BIM and Information Management

Towards a more value-adding state by applying the Lean Theory

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

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Cover:
The figure is created by the authors including both BIM and Information elements which illustrates existing information wastes in the building sector.

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Abstract

The introduction of Building Information Modelling (BIM) to the construction industry led to great progresses in the whole industry. 3D visualizations and clash detections are some of the important features that BIM provide in which they have essential impact on the duration and execution of a project. As a result of this development, complicated projects and sophisticated designs cost less, and take shorter time. However, this new concept comes along with some new problems, including how to manage the big amount of information that is generated, how to differentiate between value-adding and non-value-adding information and how to decide the type of information that should be added.
The aim of this thesis was to investigate the current state regarding information exchange and management through Building Information Models and whether companies in the building sector look at the information contained in these models from a value-adding approach or not. The qualitative study was based on a literature review alongside a number of interviews with different actors in the Swedish building construction industry. By analysing the collected data it became evident that the integration of BIM is still in its early stages and BIM workers do not primarily look at information from a value-adding point of view. In addition, an information-centric adaptation of the Lean Thinking theory was applied to the data in order to map the most probable types of information-waste as well as the most probable contexts for these wastes. The results, consequently, provided the main areas where further considerations should be taken which were accordingly information sharing and communication, value-adding information introduction/familiarity, Information Management Strategy, the trust issue, feedback systems, the shortage of as-built models and finally the lack of integration in BIM philosophy/definition. Moreover, by considering the principles of Information Logistics (IL) in addition to the Lean Thinking principles, a set of recommendations were proposed in order to move towards a more value-adding state. Consequently, the study concluded that BIM is still in the early stage in the regard of information value, information wastes exist in both strategic and system levels, the full BIM capacity is not utilized and there is a great room for improvement in the structure of different management systems as well as standardization and the level of trust. The results of this study offer a huge variety of contributing issues that can be each solely investigated through further research.

Key words: BIM, Building Information Modelling, BIM & information, Information Management, Information exchange, BIM and value, Value adding information, Lean Theory, Lean Construction, Information Logistics, BIM and Lean

Contents

Preface

This study started for more than ten months ago as a part of the master programme for the Civil and Environmental Engineering department and it was conducted at Chalmers University of Technology in Gothenburg, Sweden.

The authors would like to thank the department for all the help they provided and in particular our supervisor, Mikael Johansson, who was highly engaged with the project and dedicated a lot of time supervising us. Moreover, we would like to thank all the engineers and managers in the Swedish construction companies who dedicated their time to interview us and answer our questions.

Göteborg, October 2013

Shahram Mohseni & Ahmed Nassir Ali

1 Introduction

The introduction of Building Information Modelling (BIM) in the construction industry was not just a matter of introducing a new tool to the industry, but rather a new philosophy, a new way of thinking and collaboration. The main idea behind BIM is to use 3D-drawings to transmit non-geometrical information as well as geometrical. In other words, a BIM is an object-oriented model which means that it does not only contain lines and circles, but also it contains specific objects with specific functions for instance walls, windows and doors (Azhar et al., 2008a). Furthermore, with the aid of BIM, companies are now able to do an accurate time scheduling, cost and material estimating, and take some environmental aspects into consideration (Azhar et al., 2008a). Because of the fact that BIM has a big potential to improve the way of thinking, working and collaborating and thus improving the whole industry, companies invest a lot of time and money to implement it and educate personnel to use it (Motawa and Almarshad, 2013).

Moreover, when generating a BIM, a large amount of information is generated. This information is related to the components in the project. For instance, for the design of a door to be complete it should contain some geometrical information such as the length, width and thickness of the door and some non-geometrical information such as the type of material and manufacturer. This information is of the “Big data” type which indicates the growing nature of data being generated that organizations have to sort, analyse and process (Jiao et al., 2012). Due to this nature, three issues rise that complicate the process of managing information and increase its cost. First is the rapidly increasing volume of information, second is the wide diversity of information and third is the high velocity of input/output data (Jiao et al., 2012).

Additionally, the value of information is not quantifiable and cannot be determined unless the information is placed in an environment that it can be used and have meaning for a worker (Eaton and Bawden, 1991). Consequently, those staff and members who are engaged with information issues are spending a lot of time and enormous amounts of money to locate the right information and put it in the right place so that it can go to the right person (Sandkuhl, 2009). This challenge and also the fact that there is unawareness of the value of information and the inefficient treatment or management of information-flow among the actors who are involved in a project, leads to inefficient decision making and thus high costs (Motawa and Almarshad, 2013).

This study is an attempt to investigate whether construction companies and thereby their involved managers are aware of the benefits that can be gained by managing the big amount of information in an appropriate way. Therefore, the findings from this work are meant to be helpful for all actors who are involved with using BIM, in terms of moving from the current state towards a more value-adding state. Consequently, this will result in knowing what type of information to include in a BIM model, improving the communication between disciplines and reducing the waste of information.

1.1 Aim of the thesis

This thesis has two main goals. First, is to investigate the current state in the building sector of the construction industry regarding information management and its flow through BIM. In order to achieve this goal, the study investigates how different disciplines distinguish between value-adding and non-value-adding information. In other words, it investigates if those working with BIM think about the information they create and place in the model from a value-adding perspective.

The second goal is to investigate and identify the impact of inefficient treatment of information in BIM on resources and how to move towards a more value-adding state.

1.2 Research questions

The following primary research questions were composed to better clarify the aim of this study:

- What is the current state of information exchange and management in BIM among the involved project actors in the Swedish building construction sector?
- How value-adding and non-value-adding information can be distinguished according to different actors' perspectives?
- Are there any information wastes? How these wastes and causes behind them can be identified?
- How can we move towards a more value-adding state considering requirements and expectations of involved actors?

These research questions were based on a hypothesis that BIM workers are not looking at information from a value-adding point of view thereby risks exist in waste of resources. Thus, BIM is in its early stages in this area meaning that no significant endeavours have been done to evaluate the status of information flow. This hypothesis was used in the interview questions as the main theme to test its validity.

1.3 Method

In order to fulfil the objectives and seek proper answers to the aforementioned research questions, a qualitative approach was used. This approach was chosen because of the nature of the topic and particularly the element of *information* as a resource difficult to quantify.

First, a literature review was carried out in order to establish a theoretical frame based on different types of existing literature such as research papers, conference papers, technical articles, standards and BIM-related web databases. This theoretical frame will be presented in the next chapter.

Further, seven semi-structured interviews were conducted with seven major Swedish companies in the field of building construction who had the experience of using BIM in their projects. One architect, one facility management, one installation, one consultant and three general building construction contractor companies were interviewed. These interviews were conducted by email, telephone or face to face meetings. As the main tool to conduct the interviews, approximately twenty questions were composed in open and semi-open forms and divided to three main themes according to the contents of the research questions. In order to establish a baseline for comparisons, the general trajectory of the questions posed to each of the respondents were identical. However, some of the questions had minor adjustments in order to conform to the role of each specific actor. The length of each interview was in average one hour long and in case of face to face meetings the interviews were conducted at the companies' facility.

1.4 Limitations

Even though the technological aspect is a major infrastructure for BIM, our hypothesis was that in a few years' time (e.g. 5-10 years) it will significantly improve and solve most of its major challenges. However, the managerial aspect of information and other related issues to the subject of this study will remain unsolved and on-going. Therefore, it was decided that the technological aspect of BIM is out of the scope of this study.

As for another limitation and also an approach to narrow down the main focus of the study due to the wide application of BIM in the industry, only the Swedish building construction sector was chosen to be investigated in the construction industry.

The results and conclusions that are presented in this thesis are to be considered preliminary. It is not possible – due to the limited scope of this study – to extrapolate the results given in this paper. However, the findings and results can serve as a foundation for extensive quantitative studies that look at the response of several companies in the construction industry. Finally, due to time shortage a case study was not conducted.

1.5 Outline of the thesis

This thesis comprises 6 chapters in addition to the current chapter. The next chapter, which is the theoretical frame of references, contains three main sub-chapters: the Building Information Modelling, the information and the Lean Thinking sections. In the first sub-chapter, the general concept and characteristics of BIM found in different references are presented. Afterwards, *information* is presented alongside its related terms. In the third sub-chapter, we represent the Lean way of thinking which includes introducing the Lean Theory and Lean Construction.

In chapter 3, the findings from the conducted interviews are presented and discussed followed by the 4th chapter in which the findings from both the literature reviews and the interviews are discussed and analysed from the Lean Thinking point of view. The results of these discussions (from both chapter 3 and 4) are illustrated further on in table-form in the same chapter.

Finally, in chapter 5 we present our conclusions based on the discussions and results from the previous chapters. Furthermore, in this chapter we present some recommendations that can serve as a template or pattern to aid actors move towards a more value-adding state. In the end, we present our contribution to knowledge in this field and give some advices for further research as well.

2 Theoretical frame of references

Multiple types of scientific literature were reviewed in order to establish a theoretical framework. This framework contributes to provide a perception for the principal elements used and analyse the validity of the research questions as well as finding proper answers and resolutions for them. The research showed few studies conducted on the same topic proposed in this thesis. Consequently, the framework was established by inter-relating the relevant findings in the reviewed literature.

In this chapter, firstly the general concept and characteristics of Building Information Modelling are explained. Afterwards, the supporting theory for the main focus of the thesis which is the *information* element in BIM will be described. And finally, the perspective of Lean Thinking, which will be later used to analyse the findings and identify the potential wastes, is presented.

2.1 Building Information Modelling (BIM)

In this part, an overview of the main concept of BIM as well as its advantages and challenges will be presented according to the relevant reviewed literature.

2.1.1 What is BIM?

There are different definitions for BIM considering diversified existing articles. A Building Information Model, addressed as BIM, is recognized by a virtual model containing all the information necessary to execute and maintain a building project such as geometry, material quantities, *object* characterises like manufacturer information and fire rating, schedules (4D modelling) and cost estimations (5D modelling) by the help of ICT (Azhar et al., 2008b, Goedert and Meadati, 2008, Motawa and Almarshad, 2013). However, to make it more concise, it is "a new approach to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format" (Eastman et al., 2011).

What is found to be similar in the reviewed literature involving the definition of BIM is the *information* perspective and the emphasis on containing *all* the information related to a building and its components. Furthermore, these building components are denoted as *smart objects,* forming a simulation of the whole project lifecycle (Azhar et al., 2008a). These smart objects or *smart models,* which contain more than just geometrical information (Grilo and Jardim-Goncalves, 2010), are characterized by the capability of intelligently associating, connecting and relating to each other, according to Azhar et al. (2008a) and Motawa & Almarshad (2013). Thus, BIM is a step further from the traditional usage of 2D and even merely 3D geometrical drawings. It is both about geometry and more importantly about object-oriented in-depth information (Becerik-Gerber and Rice, 2010).

