledge
- [ ] I don't see the benefit of BIM
- [ ]

Other

30. What do you need in order to streamline your daily work? *

- [ ] Softwares
- [ ] Education/ competence
- [ ] Tutoring
- [ ] Better communication between the different disciplines
- [ ]

Other

31. Do you have any CAD/BIM education? *

- ( ) Yes, internally
- ( ) Yes, externally
- ( ) No

32. If "Yes", please specify which education you have taken?

33. If "YES", are you interested in further education within CAD/BIM?

- ◯ Yes
- ◯ No
- ◯ Maybe

34. If "No", Do you want to take CAD/BIM-courses?

- ◯ Yes
- ◯ No
- ◯ Maybe

35. If you are allowed to wish freely, how do you want to streamline your job?

36. Feel free to add other comments/thoughts! :)

C

Appendix - Questionnaire survey Results from question 21-36

The answers to the open-ended questions are presented in the tables below. There answers are in Swedish since the Questionnaire Survey was conducted in Swedish.

21. Har du idéer/förslag på områden som skulle kunna helt/delvis automatiseras i syfte att förenkla ditt dagliga arbete?
Folk använder mallar/tempaltes från början
Konvertering mellan program
Standarder för återkommande arbeten saknas. samma arbete utförs i varje projekt.
Jag modellerar eller projekterar inte i min roll.
förbättra leveransprocessen internt, modelgranska i tidigt skede.
Inläsning av data från geotekniska undersökningar
Punkt 17 borde ha ett svarsalternativ "vet ej" eller "både ja och nej" eller formuleras annorlunda. Jag använder inte några CAD-bibliotek, men jag vet att de projekterande konsulterna i mina uppdrag använder det. Däremot inte om det är alla i alla uppdrag. Jag skulle önska att modellerna blev enklare att läsa för någon som inte arbetat i dem, alltså någon som inte varit med i projektet. Information behöver standardiserat mer än vad den är idag, tex. En (för projektet) ny BIM-samordnare ska kunna gå in och direkt kunna utläsa vad allting är. Nästa steg, skulle jag önska att även icke-projekterande personer skulle kunna läsa informationen, men det vet jag inte om det är görbart. En annan sak; idén att döpa dokument (ritningar såväl som PM och andra dokument) enbart med en sifferkod, det är säkert snyggt och effektivt vid leverans. Men det är totalt hopplöst att gå tillbaka. Då måste man först leta rätt på en förteckning av just den leveransen eller så måste man öppna en himla massa dokument innan man hittar rätt. Det är tillräckligt jobbigt om dokumentet är knutet till ett visst teknikområde, men extra jobbigt om det är något teknikslagsövergripande. Dokument bör döpas med både kod och med dokumentets namn. En annan sak: vår interna IT måste finnas till för att stödja projekten och inte tvärtom. Vi har behövt lägga sjukt mycket tid på att hitta information på nytt, sortera om, och bygga upp projektsidor på nytt, för att vårt intranät har uppdaterats. All migrering från det ena till det andra, utan förståelse för att vi har stora projekt med massor av information. Inte
Gemensamma plotstyles, speciellt för VU-planer
Mängdning skulle vara skönt att kunna automatisera. Jag har dock svårt att se hur det skulle fungera fullt ut för signals del.
Mycket inom ritningshantering skulle kunna automatiseras. Även få fram mängder till mängdförteckningar/masshanteringsplaner mm.
Vet ej.
Utnyttja funktionerna att generera handlingar utifrån modellen. Som det är nu är det bara som 2D, fast extra krånligt.
"Smarta ritningar", dvs att ändrar du t.ex. bladnummer på en ritningar så kommer detta ändras överallt. Att inte behöva göra detta manuellt hade sparat väldigt mycket tid.
Jag vet egentligen inte vad som menas fullt ut. Klart det hade varit gott att kunna trycka på en knapp ibland för att få ut färdiga ritningar i rätt skala etc, men det är rätt sällan som det handlar om särskilt många ritningar i mitt fall.
Nej
Vet ej
Modellgranskning samt få ut mängdlista för objekten
Vet ej.
hjälp att ta 2D höjsättning till 3D
Allt från leveranser, ritningsframställning, modellgranskning med mera.
Tydligheter innan leverans för ex namnruta
Leveranskontroller, förteckningar, osv
Applikationen Promis-e med tillägget Rail Signaling har goda möjligheter till automatisering. Men buggar och brist på intern utveckling hämmar användandet.
Ett smidigare sätt/verktyg för ritningsframställning.
Jag tror att ritningsframställning skulle kunna effektiviseras genom att man utveckla en teknik som gör det möjligt att mata in exakt data/information om hur modellen ska utformas, som programmet per automatik ritar upp och sammanställer.
Har svårt att se något som helt kan automatiseras men det går säkert att skapa väldigt bra referens modeller som kan användas tex teckenförklaringar, ritdeffar etc. Det underlättar ritningarbetet väldigt mycket. Sen kan modell biblioteket utökas mer för att innehålla fler objekt, som också redovisas på ett realistiskt sätt.
Modellgranskningar, användning av rätt mallar för modeller, mm.