Most importantly, it should be considered that BIM is not independent software by itself, but a *model* combination of building design and calculation software/applications linked together. (Chang and Shih, 2013).

2.1.2 What can BIM do? What advantages does it have?

A Building Information Model is meant to be used as a tool in order to construct the project *virtually* before its realization, thereby adjusting and optimizing building information (Grilo and Jardim-Goncalves, 2010). In other words, BIM is a collaboration of information tools for aiding the construction management of a building from the initiation phase to the delivery phase as well as operation and maintenance for the Facility Management (Chang and Shih, 2013). In the initiation phase it can facilitate having an optimal conceptual design, among the existing alternatives, before the construction of the building and then helps the constructors with detailed information of the building's structure and architecture. The advantage of having in-depth building elements information enables the accessibility of more than geometrical information e.g. colour, materials, manufacturer, supplier and alike for a building component like a wall. This approach is known as *object-based modelling* (Grilo and Jardim-Goncalves, 2010). Object-based modelling can increase the accuracy of building components' information, because of all possessive attributes assigned to each object. In this way, the quickness and accuracy of shop drawings are also facilitated (Azhar et al., 2008b). Furthermore, the project information can be reused and changed by all project workers separately and then compiled into one model. This utility can make project processes more efficient and also add value to the information.

The BIM approach is also designed for having better collaboration, coordination and communication among different involved disciplines in the lifecycle of a building project (Motawa and Almarshad, 2013). This will lead to less costs and more efficient business relationships (Azhar et al., 2008b). Moreover, BIM can facilitate organizational learning or, in other words, 'lessons learnt' in and after projects i.e. it is also supposed to generate an improved 'knowledge-based' environment of working in the industry.

From the owner's perspective, BIM can provide the owner with an accurate and better observation of the project's overview before and while it is being constructed, Grilo and Jardim-Goncalves (2010) point out. This advantage is of high value especially in large projects.

One of the most important advantages of BIM is *clash detection* esp. in the MEP (Mechanical/Electrical/Plumbing) construction coordination (Chen et al., 2012). This control is executed by detecting possible collisions/clashes and eliminating them by the contributing project disciplines. In this way, the uncertainty of future conflicts in the execution phase decreases, thereby less rework will be expected (Grilo and Jardim-Goncalves, 2010). Additionally, in case of any further issues, the model can be of significant help to provide optimal and more realistic remedies because of the 3D visual possibility it provides to observe clashes e.g. between the HVAC system and the structure of the building.

Time planning or 4D modelling is another benefit BIM offers. There are multiple applications like MS-Project and Primavera that are famous for time planning and can provide the modules with schedule/sequence e.g. floors or phases of construction and also monitor the progress of the project (Goedert and Meadati, 2008). On one step forward, 5D modelling is achieved when cost estimations are attached to the model by selected cost planning applications. The changes in costs due to material quantity changes can be indicated by this feature during the project lifecycle (Azhar et al., 2008b). Therefore, the higher accuracy of time and cost estimation and planning can lower the overall time and cost of the project.

Execution or assembly guidelines can also be added to the model for the contractors (Grilo and Jardim-Goncalves, 2010). Furthermore, an adjusted *as-built* model will be significantly helpful for the Facility Management (FM) parties to execute operations and maintenance in the post-construction phase. Authorities and quality assurance officers can also use the model in order to access the model information e.g. for fire ratings or energy efficiency analysis, according to Azhar et al. (2008b). This function is a substitute for the less efficient traditional 2D as-built drawings (Goedert and Meadati, 2008).

2.1.3 What challenges does BIM have?

From a holistic perspective, BIM was introduced and employed in the building industry mainly in order to increase *productivity* (Becerik-Gerber and Rice, 2010). Efficiency and effectiveness of processes and cost estimations, quality improvements and material estimation accuracy throughout the lifecycle of the project are indicators of productivity enhancement, as shown by Azhar et al. (2008a). As an example, factors such as safety, cost and cost-per-unit, units per man-hour, duration and quality were the only key performance indicators employed to assess the impact of using BIM in the industry in a work cited by Becerik-Gerber and Rice (2010). They have also pointed out that the *value* of BIM cannot be considered independently i.e. it depends on the actor/discipline's perspective, expectations or requirements of using BIM.

The main source of what has been reviewed above is that all disciplines believe that BIM is still in its early stages and under development (Becerik-Gerber and Rice, 2010). Due to this fact, there is a lack of experts in this area which should conform the speed of their competence development to the speed of market requirement growth (Azhar et al., 2008a). Considering the existing literature involving BIM, some challenges are observed to be common in different authors' perspectives

One of the challenges is related to interoperability issues. The Institute of Electrical and Electronics Engineers in USA (2010), has defined the term of *interoperability* as "The ability of two or more systems or components to exchange information and to use the information that has been exchanged." This challenge is observed to be one of the main challenges, since BIM is about collaborating among different disciplines' applications in order to work in an integrated information model. This integration is needed to improve the management of the project and also increase trust in the model (Goedert and Meadati, 2008). In order to overcome the challenge, buildingSMART (2010) has introduced Information Foundation Classes (IFC) as follows:

"The Industry Foundation Classes (IFC) data model developed by buildingSMART is an open, neutral and standardized specification for Building Information Modelling (BIM). We have developed a common data schema that makes it possible to hold and exchange data between different proprietary software applications. The data schema comprises information covering the many disciplines that contribute to a building throughout its lifecycle: from conception, through design, construction and operation to refurbishment or demolition."

Further, different studies indicate that the lack of interoperability has resulted in resource losses i.e. temporal and monetary (Goedert and Meadati, 2008). Information re-addition due to inaccuracy and low trust or low capability of collaboration, duplications and returning to the usage of traditional documents and 2d drawings are among the main causes of these losses (Grilo and Jardim-Goncalves, 2010). This lack of efficiency will lead to three types of extra costs as ‘avoidance’, ‘mitigation’ and ‘delay’ costs, according to Grilo and Jardim-Goncalves (2010). All these costs are incurred to the project in order to avoid or solve interoperability issues besides the costs that are incurred if these issues delay the closure of the project or stop the functionality of facilities. Therefore, there is still room for the AEC (Architecture, Engineering and Construction) industry to improve the level of interoperability through technology i.e. collaboration of diversified applications within BIM, and also through non-technological aspects such as ‘business processes ’ e.g. efficient relationship among different disciplines’ elements, ‘culture and values’ and ‘management of contractual issues’ (Chen et al., 2012, Grilo and Jardim-Goncalves, 2010). Considering these aspects, the authors point out that the endeavours are not still adequate, for example, by only introducing guidelines like ‘Information Delivery Manuals (IDM)’ by the BIM community. IDMs are described by the buildingSMART standard as follows:

> “The buildingSMART standard for processes (formerly known as the Information Delivery Manual or IDM) specifies when certain types of information are required during the construction of a project or the operation of a built asset. It also provides detailed specification of the information that a particular user (architect, building services engineer etc) needs to provide at a point in time and groups together information that is needed in associated activities: cost estimating, volume of materials and job scheduling are natural partners. Thus the buildingSMART standard for processes offers a common understanding for all the parties: when to exchange information and exactly what is needed. The linked Model View Definition or MVD turns the prerequisites and outcomes of the processes for information exchange into a formal statement. Software developers can take the standard and specific Model View Definitions that derive from it and incorporate them into their applications.” (BuildingSMART, 2010).

Lastly involving this challenge, the ideal picture that Grilo and Jardim-Gncalves (2008) depict for the future of BIM is an environment with higher profitability and less perils because of more collaboration among disciplines. Moreover, it is encouraged in this paper to concentrate on *value innovation* in order to achieve this goal. In the end, the necessity of change in business relationship management is also addressed.

Another challenge of BIM is that it is much more applied in the design phase in comparison to the execution phase. As mentioned in the BIM advantages section, one of the ambitions of BIM developers is to develop information/knowledge sharing and exchanging in projects. However, among subcontractors e.g. in the MEP (Mechanical, Electrical, and Plumbing) sector it is still common to have frequent synchronization meetings with other disciplines, like architects or constructors, to know their requirements in order to minimize the clashes that are probable to occur (Chen et al., 2012). Nevertheless, these meetings have implications for low efficiency. This is an indicator for the fact that even though BIM has proved to be very helpful in the MEP industry, the main issue is that BIM is mostly targeted for the design process and less for the building process.

Further, since the total cost of employing BIM technology in a project can be high, it is very important to decide on the initial investment. It should be noticed that these costs can be compensated through the operation and maintenance phase by the cost cut-offs resulted from the employment of a BIM. However, the respective challenge is that there is still not enough ability in the BIM system to comprise the required information in order to obtain the knowledge for operations and maintenance (Facility Management) (Motawa and Almarshad, 2013). In other words, the current situation indicates the efficient application of BIM only in the design and construction phases (Goedert and Meadati, 2008).

The legal risks should also be added to the above challenges. Legal issues like model and component information copyright can impose challenges to communication and collaboration. In the same regard, accountability for the validity of the information transmitted is another important issue (Azhar et al., 2008a, Azhar et al., 2008b).

In total, a proper strategy of how to define the scope of the information for the project and the procedures to transmit and exchange the information is the most important step to start with (Azhar et al., 2008a).

2.2 Information

"*The problems are solved, not by giving new information, but by arranging what we have known since long.*"
Ludwig Wittgenstein, *Philosophical Investigations*

The usage of terms like information, information management and information resources have been increased dramatically in the last decade. The main reason behind this is the rising awareness of the importance of information. Moreover, information is the key element of Building Information Modelling, and thus a full understanding of this term leads to a better understanding of the entire concept of BIM.

In general, there is a lot of confusion between the word *data* and the word *information*. Data can be defined as numbers, digits, events, activities and unanalysed facts or figures that do exist but do not have meaning of itself (Engineers, 1990). These data can be managed, processed and analysed (Jiao et al., 2012). Managing data in the AEC/FM industry is complex because of the fact that data are being generated in large amounts. Furthermore, the rising complexity of managing data is a result of the increasing volume, increasing variety and increasing velocity (input/output) of data (Jiao et al., 2012).

Information, on the other hand, can be defined as a set of data that have been put in context and given a meaning (Engineers, 1990). However, the meaning may be important or not depending on how information can be used. In addition, studying and dealing with a collection of information can result in gaining *knowledge* which has a significant impact on organizational learning. Knowledge can be defined in several ways but in this context knowledge is the usage of a set or a collection of reliable information in a valuable way (Engineers, 1990). At the present time and with the great development in various technologies and ICT in particular, information can be treated in a similar way as tangible things like plastic ribbons or steel bars which means that information can be managed, processed, and changed form (Mutch, 1996).

2.2.1 Terminology

As a result for the rising awareness of information and value of information among companies in the construction industry, new terms and expressions are being used to express different ways of treating information in different context. Here follows the clarification of some of the terms in use.

1. Information Resource Management (IRM)

   The idea of the information resource management (IRM) had its start back in the 70s when the US government was attempting to control its paper work mountain (Eaton and Bawden, 1991). The whole idea was to consider information as a tangible resource in order to manage it in a more proper way. Bryce (2007), argued that the IRM concept is to control resources with the intention of satisfying the informational needs of a project. He also emphasized that all information, regardless of the context, should be stored and archived for later use. The significance of IRM for the construction organizations can be understood by perceiving that the objectives behind managing information are to save time and money, be more effective and support the organizations to reach their goals. Moreover, in order to be certain that the objectives of IRM are applicable and can be accomplished, standards and principles should be improved as well as policies (King and Kraemer, 1988). In addition, King and Kraemer (1998) stated that one of the fundamental beliefs in the IRM concept is that information can be economically analysed and rationally managed. One of the advantages that can be obtained by applying IRM is that it will provide managers dealing with information the possibility to select the best mix of information necessary to perform a certain task. Another advantage is that IRM helps dealing with information overload by providing outlines on how to evaluate the gathered information. Moreover, IRM can facilitate the comparison between the benefits of saving information with the cost of it (King and Kraemer, 1988).

2. Information Strategy

   The National BIM Standard-United State (NBIM-US) Version 2 defines information strategy as follows:

   "*Every organization involved in the design, procurement, construction or operation of capital facilities should develop an information strategy. The strategy will be driven by business purpose. The information strategy should prioritize information and assign a business value to various information packages. The strategy should also be consistent with the organization's data security*".

   Moreover, the NBIMS-US defines some aspects that information strategy should cover e.g. contractual, legal and regulatory aspects, who is responsible for checking and updating information, and when the information was generated and by whom.

3. Information Value

   The users of information find it impossible to predict the value of the information in advance. This is because the value of information depends upon its context and its use (Eaton and Bawden, 1991). For instance, a buyer of information cannot anticipate the actual value of it until he receives the information and starts to use it. Moreover, the value of information can be managed as an accountable asset. This means that valuable information can be quantified, treated, moved and used (Eaton and Bawden, 1991). In addition, while literatures agreed that the context and the reason for the information use give it its value, they could not agree whether it is beneficial to gather and store all the information available or not (King and Kraemer, 1988). Eaton and Bawden (1991), argued that in order to understand the real meaning of value of information, one should distinguish between information and tangible assets. They state that information is not easy to quantify and, on the contrary to other assets, the value of information does not change with time. Moreover, it is of vital importance to distinguish between value and cost. There are numerous types of costs during the lifecycle of information such as the cost to create the information, cost to source purchase, the staff cost, time cost, etc. However, these different costs does not say anything about the actual value of information to the user (Eaton and Bawden, 1991). On the other hand, if the reason of information usage is vague and the user does not know which information is relevant for a certain task, then the information is to be considered as non-value added (Sandkuhl, 2009).

4. Information Flow

   Investigations and studies have shown that information stands still during almost all of its life-cycle. However, information has to be transportable in order to have value (Jagersma, 2011). Moving information to, through and from the organization is called information flow (Jagersma, 2011). Sandkuhl (2009) argued that the importance of the information flow lies in its ability to provide the required information at the right time and place and to the right user. In addition, by moving information in a proper way, a significant improvement in saving money and time will be possible. Moreover, Sandkuhl (2009) added that there are some barriers facing the information flow concept e.g. whether the users know what type of information they need and if the information exists.

5. Information Logistics (IL)

   Today, the world has become a small village because of the marvellous advance in technology. For instance, small size and more powerful computers make it easy for people to carry the technology everywhere and new software can solve complex problems. Furthermore, the use of the World Wide Web (WWW) and the social network communities on the Internet, e.g. Facebook, Yahoo, LinkedIn and other types of forums, overcome the geographical hindrances in terms of connecting people with each other and secure the rapid transfer of information from one side of the world to the other. Therefore, large companies and worldwide organizations are taking advantages from the technology. For instance, in the construction industry companies are doing much more complicated designs than before in terms of 3D modelling and visualizations. In other words, the technology has made it possible for widely distributed organizations to communicate and perform tasks through networking. However, new technologies have some side effects and one of these side effect is that it is difficult for the users of information to find the right information at the right time which cause unnecessary waste of time and cost (Sandkuhl, 2009). Sandkuhl (2009) added that the difficulties become more obvious in construction projects because of the nature of project teams continually shifting, and lack of interoperable systems. Jagersma (2011) declares that finding specific information has become more difficult now because of the fact that information databases are continuously growing. In order to resolve this problem, researchers and managers have presented *Information Logistics (IL)*. Information Logistics can be defined as "*to make only the right information available at the right time and at the right point of location. This leads to a Just-In-Time information distribution where like it is in material logistics in a given situation exactly that information that is needed is delivered to the user*." (Liker, 2006).

In order to use the concept of Information Logistics it is of high importance to define what the right information means. On the other hand, since the needs and requirements of information users change from one user to another and varies over time, it is important to determine these needs and requirements for different users (Sandkuhl, 2009). IL is, therefore, a powerful tool that companies and organizations use to allocate, transmit and synchronize information to provide better service and quality (Jagersma, 2011).

2.2.2 Information Characteristics

Information is the key element of Building Information Modelling (BIM). Without information there is no BIM. As a result, researchers and managers are trying to agree upon some general features that are common for information. Cleveland states six unique characteristics that are important to keep in mind when managing information (Howell, 1999). These characteristics are summarized as follow:

1. Information is expandable. Information in use becomes larger with time. There are no limits for how information expands and therefor uncertainty increases.
2. Information can be combined, summarized and compacted.
3. Information can be transported.
4. Information can substitute other physical resources.
5. Information tends to leak. It is diffusive.
6. Information can be shared.

Moreover, Eaton and Bawden (1991) added five more "*special characteristics*". These are mainly to distinguish between information and other traditional tangible resources and to establish some differences between them. The special characteristics can be summarized as follow:

1. Dynamics of information: information can be considered as a dynamic force that is able to change the system in which it is operating in.
2. Life-cycle of information
3. Individuality of information: information can take many different forms, and can be expressed in different ways.
4. Consumption of information: using information does not lead to losing quantities in comparison to the usage of traditional resources.
5. Value of information: the value of information depends on the context it is used in.

2.3 Lean Thinking

Integrating the approach of "Lean" with the concept of BIM in a construction project can be beneficial in terms of the ability to detect and remove wastes in all phases during the execution of a project. In this chapter the Lean Theory and the Lean Construction theory will be presented.

2.3.1 Lean Theory

Taiichi Ohno, an engineer at Toyota, was the first one who tried to maximize the profits by eliminating the waste rather than increasing the output. He studied how to reduce the time from the moment the customer gives the order to the point when the company gets paid by removing the non-value added activities. This was known as Lean which means basically identifying and reducing waste (Koskela, 1992). The fundament in this new way of thinking is to consider the work process as a timeline of activities, materials and information flows. In this way, it is not difficult to find potential waste in a process and hence eliminate it. The elimination of wastes can lead to improve the production efficiency, reducing the time of the production process thereby reducing cost (Jiao et al., 2012). The Lean Theory identifies seven major types of waste (Koskela, 1992). Liker (2006) described these wastes as follows:

1. **Overproduction:** Producing more than it is needed and/or producing earlier. Other types of waste can also emerge because of the overproduction waste such as storage waste and transportation waste.
2. **Excess inventory:** Finished goods, damaged material or raw materials that cause longer lead time. Also, some hidden inventory problems can be included here such as the production imbalances, defects equipment downtime and long setup time.
3. **Over-processing or incorrect processing:** Taking unnecessary steps to produce a part. Incompetent tools used in the production process or poor design can be the reasons for why staff can take these unnecessary steps.
4. **Unnecessary movement (Motion**): Any non-value-adding movement that the employees have to do during the production process.
5. **Defects:** Production of defective parts, repairing of rework and replacement production.
6. **Waiting:** Workers do nothing but wait for next processing step, tool, part, etc.
7. **Transportation or conveyance:** Moving work on process or having to move materials and parts from place to place.

The Lean production was so fruitful that Toyota became one of the world's most well-known and successful companies in a rather short time. As a result for this success, a lot of researchers tried to introduce the Lean production to the construction industry. Their attempts were not successful, however, because of the difference in nature between the manufacturing industry and the construction industry. For instance, the uniqueness of construction projects, the site production and the project based organizations are some of the differences between the two industries. In 1992, Koskela introduced a new philosophy to the construction industry based on the Lean Theory, called Lean Construction (GRAPHISOFT, 2013). He proposed to consider construction work as a set of flows i.e. work, materials, construction and information exchange should be recognized as flows and measured in order to be able to identify and eliminate waste.

2.3.2 Lean Construction

Lean construction can be defined as " *a clear set of objectives for the delivery process aimed at maximizing performance for the customer at the project level, concurrent design of product and process, and the application of production control throughout the life of the product from the design to delivery."* (Bryce, 2007). Messner and Dubler (2010), in their article (Evaluating the Value of Early Planning for Building Information Modelling Using Lean Theory) summarize the principles of Lean Thinking as follows:

1. **Value**: Specify value in the eyes of the customer.
2. **Value Stream**: Identify all the steps in the value stream and eliminate waste.
3. **Flow**: Allow the value to flow without interruptions.
4. **Pull**: Let the customer pull value from the process.
5. **Continuously improve** in pursuit of perfection.