Vi som hållt på ett tag har ju ett bibliotek över cad saker som vi använder och kan copy paste mycket av det. Men det skulle nog vara bra om någon ville samla ihop allt vi har och sammanställa det. Sen en enda stor lista med linjetyper/objekt som alla ska använda med rätt lagernamn mm vore guld. Eller iaf två/tre olika så man kan välja vilken skola man vill tillhöra.
Modellgranskning
Enklade ritningsframställning utan så mycket handpåläggning
3D-modellgranskningen behöver förbättras, och då tänker jag teknikspecifikt. Teknik-kunniga saknar större kunskap kring 3D och modellsamordnare saknar kunskap kring det rent tekniska och kan då inte göra en annan granskning än eventuella kollisioner. Granskningen är ett område som kan förbättras.
3D-företeelser i form av vägräcken, stängsel, belysningsstolpar o.dyl. Både vad gäller inmätta objekt och projekterade.
Avsätta tid för att bygga upp templats och bibliotek med lager i nya programvaror. Utbilda användarna och gärna uppföjlning.
Nej
Nej
Nån form av linjeföringsrobot. Ett program som ger förslag på linjeföringar baserat på ett bestämt antal parametrar. Sen kan man själv välja den bästa linjen.
leveranser
skapandet av 3D objekt från inmätningar (Befintligheter)
Automatisera kopplingen mellan vägprojekt och byggnadsverks modellerna.
-Ritningsframställning från 3d modeller. -Konstruktionsgranskning av 3d modeller. -Interaktion mellan beräkningsprogram och BIM modell (avser den modell som används för generering av ritningar) - Interaktion mellan beräkningsprogram och MathCad(XML) för redovisning av konstruktionsberäkningar.
Nej
jag vet inte, känner inte så just nu
Utveckling av mallar så dessa är användbara och inte behöver hela tiden startas från skratch.
Ja
Vet ej
Man önskar att mer saker skulle kunna automatiseras som tex stämpling av ritningar, men behövs ändå handpåläggning för att kunna lägga stämplar i ritning där det finns plats, en automatisering skulle väl betyda att alla stämplar hamnar på samma ställe i alla ritningar och det fungerar inte, iblad har en ritning även många stämplar. Ett smidigare sätt att byta namn på filer, tex när ritningar har varit utskrivna för signering och sedan blivit incannade, vill man snabbt kunna lägga till namnen igen som de hade/har digitalt, vi har ett sätt men det strular ofta, namnen hamnar på fel ritningar osv, opålitligt, gäller även metadatan Det finns mycket man skulle kunna digitalisera, även sånt som redan är digitaliserat men som skulle kunna fungera bättre
Nej, det krävs ofta handpåläggning/granskning av en person
vi behöver mer kunskap om chaos desktop och om hur vi lättare får över arbete i 3D till 2
Nej

22. Har du förslag på områden som kan effektiviseras inom ditt teknikområde/din roll?
Modellering via parametrisering och användning av mallar, skulle hjälpa många projektörer (även om jag inte projekterar...)
Nej tyvärr
Standardisera återkommande arbetsuppgifter.
oftare fysiskmöte (med FhM rekomendationer)
Nej
Effektivisering av uppritning av grafer / ritningar och modellering.
Det är just det här med informationen. Jag vill nå dithän att vi verkligen har all information på ETT ställe; senast levererade, arbetsmaterial, sidoutredningar, etc. För alla teknikområden. Och på ett sätt så att alla enkelt kan ta fram det de behöver och veta att det är rätt version etc. Alldeles oavsett om det är information från ett annat teknikområde eller om jag inte har arbetat i projektet tidigare. Det kan ju vara ett sedan länge pausat eller avslutat projekt som startar om eller startar upp i ett nytt skede. Och de som jobbade i det tidigare kan ju ha slutat för länge sedan. Eller för den delen, vara ringrostiga för att det var ett tag sedan sist.
Ja, VU-planer och TA-planer, jobba mer likadant med gemensamma plotstyles och samma verktyg osv. Nu gör alla lite på "sitt sätt".
Bättre mallar för olika dokument.
Att rita upp modellfiler
Nej.
Utnyttja funktionerna att generera handlingar utifrån modellen. Som det är nu är det bara som 2D, fast extra krånligt.
Det borde vara möjligt att första ta fram geografiska ritningar, därefter så borde det vara möjligt att generera ritningar med kretsscheman etc automatiskt utifrån de geografiska ritningarna och andra parametrar man kan mata in. Självklart kommer dessa behöva projketanpassas, men att få grunden hade gjort otroligt mycket.
Jag gillar enkelhet, det betyder att jag inte vill behöva göra mer än vad som behövs i det projektet och jag vill inte behöva göra en stor modell/använda en arbetsmodell för stora projekt när jag jobbar med ett litet uppdrag som kanske bara genererar en ritning.
Leja bort 3D-modellering till CRC-resurser.
Nej
Snabbare program och effektivare sätt att flytta objekt vid förändringar
Om tool palettes och rörspecar är uppdaterade kan rörlister tas ut utan överdrivet mycket handpåläggning. Även uppdaterade tool palettes enligt SSG för flödesscheman skulle underlätta arbetet.
Ovanstående
Granskning -> ritningar
Osäker.

Inom de allra flesta projekt används inte 3D-modellering överhuvudtaget (broar). Något som vi borde börja jobba mer med, vara mer aktiva på den fronten så att vi får öva och lära oss att bli bättre på 3D-modellering. Har vi inte tillräckligt med kunskap eller erfarenhet inom 3D så kommer vi framöver, i takt med att det kommer bli mer ett krav från beställare, inte vara tillräckligt attraktiva för jobb som kräver 3D-leveranser.
Ett mer standardiserat arbetssätt. AFRY har inte kommit tillräckligt långt inom BIM för att ha det. I dagsläget är det öar av BIM-kompetens inom företaget (min uppfattning) och jag misstänker att hjulet uppfinns på nytt många gånger.
Se ovan.
Nej
nej
Nej
Inte i nuläget
Smidigare automatisk hantering av CAD-lager
Nej
3d modellering av VA
Jag har ingen förslag
Från AFRYs mätenhet till AFRYs projektering kan effektiviseras med konverteringsregler av inmätningslinjer / intmätningspunkter till 3D objekt i Quadri. AFRY kan skapa egna konverteringsregler till Quadri.
Utveckla en AFRY rutin för att ta fram ritningar från 3d-modeller. / Pressa kunden att endast acceptera 3d-leveranser utan 2d-ritningar som andra länder redan gör.
Samma som för fråga nr.19
Nej
vet ej
Standardkonstruktioner kan det skapas ritmallar för som sedan appliceras och anpassas i de olika projekten. Bro- och anläggningskonstruktion arbetar redan på ett bra sätt, men kan effektiviserar sina rutiner, dock är belastningen ofta redan högt, så finns det för lite tid för att utveckla bättre verktyg.
Många
Nej
Geotekniska tolkningar, tolkning av jordlagerföljder m.m. önskar jag kunde göras mer i 3D eller helst BIM-liknande format för att få en bättre uppfattning det faktiskt kan se ut och på så sätt kunna göra bättre analyser. Borrhål i 3D med information om jordart, skjuvhållfasthet etc.
Nej,
se ovan
Nej
samordning och tätare dialog mellan olika teknikområden, fler som kan 3D inom mark och landskap
Nej
Grundfil för befintligheter saknas
effektivisera framtagandet av 3d modeller utifrån enklare 2d modeller
Allt från leveranser, ritningsframställning, modellgranskning med mera.
Mallar med en standard av lager och liknande.
Undvika att göra ritningar och istället leverera i 3d
Det finns säkert men vet inte vad jag ska lyfta
Det känns som att jag och vi alla andra kollegor på transportation uppfinner samma hjul om och om igen. Jag tycker att det skulle vara fint om det fanns en fil där alla kan plocka på sig nya objekt. Sen att Novapoint blir som Sims där det är drag and drop på objekten hade varit otroligt smart!
Om det är möjligt att kunna utveckla plug-in program till våra cad-applikationer så borde man kunna locka examensarbete till detta. Men jag misstänker att våra licenser och avtal med cad-leverantörerna inte medger det.
på AFRY finns ingen gemensam mall för ritningar, templates, plotstyles.
Tillgänglighet av objektbibliotek.
Vet ej.
vet ej
Använda mer smarta funktioner i civil3d som jag vet finns man inte vet hur jag ska använda. autogenerera.
Vi behöver utbildning för att projektera mer i 3D på landskap
Se pkt ovan.
Digitalisering

23. Vad saknar du idag som DU anser försämrar kvalitén och/eller förlänger leveranstiden i dina projekt?
Slarv och att "folk" inte har läst och tagit till sig instruktioner
Snabbare itereringar. Testa nytt och göra ändringar är jobbiga och tidskrävande.
Villighet från kollegor i projekt att samarbeta/arbeta med smartare verktyg.
Försenade internleveranser försvårar mitt arbete som datasamordnare. Svårt att planera ett strukturerat arbete vilket kan försämra kvalitén eftersom det leder till tidsbrist för projektörerna att rätta upp granskningarna.
intern granskning av arbetet, mycket belastning
Digitalisering av arbetsprocessen. Nya mallar behövs, bättre kommunikation internt och externt. Bättre IT-miljö.
Slöa programvarror, oeffektiva arbetssätt, mer kunskap inom exempelvis programmering för att kunna producera enklare skript. Mycket tidsåtgång att föra över data mellan programvaror, exempelvis uppritning av sektioner för att sedan flytta till beräkningsprogram.
Att våra teknikansvariga ofta har för lite tid för varje projekt de är med i. Att våra BIM-samordnare med för lite erfarenhet för de projekt de kastas in i får för lite stöd. Att fler av våra projektörer och teknikansvariga faktiskt använde sig av vår BIM-modell, om vi har en sådan i ett projekt. Den är inte bara för leveransen till kund utan också för vårt arbete.
Att vi inte bör sätta tid på interntid vilket gör att folk bara jobbar på istället för att ta sig till för vidareutbildning eller interna workshops för hur vi ska jobba ihop osv. Har inte konkret förslag exakt på vad jag saknar. Saknar checklistor
Mallar för dokument lämnar ofta en del att önska.
Bättre kunskap om hur man kan jobba smidigare i CAD, behövs mer kompetens inom CAD-hantering. Bättre mallar för ritningsförteckning, egenkontroller, checklistor mm.
En bra form för samgranskning.
Bättre programvara och för lite tid att "leka runt" och lära sig.
"Smarta ritningar"
Ibland, men ändå väldigt sällan, är autoturn inte tillgängligt pga användare fullt. Jag tycker den interna granskningen ofta kan bli bättre och ges mer tid (även under projektets gång). Leveranstider håller vi nästan alltid, och om den förlängs beror det nästan alltid på att det tar tid hos beställaren att fatta beslut etc. Jag hade velat kunna 3d bättre.
Microstations 3D är väl ganska långt efter enligt vad jag har hört, det är ju negativt.
Bra mallar är alltid ett bra sätt att spara tid och få bättre resultat
Slöa programvaror och svårt att flytta objekten om det behövs
Ordentliga och bra mallar.
Att det skiljer mycket mellan arbetssätt och mallar mellan projekt gör att det tar längre tid.
Dåliga rutiner för granskning och kontroll
Effektiva mallar som används etc.
Finns ej tillräckligt många som kan granska våra 3D-modeller. Förlitar sig för mycket på egengranskning.
Orealistiska tidplaner från beställaren är många gånger ett växande problem.
Se ovan
Programvaran inte optimal i alla lägen.
vet ej
Vet ej
Jag upplever generellt att arbetsbelastningen är hög, vilket minskar tiden för kvailtetssäkring i uppdrag. Mer tidsmarginaler är att föredra.
Ibland slöa programvaror, mycket manuell handpåläggning.
Långsamma servrar.
Möjlighet till utbildning, rätt (senaste) vesioner av programvaror i software center.
mycket ändringar i projektet vid leverans
enbart 2D arbete och inte 3D arbete. Försöka att påskynda och testa modernare arbetsmetoder. Som granskning i modell istället för granskning av enbart pdfer.
Stöd från kollegor som att dela tips, erfarenheter och kunskaper.
Samma som för fråga nr.19
En bra lagerstruktur
program och mallar kanske
Jag använder mallar i så stor utsträckning som möjligt.
Mycket
Personalresurser
Bra mallar, enklare konvertering av filformat för att kunna jobba i olika programvaror. Fleravstämningar med de ingående teknikområdena i projektet.
Bra mallar
slöa och buggiga program, tex Projectwise, Promise
Hög belastning samt dåligt bibliotek av objekt både i 2D och 3D
fler erfarna kollegor som tar ansvar inom sin teknik. nu hamnar oerhört mycket på uppdragsledare att granska andra och även på ta Landskap, jag arbetar oftast i dessa roller
Inget
It strul är ett problem. Bra referensbibliotek med andra exempelprojekt hade underlättat.
Mer tid i respektive projekt för att kunna utveckla arbetsgången
Det saknas bra mallar för användning av Tekla så med sämre underlag kan det leda till att kvaliteten på modellen kan bli något sämre då man blir själv osäker på hur programmet ska användas och vilka metoder/lösningar är bättre att ta vilket i sin tur leder till att mycket tid går åt funderingar och då förlängs leveranstiden.