Furthermore, both Building Information Modelling and Lean Construction have huge impact on the construction process (Sacks et al., 2010). Sackes added that in order to improve the process of construction and thus the construction industry, the aforementioned approaches have to be integrated with each other. Applying Lean thinking to the BIM concept means that staff and members should identify the information flow as early as possible in order to be able to eliminate the non-value added information in the process of exchanging information (Messner and Dubler, 2010). Similar to Lean Production in the manufacturing industry, Lean Construction in the construction industry has to identify and eliminate waste in order to achieve its objectives. Messner and Dubler, in their abovementioned study translated the manufacturing wastes, which were identified by the Lean Theory (see section 2.3.1) into information waste in the process of information exchange. This is shown in Table 1 below:

Table 1 Seven types of waste adapted for the information exchange process (Messner and Dubler, 2010)

Type of Waste	Information exchange translation
1.Overproduction (O)	More information than required by BIM users; Early release of information causing revisions after initial release
2.Inventory (I)	Push instead of pull – "Take what is given approach"; Underproduction of information
3.Extra processing steps (EPS)	More manipulation of information than is required by users
4. Motion (M)	More file transfers than is necessary; Not placing the model in a common location
5. Defects (D)	Model inaccuracy / Incorrect information
6. Waiting (W)	Late delivery of information
7.Transportation (T)	Inoperable hand-off of information – file type and version

All the different types of wastes in the left column of Table 1 are converted to fit the information exchange process as described in the right column, see Table 1. Identifying these wastes and removing them leads to shorter non-value-added time and lower costs (Messner and Dubler, 2010).

The above theory will be employed to apply to the interview findings in the forthcoming chapters in order to map the most likely areas for the risk of waste, the related causes and the consequent effects.

3 Findings from the interviews

Seven interviews were conducted with seven major companies in the Swedish building industry. The interview questions were used in order to map the probable risks of resource waste during the lifecycle of building projects from different actors' perspectives. In addition, the purpose was to identify the current situation of the sector and the potential wastes in the information transmission flow to BIM.

On the first step, a managing architect accompanied with the CEO of an architecture company was interviewed. Second, a CAD manager working with BIM was interviewed in an installation company. In order to have a diversity of investigations from diversified actors, on the next steps a facility manager from a facility management company, a development manager from a construction consultant company and finally three-BIM working managers from three general construction companies were interviewed.

All interviews were transcribed carefully after conduction in order to be classified and analysed to serve the aim of the thesis. In order to achieve the core objectives, the classified findings were analysed by the perspective of *Lean Thinking* to identify potential wastes in accordance with the seven types of waste translated by Messner and Dubler (2010).

Among the average twenty questions plus sub-questions asked in each interview, sixteen subjects were classified. These subjects are involving general areas such as the definition/philosophy of BIM in the companies, challenges and strategies as well as more specific issues in relation to the research questions of the thesis about value-adding and non-value-adding information.

In order to clarify the structure of the questions, these questions were schematized in three main themes as follows:

Theme 1: General BIM overview

This theme was designed in order to investigate general BIM aspects such as actors' fundamental overview or philosophy of starting and continuing to use BIM in contrast to traditional 2D/3D drawings. Additional perspectives like benefits, challenges and any pre-/post-usage-performed evaluations of using BIM by the companies were also investigated. These findings were aimed mainly to answer a part of the first research question.

Theme 2: BIM and information

The contents of this theme constituted the core findings of the study in relation to the aim as well as especially the second and third research questions of the thesis. In this stage, the interviewees were required to reflect upon the terms of *value-adding* and *non-value-adding* information. Afterwards, their perspectives on *required information*, was examined in order to reveal the differentiation or similarity between *required* and *value-adding* information. Moreover, other important issues such as their structured information *management strategies* and any related assigned roles/positions, structured information *sharing* and *feedback* systems, their *trust* in the models and finally the existing *communication* challenges were investigated so as to map the most probable areas of information waste. These areas of investigation were thought over and chosen according to existing experiences from the reviewed literature based on the hypothesis and the main aim of the study.

Theme 3: Future of BIM and information

The last theme was concerning the issues that are involved with the future of BIM and information, so to say, the final research question. BIM's contribution to quality improvements and innovation, the existing level of satisfaction and reflections on standardization were investigated in this theme in order to come up with implications for transmitting towards a better value-adding state.

The above themes were selected in accordance with the research questions in order to help identify the current state, probable gaps and further required improvements.

A list of the questions and the themes can be found in the appendix chapter.

3.1 General interview findings

In this section, the answers gained from the interviewed companies in relation to the themes, introduced in the previous section, will be categorized and described.

3.1.1 Theme 1: General BIM overview

BIM definition/philosophy – Comparison between BIM and 2D drawings/3D modeling

All of the interviews were started by asking their definition of BIM and the philosophy they had for starting using it. This question was designed as an opening question in order to identify the companies' backgrounds in using their BIM definition/philosophy. From a background perspective, the answers indicate that most of the companies have had experiences in 3D modelling, which is purely concentrated on geometrical data and drawings. However, in most of the interview cases, the usage of BIM concept was no older than 3-5 years, except for the architecture company which stated to have been using the concept for 10 years through using Graphisoft's ArchiCAD (GRAPHISOFT, 2013).

The architect company's definition was mainly focused on engaging the *architect* in the whole lifecycle of the project by using object-based modelling. Furthermore, they mentioned that being object-based instead of having pure geometry, working in a single model and quality improvements were the main differences between 3D modelling and BIM. They also highlighted that they produce their 2D drawings out of the information in a BIM.

The installation company's definition was simply based on *3D coordination* and sometimes 4D modelling. For them, as expressed by the interviewee, BIM was not much different form 3D modelling plus calculations and components' values.

The interviewee from the Facility Management Company defined BIM as an approach to describe a building to its smallest details e.g. room, window and wall attributes and technical installation details. The interviewee distinguished between 3D modelling and BIM by expressing that merely 3D geometry is considered as "dead graphics" to them, meaning that it is not object-based modelling. It was also mentioned that existing 2D drawings are their basis for creating BIMs.

For the consultant company, BIM was a combination of technology, process change, information flow and communication esp. the way they can use the model to communicate better in projects. Moreover, the interviewee stated that they have always employed this philosophy to improve efficiency and productivity. These statements also describe how they distinguish between 3D modelling and BIM. An exclusive finding from this interview was the fact that there is still a significant emphasis on delivering the projects by using 2D drawings and multiple text documents. However, the interviewee mentioned also that employing information modelling in projects has increased efficiency and reduced mistakes.

The answers from two of the construction contractors, Contractor 1 and Contractor 3, were differentiated from the simple perception of using tools and methods to predict building processes, to more specific definitions i.e. object-based modelling with more information than merely geometry. However, both companies showed having distinguished pure geometry from more object-oriented properties in BIM. Contractor Company 1 also mentioned the better understanding of 2D drawings with by the help of 3D modelling. On the other hand, Contractor Company 3 had a more comprehensive definition by expressing that it is involved with using 3D modelling in different work areas for different purposes i.e. calculations, time planning and clash detections in order to visualize how constructible the concept is. In Fig. 1, a better conception of these levels of service can be observed.

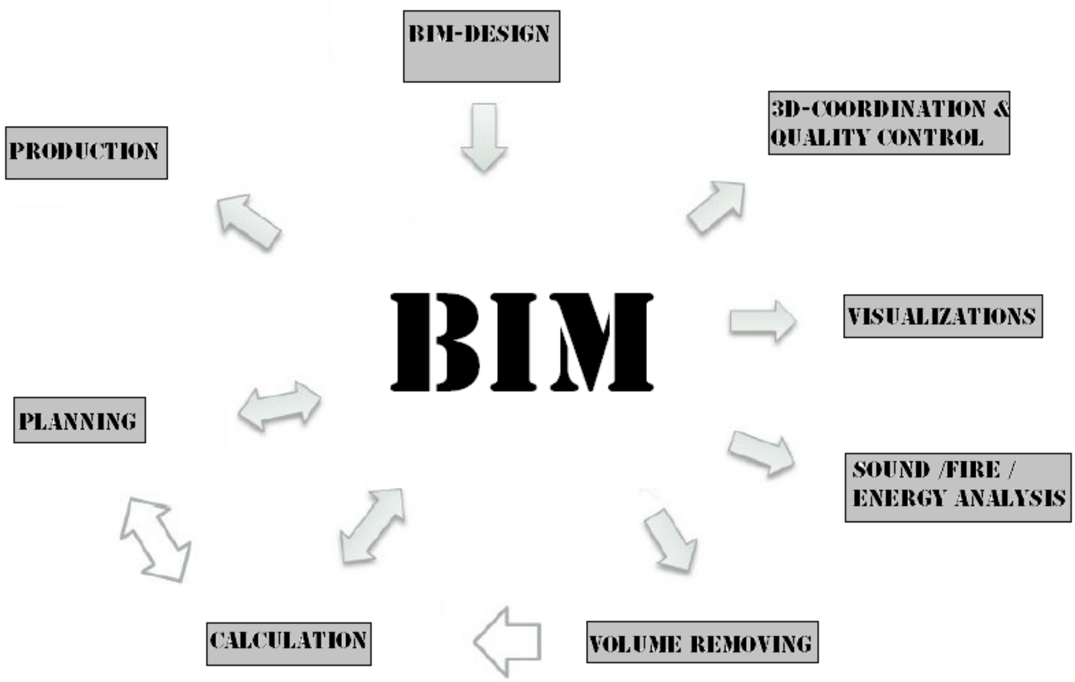

Figure 1   3D modelling for different purposes in Contractor Company 3

The above figure illustrates the main levels of their perceived philosophy in the company which are *geometrical level* for visualization and clash detection as well as another level for *implementation* and quality assurance. The interviewee also stated that a BIM makes the user think comprehensively about the building, since it makes a better sense of the realistic 3D environment in comparison to 2D drawings. Moreover, when comparing 3D modelling to BIM, he directly stated the characteristic of having *smart objects* in a BIM that are readable by their IDs and properties in order to use e.g. for quantity calculations.

BIM usage reasons/BIM benefits

Considering BIM usage, the main needs and requirements that have made the companies start using BIM according to their own definition of BIM was investigated. Further, how it has been beneficial for them to use BIM.

The architect company stated that it has not been a conscious decision for them and has been more of an investment issue in the beginning. However, the value of visualizing the building before being constructed and also quality improvement were their main requirements of starting using BIM. Moreover, about the benefits they perceived as the most important benefits after using BIM, they mentioned "working in another way in projects by collaborating among all actors" and also "a much quicker approach to come up with solutions in comparison to the past".

The installation company stated that they have been using 3D drawings with information in them since 1998 and have started using BIM because of the shortage of applications to draw pipelines and ventilations. As for the benefits after using BIM, the interviewee highlighted that it is more suitable and value-adding for large projects and also that employing BIM makes processes smoother and easier. In addition, less collision will be encountered on construction sites.

The Facility Management Company stated their initial goal to be improving efficiency and the quality of management in projects. They mentioned also that they think it is beneficial to allocate resources early in projects to employ BIM and get consulting support.