Mallar Bearbetning av höjddata (slö programvara)
Bra script som inte felar
att alla jobbar på samma sätt och vet hur de ska jobba, standardiseringar och bra uppdaterade mallar, för lite tid från internleverans till slutleverans så leveranskontroll inte hinns med, interngranskningar görs för slarvigt
Slöa programvaror och stor handpåläggning av cad-materialet när det är dags att rita ut ritningar.
Pålitlig programvara
bra och framförallt övergripande mallar
Huvudsakligen objektbibliotek och bra mallar.
Jag skulle vilja ha bättre mallar som tydligt visar på vilka rutiner som gäller t.ex. vid interngranskning och leverans.
bra mallar, mkt belastning
Känner inte att jag kan ta mig tid i projekt till att lära mig använda mallar och verktyg som finns att tillgå.
hög belastning
Oftast är en hög arbetsbelastning och ont om tid/budget saker som gör att kvalitén i en leverans blir lidande. Har man bra mallar skulle det underlätta mycket av arbetet.
Mycket dataproblem vid arbete mot X:\1-prj\SE serverna. GeoSuite och Autocad/Civil 3D slutar att fungera och/eller går trögt.
Lämpliga mallar och tillgång till bättre hårdvaror (datorer). IT-systemet kan anses vara besvärlig vid diverse ärenden.

24. Hur validerar/säkerställer du att data/handlingar/dokument/modeller du levererar är korrekta?
Primär granskning, Checklistor och stickkontroller,
ber kollega/ uppdragsledare att granska, oftast har jag inte fullt koll på projektet eller har inte den tekniska kunskapen.
Egenkontroll (checklista) + kontroll av kollega.
Dubbelkollar samt ber kollega kontrollera mitt arbete.
checklista, slumpmässig validering.
Checklista, intern granskning. Dubbelkolla,
Checklistor, granskning
Jag dubbelkollar oftast att alla andra har följt våra rutiner; använt sig av checklistor, att de som ska granska har gjort det, att alla känner sig trygga med det vi levererar. Projektörer, teknikansvariga, kvalitetsansvariga, etc.
Ber kollega granska. Involverar också ofta kollegan i projektet under tidens gång så att den har lite koll sedan tidigare. Vi saknar checklistor för vårt arbete vilket gör att saker ändå kan missas.
Checklista/egenkontroll, interngranskning och till slut säkerhetsgransning.
Kontrollerar själv mitt arbete, därefter samgranskning och interngranskning.
-Egenkontroll i form av checklistor. -Interngranskning.
Checklistor, interngranskningar
Checklistor, obligatorisk interngranskning sen säkerhetsgranskas signalritningar.
Jag kollar själv mot offert etc. Jag granskar både ritning och cad-material själv. Jag låter kollega interngranska. Dock inte med en checklista utan bara från det jag ser/tänker på. Så en bra cheklista hade ju varit bra, givetvis.
Granskning
Checklista och interngranskning
Använder cheklista samt kollega granskar
Använder checklista (som dock skulle behöva uppdateras och granskas ordentligt). Interngranskning genomförs av lämplig kollega.
Vi använder checklistor från nätverket. Om jag är på kontoret så skriver jag ut i A3. Vi projar så att allt ska synas på en A3 ritning.
Checklistor + dubbelkoll
Checklista, intern granskning, dubbelkollar mått och sektioner/elevationer osv.
Checklista, kollegor granskar handlingar, egengranskning.
Egenkontroll utan checklista. Tid för validering är oftast alldeles för kort.
Cheklista och exoprterar modeller till andra filformat och samgranskar.
Dubbelkollar, interngranskningar, checklista
checklistor, granskning
Checklistor och granskningar
jag dubbelkollar själv. tid för att en kollega ska granskar finns oftast inte, samtidigt har alla för mycket att göra
Använder checklistor och har intern granskare.
Jag ber en kollega granska mitt arbete.
checklistor, program för kontroll, dubbelkollar
ber en kollega granska mitt arbete
checklistor, interngranskning
Intern granskning av en oberoende kollega. En sak som kan vara ännu bättre är att använda kollegor i andra (AFRY) städer för att granska ens dokument.
ber en kollega granska mitt arbete
Ber kollegor granska mitt arbete och utför egenkontroll. Ibland saknar man tid för granskning och validering i olika uppdrag.