The consultant company had a reaction similar to the architect. The interviewee said that their main driver to start using BIM has been that "the client asks for it". In addition, he expressed that they have started using BIM for the promising overviews in the initial package to solve efficiency issues. Market requirements were also another force for them to start using BIM. However, the interviewee believed that depending on the conservativeness of the client and the staff in a project, it is not always beneficial to allocate the same amount of resources. This means, for example, that if there are a competent team and client with enough BIM experience, it is more beneficial to allocate resources to employ BIM in the project.

Among the three general contractors interviewed, Contractor 1 stated that their requirements have been different esp. coordination and application that in the long run spared them time and capital. They also pointed out that awareness has increased by having better visibility and sense making of project properties e.g. costs. Contractor 2 did not specify any particular reasons for starting using BIM. Nonetheless, the interviewee addressed the benefits after using BIM as fewer collisions, clearer understanding of what to build (4D modelling), better tendering, better marketing and cost estimations. Contractor 3 expressed their initial requirements as higher productivity and better design. In addition, they used reports which took cost savings into consideration. This company believed the application of BIM to be beneficial qualitatively for each project. This is due to the unique nature of construction projects, meaning that it is hard to measure the benefits in the same project. The interviewee therefore, mentioned "more effective ways of working" and "easier communication" as the major benefits of using BIM. The main reason is that the visual capabilities facilitate the expression of problems thereby saving hours of time spent in the traditional ways to explain the issues.

General BIM challenges

Challenges involving the usage of BIM from either organizational or project perspective was investigated. This question was asked in order to contribute to the first theme of the interview questions i.e. general overview of the companies towards BIM and at the same time map the possible areas in which non-value-adding information can be transmitted.

From the architect's perspective, these were the challenges:

1. Lacking BIM for operations and maintenance
   This challenge was the most important one from the interviewees' perspective. They repeated a number of times during the interview that the Facility Management party should be more and more engaged with using BIM.
2. "A *project-based* definition of BIM originating from the *client* perspective in setting requirements".
   This issue was a very important challenge in their opinion. The interviewees continued by saying that this type of information will resolve the missing exact details of each stage's contents. In other words, there is no clarification by clients of their exact requirements form the early stages of a project due to the different levels of clients' BIM experiences.
3. *Missing information* that causes more time to acquire through processes.
4. Information loss
   The more information added, the more control is needed and the more missing of quality is probable.

From the installation discipline's perspective, the challenges were as follows:

1. The software
   The interviewee expressed that the software is more dedicated to design and construction rather than installation.
2. Lack of *standards* to know what exact information/parameters to put into the model e.g. like the National American BIM Standard
3. Facility Management
   They still use paper drawings mostly. They should start using more the model information which the builder supplies.

According to the FM Company the only challenge was avoidance of having too much information. This is due to the issues that may occur in the updating process when there is too much information in the model. Esp., when documentation is needed, the updating becomes essential.

In a similar way like the architect, the consultant also transferred his opinion through two main points:

1. Poor definition of the purpose of using BIM in the starting phase of each project

This issue was said to be the biggest challenge. The interviewee continued by explaining that people think that BIM is the Holy Grail and the solution to all problems. Furthermore, the purpose of using BIM should be defined for each project separately.

2. *Clients* not good enough in specifying their requirements in each project in relation to BIM in the early stages

The contractor companies expressed these issues as the existing challenges:

1. Insufficient competence
   The compatibility between the software and the development of reliable methods evolves continuously depending on the new needs and technological opportunities. Moreover, technology does not allow all the things we want to do today e.g. comprehensive material information and communication with the subcontractors and distributors. In addition to the technological aspect, the competence issue also exists among the people in the bottom line of the hierarchy, not motivated enough to use BIM.
2. File size optimization
   BIM tools also need to be developed in terms of file size and optimization as the model files too quickly become very heavy.
3. Insufficient usage of BIM on the construction site
   Throughout the design phase the models are used a lot, but sometimes we don't get full use of the BIM on building sites. However, it may be used for visualization onsite, but not for quantity-take-offs.
4. Interoperability issues
   The complexity of the models and different software makes it difficult to easily get all needed information quickly.

Evaluation/Survey

To our surprise, only two of the companies that were interviewed, contractor 2 and 3, expressed that they have done some kind of evaluation/survey before or after implementing BIM in order to identify its impact. The facility management company conducted a survey before starting using BIM only (they started using BIM for not so long ago so they do not have enough information to do an evaluation yet) and the rest of the interviewees stated that they did not do any kind of evaluation before or after. As an excuse, the architect company said that they evaluate the usage of BIM "all the time" through better quality control that BIM provides. In addition, the best evaluation for them is if the client is satisfied and does not have problems with the structural engineers and ventilation. The installation company, on the other hand, said that they feel good about using BIM because they use much less papers and sheets and they also noticed that clients are satisfied. Moreover, the consultant company said that the only kind of evaluation they do is that after finishing a project they ask staff who were involved in BIM about their feelings regarding the usage of the 3D models and BIM.

3.1.2 Theme 2: The value-adding state of information

Value-adding and non-value-adding information perspective

The definition of value-adding information according to the interviewees can be summarized as follows:

- The information that is going to be used by someone else for a purpose
- The information that is required by the client
- The information that the business needs and can be used effectively
- Correct and structured information. This means that each component should have enough detailed attributes
- From an information model perspective, all objects are value-adding e.g. windows and doors.

In addition to the abovementioned definition, the installation company added that they consider features such as visualization and clash detection as value-adding since they can use it to show the client how the final product looks like. The facility management company added that the ability to access information at any time is also value-adding.

On the other hand, the companies stated four features to identify non-value-adding information. These features are:

- Information that is difficult to develop and is not needed or requested
- Too much information is considered to be non-value adding e.g. in some cases the provider of the products provide some production information that are not relevant.
- The information that is automatically added
- The difficulties in getting information

Contractor 2 stated that all kind of activities they have to do before erecting a structure is considered to be non-value-adding e.g. looking for materials/equipment, getting the right information, understanding what the task is about etc.

Required Information

Required information is a part of value-adding information. In other words all required information is value-adding but, not all value-adding information is required. In the interviews we investigated that matter.

The architect said that required information is what other disciplines require from them. For instance, the contractors require information regarding energy analysis, cost calculation etc. They added that this information is mainly related geometrical analysis and 3D clash detections.

The installation company agreed with the architect regarding that this information is mainly data required for the analysis. However, they interpreted the term “required information” as the information they require. In other words, they require information, for instance, on wall construction for the heat-loss calculations which most of the time is lacking in the model (there are generic walls only).

Contractor 1 underlined that using different software makes it difficult to get all the information. In addition, they claimed that it is desirable to deliver the required information, especially the quantifying information, in a good way through BIM.

Contractor 3 described required information as the information taken from the drawings directly.

For the consultant company, the main issue with required information and generally all information in the model was the tools. The tools that they are using to put information in models are not developed enough. Thus, they have to use other software to put in information and that's where the interoperability issue rises.

Moreover, most of the interviewees stated that if the required information exists in the model then it is easy to find. For instance, Contractor 1 emphasised that information should be specified form the beginning in order to simplify the process of finding it. Otherwise, it will take long time and cost a lot of money and the staff should be really good in using the software.

Strategies and Protocols in sharing information

All construction companies need and have sets of procedures, guidelines, checklists or design manuals, for example, in order to specify what to share and what not to share. This is also applying to the communication strategies/protocols with other actors. To gain this knowledge, a direct question was proposed to the interviewees.

The architect expressed using IFC format base models as the main sharing tool, but also reflected the serious gap in the absence of sharing and communication strategies/protocols. They said they only use structural templates to share information.

Secondly, the interviewee of the installation company expressed that they mainly use traditional means of communication and information sharing. These routes consist of emails, telephone calls, documents and Byggnet. The most important finding is the fact that "information can get lost when shared by email, telephone, etc." as pointed out by the interviewee. In other words, sticking to traditional ways of communication and information sharing increases the risk of more and more inquiries for information and also possible changes and alterations thereby waste and non-value-adding processes in the system. On the other hand, the interviewee pointed out that if only the model itself is used to share information it can lead to too much information in the model. Consequently, the high amount of information slows down the operations of the applications due to the additional non-value-adding information in the system. Instead, external databases can be used.

Among the contractors interviewed, there were almost no official approaches identified. However, Contractor Company 2 reflected of having a VDC (Virtual Design & Construction) manual and VICO estimate database and Contractor Company 3 answered to use share-point portals and the model itself which again shows the shortage of strategies and protocols among the contractors.

The facility management company also concentrated on the Industry Foundation Classes (IFC) as their main route of information sharing in projects. However, they pointed out as well that they have not defined how to share information in projects, thereby they do not have any structured protocols/strategies.

Finally, the development manager in the consultant company emphasized on the existing gap in the area of information sharing by expressing: "Esp. in the housing industry it is hard to cooperate because there are many actors/companies involved. We lack the business setup that gives us a driver to talk efficiently in projects, because it is more about talking to each other in projects. We are good in solving technology stuff but we are no good at solving soft value stuff."

BIM/ Information coordinator/manager

BIM and information manager has a very significant role in terms of updating the models, putting the right information in the right place at the right time in the hand of the right person and make sure that the information flow goes smoothly. To investigate that such title with such type of responsibility existed, the interviewees were asked whether they have such title in the company or not. Surprisingly, only three of the companies had such title (Only BIM manager and no information manager). All the other companies had other positions e.g. CAD manager, BIM specialist and BIM coordinator. However, these titles don't have a defined role and they mainly deal with CAD drawings only.

As-built model

Possible provision of an as-built BIM was considered i.e. a model with all updates and alterations for the finished project. When asking if they provide such model, some of the interviewees answered that they do not do that because it is too expensive to do plus the fact that the as-built model is infrequently requested. Other interviewees said that they provide as-built models to clients only. Moreover, one of the interviewees stated that they request as-built models from other disciplines because they need it to do calculations e.g. energy calculations.

Feedback information system from previous projects

Almost all of the companies reflected to have some sort of feedback system, however, not structured. In other words, they stated that they have some kind of an internal feedback system. This is a database were documents and models regarding each certain project are stored and companies can at any time access the database and bring them up for knowledge and learning purposes. However, some of the interviewees added that this system is neither structured nor defined. Moreover, most of the time the system is for internal use only i.e. some of the disciplines do not receive any kind of feedback at the end of the project from other disciplines

One of the interviewees, particularly the installation company, specified that they send back models to the architect sometimes and request some changes. However, these changes and feedbacks are mostly geometrics. In addition, some of the companies provide feedback through meetings, mails or through integrating the feedback system in their project management system. Nevertheless, they don't use the BIM to provide feedback in a project.

Information Management Strategy

Generating a BIM model means among other things that huge amount of information will be generated. Because of this fact, the disciplines were asked if they had any kind of strategy to deal with the constantly increasing amount of information. The architect company stated that they have an unofficial strategy which means that they decide what information they need according to the client requirements. The consultant company said that they use information delivery manuals (IDM) to deal with information. Moreover, Contractor 1 said that the only strategy they have is to train and educate staff in projects and receive as much information as possible. Contractor 2 said that they developed a project management system in share point to manage information. And finally, the third contractor plus the Installation Company and the FM Company stated that they don't have any kind of strategy what so ever.

Trusting the information in a model

The trust issue among the actors in relation to information in BIM was investigated. It was asked to what extent they trust the information in the model. In addition, a follow-up question was asked regarding the level of trust they have observed from the other collaborating actors to whom the information in the model is forwarded.

The architect interviewees showed their very high confidence and level of trust in the technological aspect. This aspect comprised the accuracy and reliability conversions from the model to IFC format, information files and also their high confidence in the main software they have employed for years i.e. ArchiCAD. On the other hand, they expressed a little distrust form the contractors reassuring and re-measuring the information they get from the architect.

The interviewee from the installation company expressed their obligation to trust by stating the shortage of time for recalculation or re-measurement. However, he also mentioned the need for re-consideration when there are serious inaccuracies.

The answers from the consultant company were rather different with more considerations. The interviewee associated the level of trust with the knowledge of the source of information. This exact perspective was also mentioned by Contractor 3. Putting it to simple words, if they know the source and the history of information, then the trust is higher. The consultant interviewee further explained the existing occasional recalculations esp. involving quantity lists and also distrust seen from other disciplines in case of occurring mistakes. He addressed this as an inevitable process that cannot be considered as mistrust all the time by indicating: "Complete trust is generally a sign of high risk; re-checking and re-measuring are inevitable".

The aforementioned inevitable process of re-assuring the accuracy of information was found among the contractors. Contractor 1 said that he trusts the information as long as he is sure the drawings are taken from the 3D model. However, he expressed his lower trust when it is about quantities and calculations. Contractor 2 showed their high level of trust by expressing that they usually trust the information and leaving the adjustments to structural engineers or architects. More interestingly, Contractor 3 communicated two criteria considered by them to trust the information by expressing:

"If the information is correct (accurate) and structured then it is secure, quality assured and trustable."

By "structured" he meant that every component should have enough attributes and should not lack the required information.

Finally, the only company that did not answer the question was the FM Company because of not having enough experience and background in this area.

Communication challenges

The interviewees in the architect company stated that there is still a lot of information saved in 2D and CAD (DWG) files which can lead to information loss. They pointed out that some standard approaches like CAD manuals are missing in this area. Moreover, there is a shortage of learning for each actor from its own kind.

The installation company highlighted this challenge by using two principals of Information Logistics i.e. delivering the right information to the right person. He also added that identifying the right person is challenging, and therefore information can easily be lost in this process. As a suggestion, he expressed that communicating information through the model can help improve delivering to the right person.

The FM Company focused on the various design tools not being always compatible and combinable. They explained this issue more by the shortage of better IFC import/export tools.

A whole new business model was the idea suggested by the consultant as a missing component in the communication area. In this business model, the actors shall benefit a same system of communication. This business model is also supposed to create a common feeling of success among all participants. Further, the interviewee indicated the current state of information exchange that needs to be improved.

As an answer to the aforementioned question, Contractor 1 and Contractor 3 expressed that we lack an *agreed way of communicating*. This comprises, according to all three contractors, finding better ways to communicate among different project participants in order to improve common understanding. Contractor 3 also mentioned that the way of communication is not well integrated today and is still depending on traditional routes e.g. telephone, email, documents, etc.

3.1.3 Theme 3: The future of Building Information Modelling

Improvements and standardization

This issue was investigated to establish what the different disciplines think that is significant to improve, regarding information and information exchange. Generally, a rather high demand for standardization in all BIM processes was identified among different disciplines.

The architect company firstly talked about the lack of collaboration in bringing information to one 3D model from different disciplines. This viewpoint implies the conventional idealistic vision that exists in the industry i.e. “to be able to work in a single file in real time in the long run”. Such an integrative goal requires high level of standardization among all the disciplines. Furthermore, the interviewees of this company emphasized on having a “common definition of BIM” in the beginning of each project, which was also indicated by the consultant company. This also implies a standardized way of working in projects by specifying the scope of information that we can have to add value to the model. The consultant company also indicated the need for improvement of standardization in the coding systems, but disagreed with working in a single file. The disagreement was in order not to make the model containing too much information.

One of the interviewees that clearly expressed the need for “information standardization and structuring instead of project-based standards” was the installation company. The interviewee pointed out that “we are early in the process” and in the future “we should develop general standards for BIM instead of sticking to project-based standards and arrangements”. On the other hand, a different perspective on standardization was indicated by the facility management company i.e. “better support for standardized information transmission of object models through IFC or FI2XML formats”. This perspective relates more to the technological aspect of interoperability challenges discussed in the previous chapter, which is out of the scope of this study. However, the non-technological aspect of interoperability was also addressed as improvement of business processes which can be inter-related to this subject. This inter-relation leads to more standardization of business processes that will affect every element including the frame in which technological communication occurs.

Considering the interviewed building contractor companies, Contractor 1 had the perspective of moving towards standardization through information management. On the other hand, Contractor 2 focused on "having a single tool which can integrate the diversified applications contributing to a BIM". This focus is very close to the FM Company's perspective and relates more to the technological context. Finally, contractor 3 did not focus directly on standardization. However, he expressed the desire to have higher level of details like the mechanical industry. Since this level of detail can create huge amounts of information which consume large amounts of resources, a set of standardized limits need to be defined.

BIM Expectations/level of satisfaction

The concept of BIM is a rather new concept in the field of construction engineering. Some companies that were interviewed have been using BIM since 2010 only. Others have been using it for 10 years "before anyone start calling it BIM". Consequently, the experience they have is different as well as their expectations. In this regard, a question was proposed in order to investigate to what level the current usage of information in BIM fulfils their expectations/requirements.

The architect company did not feel that there are any gaps or missing information and thus they were satisfied with BIM. However, they said they face some problems sometimes with other disciplines regarding information.

The installation company, on the other hand, expressed that since the concept is still in the early stages they do not have high expectations. However, they are satisfied with what they have.

The facility management company stated that they have not been using BIM for a long time but the concept is useful for them especially if the model is made according to their guidelines. Contractor 1 added that this new concept gives good overview and facilitates understanding of how the final product will be and Contractor 2 said that the tools available today fulfil their expectations. In addition, Contractor 3 criticized that the BIM can contain too much information and they consider if information is secure and if quality is trustable. That is why they delegate the responsibility of the accuracy of information in models to consultants.

Finally, the consultant highlighted that if all the actors involved in a project know the purpose of the project (why), the strategy to conduct it (how) and the tools to do it (with what), then the expectation should be achievable. They added that if there are too many people involved in the project then there will be too many perspectives and thus the information will not be good enough.

Quality improvements

It was asked how information transmission to BIM can contribute to quality improvement according to the disciplines' experiences. This question was asked with the purpose of investigating the quality assurance system in the companies in order to see how value-adding information contributes to improving the quality of work.

The architect company stated that their definition of work quality in relation to BIM is "partly conformance to requirements and mainly the accuracy of the model." This means making sure that there are no duplications, quantities are correct, etc. They also added that quality assurance is being done automatically by the BIM teams working in the company.

According to the installation company, collision control was the most important outcome i.e. working much smoother and having fewer collisions. It was mentioned that they have had a quality assurance role and it has been seen and reported that quality has improved in comparison to using 2D drawings.

The Facility Management Company reacted to this question by expressing:

"By supplementing the model with information, quality will improve. By reviewing existing data from CAD and make them more available, this will improve the quality of information on such rooms and areas."

The consultant, again, related quality improvement to having purpose. However, the interviewee stated that even using merely 3D models has reduced mistakes and waste in construction projects thereby improved the overall quality of project execution. Moreover, he summarized his perspective by expressing that "when the required information is useful (value-adding) then it is contributing to quality improvement."

Contractors 2 and 3 also reflected their ideas to this question. Contractor 2 expressed quality improvements in the forms of collision control, better understanding of what to build and the order of work processes e.g. MEP works. On the other hand, Contractor 3 emphasized that information transmission to BIM is significantly contributing to quality improvements esp. by increasing the accuracy of estimating quantities in comparison to the traditional approach. Furthermore, the interviewee addressed the increase in the quality of drawings which leads to the quality increase in clash detections. It was added that these improvements will contribute to the quality improvement of the end-product.

4 Analysis and discussion

In this chapter, the findings will first be analysed by applying the Lean Theory and further on discussed with conformance to the research questions.

4.1 Analysis of the findings by applying the Lean Theory

In this section, the findings existing in the aforementioned themes will be analysed from the Lean Thinking perspective in relation to BIM and information. Because of the clear identification of different types of waste by Messner and Dubler (2010) which is also translated form the original and conformed to BIM and Information, shown in table 1, we decided to use Messner and Dublers's approach to map potential wastes in each area. It should be noticed that the wastes classified herein can be close together and very hard to separate. Therefore, each type of identified waste can be inter-related and mixed with the other types.

1. Overproduction (O)

In order to identify overproduction, the answers were analysed by looking at the areas in which more information than required by the BIM users exist. Moreover, early release of information that may cause revisions and re-considerations after the initial release was considered. The importance of this issue was emphasized in different parts of the answers from the respondents, esp. by using "too much information" from different actors.

To begin with, responses given to the question of BIM definition/philosophy have implications for this type of waste. That is, not having a clear and common project-based definition of the BIM and the required information in between different actors which can lead to early release of information, too much information in the model and future manipulations of information during the lifecycle of the project. This is because when there is not a common purpose-based definition of the Building Information Model in a project, there is shortage of specifying the information required in between actors thereby actors add as much information as they can. This is also clearly stated in the findings about BIM challenges with emphasizing on the ambiguous client requirements.