Vi har checklistor som jag tittar igenom när tid för validering finns. Brukar även kollegor titta om tid för det finns.
Checklista, granskning av kollega, kontroll mot "verkligheten".
Olika typer av granskningar.
Granskning och checklista
checklista, ber en kollega granska mitt arbete
Checklista och intern granskning.
Checklista, egen och kollegas granskning, export till DWG och dubbelkolla.
Använder checklistor och granskar ritningar, beskrivningar samt beräkningar i pappersformat.
Checklista och granskning
Går igenom det som har gått fel förut (typ en checklista). Om vi pratar om dokument, frågar jag min chef att dubbelkolla på det (bokstäver, komplettering, etc)
Vi har rutiner för kvalitetsgranskning och oberoendegranskning, men behöver fortsatt och kontinuerligt utvecklas
Egenkontroll och intergranskning
Egenkontroll, interngranskning.
Ofta väldigt olika från projekt till projekt - ibland ska flera checklistor fyllas i, ibland en granskare precis innan leverans.
Använder checklista, ber en kollega granska mitt arbete
checklistor, egenkontroller, kollega kollar mitt arbete
Ber en kollega granska
checklistor, granskar andras material.
Ber en kollega granska
checklistor+ kollega granskar
checklista och intern granskning
Använder checklistor, dubbelkollar själv och sen fråga kollegor och TA att ganska arbetet, så att vi går igenom allting och inte missar något inför leveransen.
Checklistor Granskning från kollegor
Ber ofta en kollega om hjälp/kolla över saker jag är osäker på
som datasamordnare leveranskontrollerar, vi använder handlingsförteckning och leveransmallar för automatisera leveranser om möjligt.
egenkontroller och ber en kollega granska arbetet internt
Egenkontroll, interngranskning och samgranskning