In the interview findings chapter, the most related findings that conform to Messner and Dublers's definition of Overproduction can be found in the section where value-adding and non-value-adding perception of information were investigated . This is especially observed when the respondents have mentioned "too much information", "non-relevant information" and "the information that is automatically added (early release of information)." In this way, non-value-adding information can be said to be an equivalent for overproduction of information. On the other hand, the general definitions of value-adding information like "the information that is required by the client" show that a major part of overproduction depends on the client requirements regardless of the fact that this information is used by the actors in the lifecycle of the project or not. This is more explicitly seen when asking the interviewees about required information i.e. the meaning of required information can be only what the client needs. Therefore, as aforementioned, the information can be added to the model yet never used and challenge the statement in the previous section expressing "all required information are value-adding but not all value-adding information are required". This important issue was especially emphasized by both the architect and the consultant interviewees when talking about BIM challenges. Furthermore, the common perception of "required information" among the actors is also the information they themselves need. The same reasoning can be applied in this perspective by stating that in this way the actors may add information according to their own requirements without considering whether it is going to be used by other actors.

If the model itself is used for information sharing and communication, it will end up in a model with too much information which can slow down the operations of the applications. In other words, when there is no limit for what and when to share, there will be too much information. Therefore, lacking of structured information sharing and communication strategies/protocols can also be a reason for overproduction.

It was stated earlier that one of the most important questions among the interview questions was about the existence of an Information Management Strategy to deal with the *huge amount of information* transmitted to the BIM. Considering the literature and also practices in the industry, this issue in relation to interoperability is the most challenging. By considering the different answers, we can see that there is no defined structured strategy to manage this growing information. Nonetheless, some companies stated to have intra-organizational tools like IDM, yet it is not either widespread or else it is not enough. Therefore, it is expected that the absence of these strategies results in overproduction.

Other additional issues can also be taken into consideration. One issue is the trend to reach a point at which all disciplines work in a single file. It was clearly stated by the consultant that this future ideal will cause the model containing too much information. Therefore, this is a complete future potential for Overproduction, yet not an existing waste for the time being.

2. Inventory (I)

The responses were analysed from information underproduction, information loss and information "Push" system perspectives in order to analyse the general finding areas with potential for the Inventory waste. In the existing push system, because of the missing information required, more time will be wasted to acquire the needed information. In addition, as pointed out by the architects when talking about BIM challenges, as the amount of information addition increases, more quality control is needed. Therefore, quality loss can be considered as a type of information loss.

Firstly, in the similar way discussed for Overproduction, lack of a common BIM definition in the beginning of a project can limit the mutual understanding among actors thereby causes information losses and underproduction.

Second, when asked about the perception of the companies about *required information*, many of the respondents stated that it is the type of information they need, which means not thinking about the other disciplines that later will use the information. This is indicating underproduction of information.

The absence of communication and sharing protocols, esp. using traditional routes for communicating and sharing information, increases the risk of more and more inquiries for information and also possible changes and alterations thereby waste in the form of information loss. Good examples for this fact can be seen in the answers companies gave when asking the question about communication challenges, such as the huge amount of information that is still saved in 2D files, problems of finding the right person at the right time to deliver the right information and shortage of more competent IFC import/export tools. All of these examples show the potential for the loss of information where a more integrated way of communication was said to be a cure to move away from the traditional routes of communication.

Another reason to have Inventory waste can be said to be the lack of a *structured feedback system* during and after each project. This tool both servers the model to be up-to-date and also serves organizational learning. The only possible information to send to other disciplines was identified to be the geometrical information and almost no company used the model as the main feedback tool. These facts have implications for the absence of the information needed either during the project or in the end of construction. In case the model is being updated frequently and verified to be accurate in the end of the project, it will be very useful for the Facility Management party. This is esp. more structured and reliable if the model is provided as an *as-built model* which found to be rarely done by the disciplines.

In order to add to the shortage of structuring, standardization should be added to the above issues as an important missing factor. According to the installation company, when addressing BIM challenges, lack of standards of what to have exactly in the model can result in missing information.

Other influencing factors for causing this type of waste can be stated as the dedication of the software mostly to the design phase. This fact that was mentioned by most of the interviewees can lead to missing information for the executing parties such as installation and constructors.

3. Extra Processing Steps (EPS)

This type of waste is translated by Messner and Dubler from the *rework* waste from the general concept of waste in the manufacturing and production industry. Since information is an intangible asset and not physical, the types of wastes related to it are also intangible. The two types of waste discussed so far, therefore, are in a way the main causes of the EPS (rework) waste. That is mainly for the reason that it is either about eliminating obsolete information, adding lacking information or changing existing information. Thus, it can be discussed that generally all areas that contain potentials for the two discussed wastes can lead to this type of waste as well. Nonetheless, the more important causes of this waste will be discussed more here.

As discussed for the other two types of waste, lack of information sharing and communication protocols can both cause Overproduction and Inventory wastes. Since both the overflow of information and information loss will lead to rework i.e. information inquiry and manipulation of information, the type of EPS waste can also be expected as a result. A clear evidence for this conclusion is observed while looking back at the quote from the consultant company when saying "…we lack the business setup that gives us a driver to talk efficiently in projects…" This shortage causes cycles of re-communicating and re-sharing information. The stated communication challenges also indicate potential for EPS waste as a result.

Earlier, it was discussed that the absence of a structured feedback system can lead to Overproduction or Inventory. These types of wastes can result in inquiries for information or extra manipulation of information thereby EPS waste.

Additionally, in the absence of an as-built model extra process steps or rework will be carried out by the disciplines, esp. the FM party.

The findings relating to the *trust* issue show high trust among the architect, installation and fairly high trust in one of the contractor companies. On the other hand, high potential for rework can be seen among the two other contractors and the consultant company. Consequently, the trust issue is considered to have high importance in minimizing the amount of rework and saving critical project resources esp. in the execution phase. However, because of the early experiences of using BIM in companies like the FM Company, it may take a while for companies to construct trust in their communicated information. Therefore, it is observed that more effort and concentration is needed in this area.

By investigating the existing responses in the general findings section, other issues come to attention that also can be counted as causes of this waste. For instance, as expressed by the contractors in relation to the required information, extra consumption of resources will occur if the information is not easily accessible in the model.

4. Motion (M)

In their adaptation for the information exchange process of the Lean Theory, Messner and Dubler defined motion as the unnecessary movement of files and not placing the model in a common location, see Table 1. By applying this definition on the interview findings from the previous section we noticed that some of the findings in theme 2 can be categorized under motion. The first finding is the way of sharing information. The interviewees expressed that files need to be exported to the IFC format in order to be usable for all partners. They also stated that sometimes files contain too much information which causes a delay when transferring them. Consequently, the movements of files among different interfaces means that it takes more time to receive and send files and thus more time to complete a process. This is a waste in resources according to the Lean Thinking.

The second finding is the absence of a BIM/Information Manager. That is, narrowing down the responsibilities of such title into just modifying CAD drawings leads to gaps in information among different files that actors have. This will lead to unnecessary movements of those files back and forward among disciplines to update files with the latest information. The third finding is the unstructured Information Management Strategy. As a result of not having well-defined Information Management Strategy to handle the rapidly growing amount of information, models and thereby files can end in wrong places. Finally, low trust in the information of the model leads to rework, re calculations and re measuring which means more movement of files than necessary.

The abovementioned issues are considered being waste because all of them lead to loss in resources such as time, money, energy etc.

There are also other findings from the interviews that can be placed in this category, however, the aforementioned are the most related.

5. Defects (D)

Defect which is the inaccuracy of model and incorrect information can be the result of almost all the findings in the general findings section. However, some of them are more importantly related. First is the non-value-adding information that when added to a model will cause a great deal of inaccuracy. During the interviews, the disciplines stated that because of the fact that models can contain too much information which is not requested, not used or automatically added, it is difficult to control and check if the information is correct. In other words, the models in a project can consist of a large portion of non-reliable information. This, accordingly, will lead to low trust in the models as well. The distrust issue leads to a lot of unnecessary rework and recalculations and also time will be wasted to find the correct information.

Moreover, the absence of a structured Information Management Strategy means that the purpose of information and why it is created as well as who is responsible for checking, rechecking and updating the information will remain unclear. Consequently, the risk of having wrong and ambiguous information is rather high.

If one or more of the abovementioned findings exist, then such questions rise in the head of the staff who are engaged with BIM like is the model reliable, is the information in the model correct or can we depend on it? It is important to deal with this uncertainty in the early stages, otherwise it will affect the quality of information and hence the precision of the model. Further, working in an uncertain environment has a bad impact on staff and members in terms of the fact that they will be more stressed. They will feel unsecure and thus the production will not be good enough.

6. Waiting (W)

The late delivery of information which is waiting, see Table 1, can be found in almost all of the interview findings in theme 2. For instance, when the disciplines specified some features to identify the non-value-adding information, one of these features was the difficulties to develop information and second feature was the difficulties in getting this information. These features, when existing, will cause a delay and thereby staff will have to wait longer time to get the information delivered. In addition, because of the fact that different actors use different software to create models and exchange information, time will be wasted when transforming files to different formats.

One of the main findings is the lack of protocols when sharing information. One of the actors confessed that by using the traditional way of sharing and communicating such as e-mails, telephones, etc. information can get lost and the inaccuracy of information increases, see general findings section. This finding and the fact that cooperation is challenging because of the different actors involved in a project, makes the waiting time to deliver information longer. Moreover, one of the aspects that Information Management Strategy should cover is specifying who in the organization is responsible to check, maintain and update the information. Since there is not such strategy among the actors we interviewed, the person with such responsibilities is not specified. As a result, waiting time will be longer.

Although companies expressed that they have some sort of feedback system, they also stated that this system is not structured. They expressed the need of a well-defined feedback system such as a database where models and information regarding a project are sorted and companies can access the database at any time. As a result of not having this kind of structured feedback across disciplines, knowledge sharing and organizational learning are not efficiently done in organizations and thus fewer advantages are gained from previous experiences. This leads to the repetition of the same processes and spending longer time in solving problems, hence late delivery of information.

In addition, from the Facility Management perspective, the lack of having an as-built model in the delivery phase of a project can cause unnecessary delay in completing tasks, because staff should take longer time to look on all the models and try to find the most recent. Finally, having to do a lot of re-working, re-calculating and re-measuring because of the distrust in information that sometimes occur, as expressed by the disciplines, makes the completion of the final model take longer time thereby results in unnecessary waiting.

7. Transportation (T)

Messner and Dubler defined transportation as the type of information that cannot be used and is in need for reparation. For instance, companies who are involved in a project use different software when creating a model. In order to transmit and use information among them, they need to change the format of the model into a more useful format such as IFC format so that models will be compatible with a broader range of software.