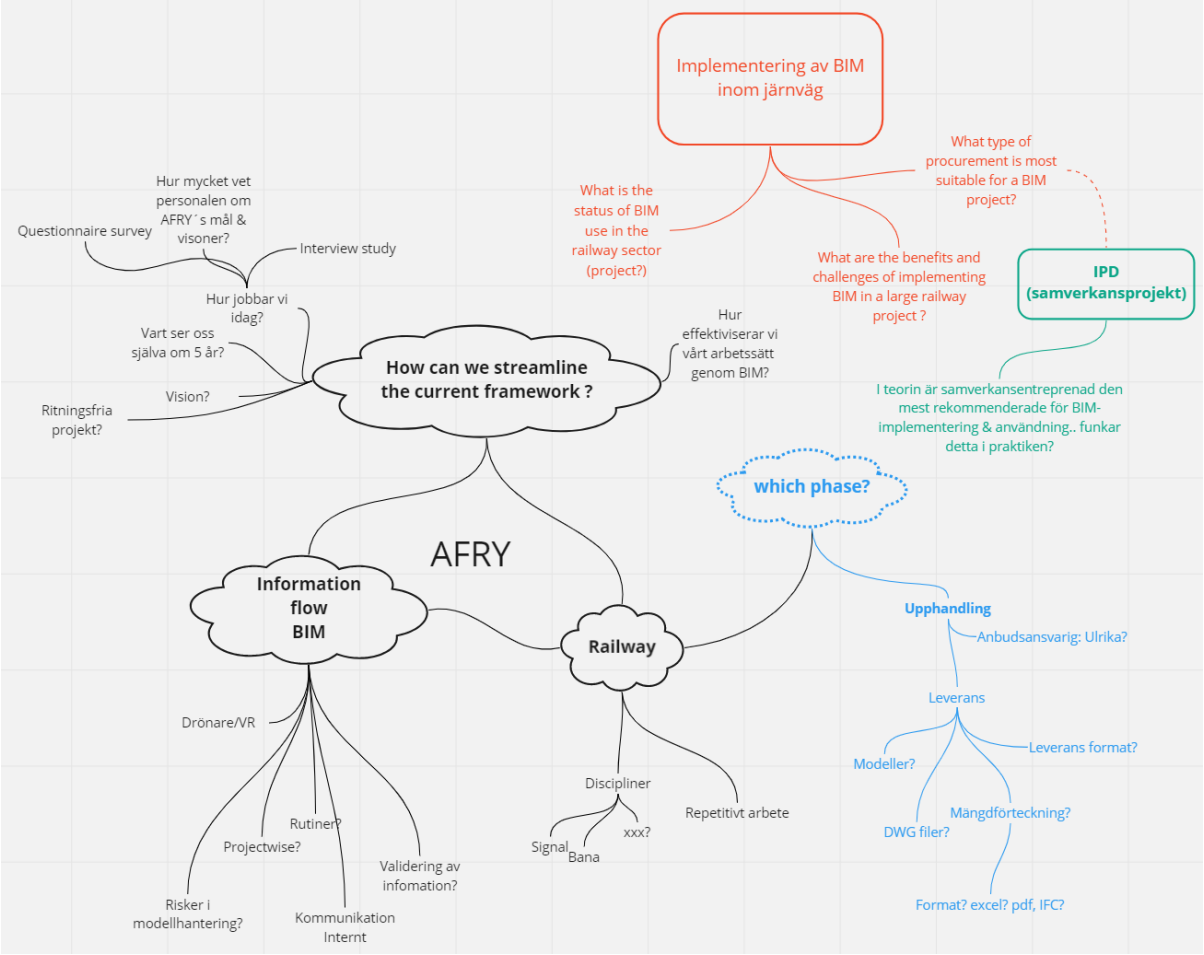
35. Om du får önska fritt, hur vill du jobba mer effektivt?
Ritningafria projekt, Projekteringmöten med projektörer, som en del av projektet
Använda ex Infraworks i ett vägprojekt där man kan rita upp förslag väldigt snabbt och sedan ta det vidare in i Civil 3D.
Vill se mer samarbete i projekteringen. tex. att man samlar alla projektörer en halvdag-heldag i veckan och löser problem "live" i modellen.
tydligare rutiner, bättre programvaror, mer tid
Bättre programvaror och effektivisering av arbetsprocessen.
Bättre förståelse för hur våra leveranser tillämpas i senare projektskeden.
Att man vet vem man kan fråga och bättre samarbete mellan sektioner (ex trafik/väg o mark/VA).
Mer tid avsatt för att kunna jobba med BIM/3D-projektering. Tydliga rutiner, med checklistor där man kan checka av arbetet/uppfyllda krav allt eftersom arbetet utförs.
Att kunna använda funktionen i programmen, istället för att bara skrapa på ytan som nu.
Smarta ritningar
Tydligare rutiner, lathundar och bättre programvaror
Tydliga rutiner och bra och tydliga mallar/tool paletts i CAD. Samt tydliga instruktioner var man ska vända sig om CAD krånglar eller man behöver handledning.
Vi har haft problem med att cad i sig är segt och att filerna på servern krånglar och det behöver bli bättre. Speciellt eftersom att vi debiterar kunden, enligt order, för strultid.
Mer tid är generellt önskvärt, alla uppdrag prutas (se nedan för ytterligare kommentar). Som tidigare nämnts, ett gemensamt/standardiserat arbetssätt skulle underlätta mycket.
Jobbar med openrail och här behövs utblidning för programvaran.
Bättre programvaror
Tydligare rutiner, arbetsgångar, uppdaterade programvaror, interna utbildningar och mer tid för just den typen av utbildning.
Mer tid, tydliga checklistor
mer tid/ ritningsfria projekt
Struktur i vad som ska levereras samt att det sällan finns tillräckligt med tid för att utvecklas i området BIM i projekten
Mer tid för utveckling eller att någon lägger mer tid på utveckling.
Bättre programvaror, mer tid och inte behöva uppfinna hjulet på nytt varje gång.
Tydligare rutiner och bättre programvaror.
Jag skulle vilja ha tydligare rutiner och instruktioner på hur ritningarna ska framställas. Och att kunden är tydligare med sina behov och krav.
tydligare rutiner

36. Har du något övrigt du vill framföra?
Generell utbildning till alla... om vad som redan finns hos AFRY, samt att jobba för att alla gör mer lika, så det blir lättare att ta över varandras arbete.
Man bör satsa på att öka lägsta nivån på CAD/BIM arbetet i projekten och sätta en minimum standard på AFRY-Transportation.
Programmering som verktyg för effektivisering av arbetsprocessen.
Vi behöver arbeta mer med att utveckla vårt arbetssätt för att bli effektivare. Få bort många onödiga moment som inte är värdeskapande och som kan utföras med enklare
Tillgänglighetsanpassning av textdokument som kommuner nu ställer krav på. Ingen vet riktigt hur man gör. Vore bra med ex ett internt föredrag om det så alla har hört samma
Min uppfattning är att många (alla) anbud prutas för att öka chansen för att vinna uppdraget. Det finns en risk med detta och det är att vi plötsligt sitter med väldigt mycket jobb till låga timpriser och orealistiska tidplaner - en icke önskvärd kombination. Ledningens rädsla att medarbetarna ska sitta med för lite att göra trumfar helt tydligt denna risk. Har ingen omedelbar lösning på detta, men något måste göras vad gäller bl.a. de låga timpriserna. Jämför hur branschen såg ut för 20 år sedan - högre timpriser och lägre debiteringsgrad, en klart mer önskvärd situation istället för att alla ska slita hund till låga timpriser. Idag sitter mycket kompetenta medarbetare med 40 års erfarenhet och arbetar för dryga femhundringen/tim i vissa uppdrag... Detta är inte naturligtvis inte endast AFRYs fel/problem, men det är ytterst tråkigt att se att hela branschen nedvärderar sig själv. Vad gäller timpriserna finns också den icke existerande kopplingen mellan ökade BIM-krav = högre kompetenskrav = högre timpris. Det spelar inte ihop.
Ställa tydliga krav i projekten från början vad som ska leveras och i vilken programvara.
Jag tror att jag vet inte vad man kan använda BIM för. Om man vet det, då kan man ha förslag, när man ser vad som är möjligt med BIM.
Jobbar med arbetsprocesser och rutiner
jag tycker att det finns dålig utbildning i Novapoint för att lära sig programmet för första gången. Sen kraschar programvarorna en hel del, speciellt vid leverans.
korta webbaserade internutbildningar.

D

Appendix - Mind map

This mind map was created in the very beginning of the Master thesis in order to capture AFRY's wishes and point on view regarding the thesis topic, research questions and content. Several meetings was conducted with my project manager and supervisors at both AFRY and Chalmers.



E

Appendix - Samplings

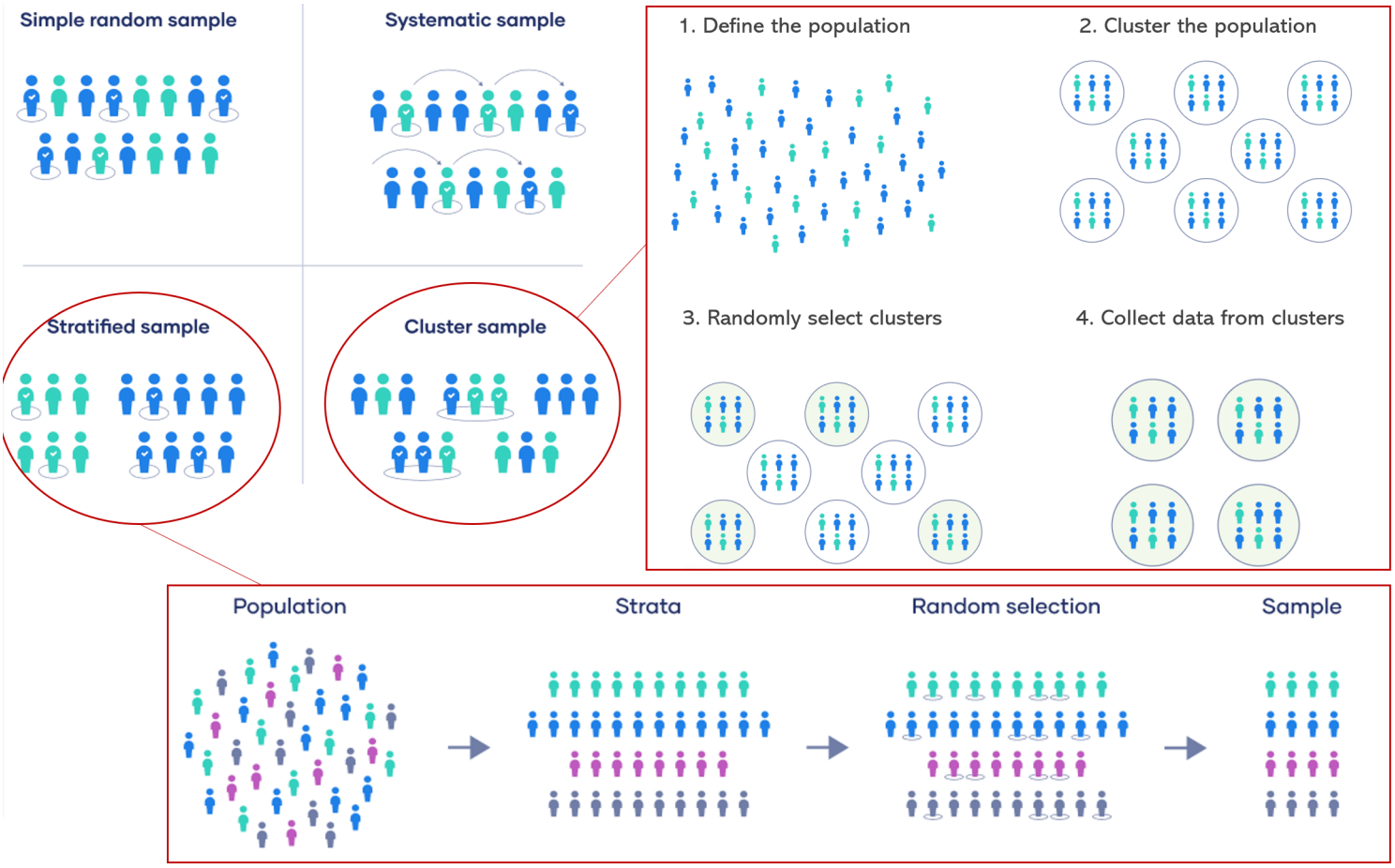


Figure E.1: Stratified sampling by Thomas, Laura (2021)

F

Appendix - STA's mission description

Uppdragsbeskrivning konsultuppdrag
Ärendenummer 161563
Dokumentdatum 2021-11-08
Väg 41 Fritsla-Kråkered

TRAFIKVERKET

Projektets totala reduktionskrav är 15 procent under framtagande av förfrågningsunderlag för entreprenad samt byggfas.

Krav på klimatkalkyl
För upprättande av klimatkalkyl ska Trafikverkets klimatkalkylmodell version 6.0 användas.

Livscykelbedömningar och livscykelkostnadsutredning
Livscykelkostnadsbedömningar ska göras av samtliga utformningar och tekniska lösningar.

En livscykelkostnadsutredning ska genomföras där livscykelkostnadsaspekter inventeras och redovisas jämte förslag på hur dessa ska hanteras i projektet. Livscykelkostnadsutredningen redovisas tillräckligt tidigt för att möjliggöra att de identifierade aspekterna kan hanteras inom uppdraget. Livscykelkostnadsutredningen kompletteras sedan i slutfasen av uppdraget med en redovisning av hur livscykelskostnadsaspekter hanterats jämte motiv till valda utformningar, kravställningar och tekniska lösningar.

BIM – Byggnadsinformationsmodell
Arbete med BIM ska uppfylla krav i TDOK 2015:0181 Objektorienterad Informationsmodell samt TDOK 2012:35 Digital projekthantering.

Informationsmodellering med BIM ger projektet förutsättningar att arbeta med objektorienterad projektering. BIM ska i projektet skapa ett sammanhängande informationsflöde mellan skeden, parter och ämnesområden och ge ett förbättrat underlag för samgranskning. I Trafikverkets arbete med BIM är samordningsmodeller, ämnesområdesmodeller och presentationsmodeller viktiga begrepp.

Definitioner av BIM-relaterade termer finns att hämta på Trafikverkets externa webbplats, www.trafikverket.se (sök på "ordlista BIM").

Innehållet i modellen:

- Objekt och företeelser med geografisk koppling ska redovisas i respektive ämnesområdesmodell och visas i samordningsmodellen.
- I ämnesområdesmodeller ska minst framgå det som tidigare redovisats på ritningar, kartor och bilder samt andra teknik- och miljöförutsättningar.
- Utskriven information i text såsom bl.a ortsnamn, vägnamn, järnvägsnamn och sjöar, andra viktiga platser, och annan relevant information som traditionellt visas i en grundkarta ska finnas med. Texter ska vara läsbara, riktade åt samma håll och samordnade med annan text som skall synas samtidigt.
- Detaljeringsgraden avseende geometrisk redovisning av objekt i 3D ska motsvara innehåll och syfte för uppdragstypen.
- Befintligheter och förutsättningar som ingår i eller berör uppdraget och som endast finns i 2D så som ortofoto, bakgrundskarta, grundkarta, bilder, fastighetsinformation, nationella kartor, administrativa gränser, utpekade, skyddade och värdefulla miljö- och kulturområden ska visas draperad på anpassad markmodell och projekterad anläggning i Samordningsmodellen.
- Underlag avseende befintligheter i 3D ska redovisas i ämnesområdesmodell samt samordningsmodell.
- Markmodell som ska presenteras tillsammans med projekterad anläggning ska anpassas och interpoleras till projekterad anläggning och redovisas i samordningsmodellen.
- Anpassad markmodell redovisas i ämnesområdesmodell.
- Den av mätningsteknik kravställda oredigerade markmodell redovisas i ämnesområdesmodell för mätningsteknik samt samordningsmodellen.
- Bilder (renderingar) och film (rörliga sekvenser) ska vara baserade på aktuell samordningsmodell.

Uppföljning av modeller:

- Samordningsmodellen ska uppdateras inför varje projekteringsmöte.
- Samordningsmodellen ska göras tillgänglig för beställaren enligt utbytesnivå C (publiceringsformat) inför projekteringsmöten och teknikmöten, i samband med mötet.
- Ämnesområdesmodeller ska göras tillgängliga för beställaren inför teknikmöten enligt utbytesnivå A (originalformat), i samband med mötet.
- Den uppdaterade samordningsmodellen ska redovisas vid varje projekteringsmöte.
- Samordningsmodellen och ämnesområdesmodeller ska göras tillgängliga för beställaren genom leverans av filer eller som URL till webbapplikation.
- Om samordningsmodellen tillgängliggörs via URL ska tidigare versioner från projekteringsmöten finnas åtkomliga för beställaren under projekteringstiden.
- Om samordningsmodellen tillgängliggörs via URL ska slutleveranser av produkten ske i DGN-format eller DWG-format med kopplade referenser enl TDOK 2012:35.
- Inför varje projekteringsmöte ska samordningsmodellen förberedas med aktuella vyer/hotspots för de ärenden som ska diskuteras.
- Samordningsmodellen och ämnesområdesmodeller ska levereras till Trafikverket när handlingar har granskningsstatus/syfte "För Granskning" och/eller när produkten är godkänd.

Redovisning av anläggning
Dokumentation ska upprättas i enlighet med Bygghandlingar 90, del 7, kapitel 5.

Digital projekthantering
Väg- och järnvägsprojekt ska hantera projektets digitala information enligt TDOK 2012:35 Digital projekthantering.

Handlingar ska levereras enligt uppdragets genomförandetidplan (se avsnitt 4.1) till rätt mapp i projektets struktur. Strukturen ska kompletteras med undermappar om så behövs.

Mätningsteknik
Datafångst (detaljmätning och laserskanning) som utförs i projektet ska, beroende på syfte, utföras med noggrannhet för att uppfylla toleranskrav enligt TDOK 2014:0571 och noggrannhetskrav för markmodell enligt SIS-TS 21144:2016 tabell 6 klass 1-3.

Trafik- och skyddsanordningar vid arbete på väg
Projekteringen ska följa "Upphandling av trafik- och skyddsanordningar vid arbete på väg, TDOK 2013:0210.

Informationssäkerhet och Säkerhetsskydd
Konsulten ska säkerställa så att beställarens eller tredje parts skyddsvärda uppgifter, verksamheter och tillgångar, inte obehörigen röjs eller påverkas under uppdraget och efter uppdragets slut.

Anläggningsspecifika krav

Projektmål

- Genomför interna APK-kontroller 1 gång/månad under entreprenaden
- Noll döda eller allvarligt skadade under entreprenaden

Följande Agenda 2030-mål tillämpas i projektet:

- Minst 50 % färre dödas och minst 25 % färre skadas allvarligt i vägtransportsystemet jämfört med 2020

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
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