When studying the answers of the interviewees regarding communication challenges, indicators were observed which relate them to the transportation waste. In their answers, the actors stated some factors that make this transportation of file necessary. These factors are:

1. The tools in use are not compatible and combinable.
2. Shortage of a better IFC
3. Lack on agreed way of communication

In addition to the causes of wastes mentioned in this section, the absence of contractual, legal and regulatory issues related to information can also be a cause of this waste. For instance, since the business lacks property rights regulations, this makes actors hesitate to put their own created components into models. The reason is that they do not want anybody else to use it. Furthermore, the shortage of such regulations result in confusion about who within the project-based organization is responsible for the documents, drawings, models, etc. These issues can cause wastes in terms of motion, files movements more than necessary, defect, inaccurate information, waiting, late delivery of information and transportation.

4.2 Discussion and results

In this section, the analysed findings will be discussed in accordance with the research questions' contexts in order to present proper answers as results.

4.2.1 Current state of the sector in relation to BIM and information

In order to depict an image of the current state of information transmission through BIM, the issues discussed in theme 1 are more straight-to-the-point to consider. However, other indicators can also be found among the investigated issues in the next two themes. The findings from the investigation of BIM definition/philosophy and 2D/3D modelling background of the companies show that most of the companies have practically started using BIM for no more than 3-5 years. Therefore, the employment of BIM is still in its early stages in the building construction sector, as also stated by all interviewees. This is also stated in multiple articles reviewed. However, the experience in the building construction sector is nowadays more developed in comparison to the employment of BIM in other sectors within the construction industry like the infrastructure industry.

It should also be added from the above finding that the concept of *object-based modelling* or *smart objects* are observed to be understood as a distinction between BIM and merely geometrical 3D modelling in most of the companies, yet not applied by all disciplines to its *full potential*. This is observed by considering the answer of e.g. the installation company stating "only 3D coordination plus calculations and components and sometimes 4D…" On the other hand, there is a very high expectation of the BIM from companies such as Facility Management companies to include all building components to their smallest detail in the model. These are all indicators of a gap in looking at BIM from its full and correct potential perspective i.e. neither high-demanding nor low utilization. As an example of BIM capabilities, few companies like the consultant company expressed using BIM as an approach to *communicate* better in projects in order to improve efficiency and productivity. The same interviewee also emphasized on the widespread usage of 2D at the same time as 3D modelling which again has an implication for not using full BIM potential. Another evidence for this fact is the differentiation of perceptions and expectations among the three contractors interviewed. Only one of the contractors had a well-structured perception of BIM, as illustrated earlier in Figure 1.

As a result, considering the definition of BIM highlighted in the theoretical framework, the above findings show that there are differentiations among what companies use as their main philosophy and what exists in theory. In other words, by juxtaposing the different perceptions, it is seen that no exact common definition exists among the actors because of the specific characteristics of each discipline.

Moreover, few companies have executed an evaluation/survey on the value of implementing BIM. Therefore, it can be stated that companies are still struggling only to embed the usage of BIM approach in their projects and dealing with the issues involved. With the same regards for information, this is why the disciplines are not engaged or unaware of considering BIM from the perspective of information being value-adding or not. This fact makes the topic of this study rather unique.

From the benefits perspective, firstly, it is rarely observed that the disciplines have been aware of any particular reasons or planned objectives for starting using BIM. As abovementioned, few companies had a survey or evaluation before and after using BIM. The main drivers for them to start using BIM have been mostly related to investment, visualization, shortage of applications, using 3D modelling and client/market requirements. This unawareness is again due to the reason that the BIM experience is still in its early stages. Therefore, it has been a source for unanticipated challenges. However, for the newcomers who enter the arena of implementing BIM in their projects there will be enough experience to learn from and also better opportunity to create definite purposes in starting employing BIM. In this way, the uncertainties will reduce and a more value-adding state will exist.

Secondly, clearer understandings of projects due to better visualization as well as quicker and smoother working approaches due to better collaboration are the main benefits found in using BIM, stated commonly by all the disciplines. Specifically, clash detection is observed to be one the main common benefits among the disciplines because of the future cost savings due to fewer collisions. On the other hand, capabilities like 4D/5D modelling seem to be less concentrated. Further evidence for this fact can be found in other interview questions where the respondents express that BIM is not employed on site as much as it is employed in the design phase. As a result, this trend is another indicator for not utilizing the full potential and having more value-adding information.

As discussed earlier, unawareness in defining the purpose of using BIM either in an organizational level or in a project level can result in challenges that will cause different types of waste thereby reduce efficiency. This is in conformance to the strategic challenges presented in the theoretical frame of references. In summary, other existing general BIM challenges and improvements stated by all different disciplines are mainly:

- The execution challenge (Insufficient usage of BIM on the construction site)
- Poor definition of purposes esp. by the client
- Operations and maintenance (FM) issue
- Missing information, too much information (file size optimization)
- Lack of standards
- Interoperability challenges
- Ownership

These challenges also conform to the challenges from the previous literature. In addition, the FM issue, the file adequacy and lack of standards are the challenges contributing to the current state of information transmission to BIM. The shortage of Facility Management parties' contribution to utilizing BIM is a cause for the absence of the driver to have an updated model with enough information e.g. in form of an as-built model. On the other hand, when looking at Theme 2, the findings about the perception of required information show that the disciplines mainly define it as the information they themselves need. Therefore, they add as much information as they can regardless of the growing sizes of model files and what other actors really need in other cycles of information usage. Here, the lack of defining standards and efficient communication is observed to give them a mind-set of what to add and what not to add. Moreover, the perceptions of value-adding and non-value-adding information among the interviewees also indicate that currently there is not an integrated adopted definition of what information is value-adding among actors and also clients accompanied with the lack of standardization in BIM processes. This is due to the unique nature of construction projects and the changing conditions during a project's lifecycle. Finally, the communication challenges presented in the general findings and discussed earlier should be added to the above challenges as a main source of inefficiency, particularly considering the existing dependence on the traditional routes of communication.

From a strategic perspective, the investigation of Information Management Strategies shows that the companies don't have a well-defined and well-structured information strategy.

The managerial aspect of information and sharing is observed in the strategic level, as well as the standardization of processes and a structured feedback system in a lower level. Having BIM Managers and Information Managers to implement these strategic steps is of importance. The improvements in collaboration and communication achieved this way will be a key to increase the level of accuracy of the information by knowing what is required. Consequently, the level of trust in the information that the model provides can be increased. In relation to implementation of BIM Information Management Strategies, the position of BIM Manager is not an officially embedded role in the hierarchy of the companies. A step further, the role of an expert

Information Manager e.g. C.I.O is completely missing. The usual popular role is a BIM Coordinator or CAD Manager.

There are no structured Information Sharing Strategies in the current state either as indicated in the findings and the usage of traditional routes of information sharing still exists. The most important finding here is the fact that information can get lost when shared by email, telephone, etc. In other words, sticking to traditional ways of communication and information sharing increases the risk of more and more inquiries for information and also possible changes and alterations thereby increases waste and non-value-adding processes in the system. As a result, there is a huge gap in the area of information sharing. Among the interviewees, the consultant company was the one to point to a higher perspective by saying that we lack a *business setup* in communication and information sharing.

The findings relating to the issue of trust show the high trust among the architect, installation and one of the contractor companies. However, high potential for rework can be seen among the two other contractors and the consultant company. Consequently, the trust issue is considered to have high importance in minimizing the amount of rework and saving critical project resources esp. in the execution phase. Considering that our study's mission is to identify possible risks for having non-value-adding information in a BIM during a lifecycle of a building, it can be said that *trust* is one of those significant risks.

There is no doubt that having a functional feedback system is very important not only for the sake of knowledge and learning but also for the information flow. Due to the absence of a defined and structured feedback system, information can be lost or forgotten in the up-stream flow of information i.e. from the construction site to the higher levels in the company. Moreover, not using BIM models for feedback, leads to a great gap between models in the design phase and models at the end of the project or during the maintenance phase. Consequently, this gap caused by the waste of valuable information in the BIM model, makes it too difficult to maintain, renew or even demolish facilities. In addition, the time to find the accurate and right information will increase and thus the cost as well. On the other hand, efficiency, quality and productivity will decrease. The findings again show no structured feedback systems. The absence of as-built models that are outputs of information updates can also be added. Surprisingly, some of the respondents even mistook the as-built model we investigated with the traditional as-built drawings.

4.2.2 The value-adding state of information and the main causes of waste

Given that the value of information depends highly on its context and usage, the results from the interview findings will have implications for the value-adding state as follows:

I. The interpretation of the word "value" in literature study is not the same as in the findings from the interviews. The main difference is that in literature study, value is the activities and the information that has a significant meaning in the eyes of the customers, see 2.3.3. While when we asked the disciplines about their interpretation of the word value they stated that the information the clients/customers require is always valuable. This is due to the fact that they need to meet these requirements in order to make a project successful. However, they added that these required information are just one part, and the information they create, develop and use are another valuable parts, see section 3.1.

In other words, companies in the building sector have a superior perspective on the meaning of value than the theory of Lean because, they include their own viewpoint to the customer viewpoint to get the total picture of the word value. However, the question remains on whether or not they apply their own definition of value and value-adding to the daily work processes. When this issue was investigated, we found out that it happens seldom either because they themselves do not get all the information they need from other disciplines, or because of inexperienced staff that are working with BIM. Another reason is that they do not know what precise information to include in the early stages of each new project due to the lack of standardization and protocols. Furthermore, clients/customers continuously change their requirements during the design phase which affect the value-adding definition and the value streaming of information tremendously. To summarize, due to different perspectives on value-adding information, i.e. client/customer's perspective and industry's perspective, and the fact that requirements and needs can change during the whole process of construction, the state of only having value-adding information will remain difficult to achieve and companies cannot avoid the existence of non-value-adding information and activities.

II. According to the Information Logistics theory, companies should be able to make the right information available to the right person at the right time and place, to have efficient information flow, see 2.2.1. In order for this theory to be applicable in the world of BIM, companies should, most importantly, be able to determine what right information is. This leads us back to the issue of "what is value-adding" discussed before. In addition, because of the fact that no company among the interviewees had a structured strategy to manage information within projects and among different actors, determining the right person and the right time is also challenging. Moreover, the fact that companies use different ways of sharing information, do not make it easy to exchange information and the potential of losing information will be greater.

In their attempt to overcome this problem, the companies start to communicate through the model. This helps improve the delivery of information to the right person. However, this type of communication creates other issues. For instance the model will be overloaded with information which makes it slow to share files and difficult to be updated. Moreover, the fact that different companies use different types of software and thus the need to export the files into different formats is another obstacle in the way of overcoming the issue

III. The processes of knowledge and learning are significant to improve the usage of BIM and the way of collaboration among partners. For instance, having staff members with long experiences of working with BIM can resolve a lot of issues regarding how to get the right information, how to transmit information in a smooth way and how to eliminate waste. Companies in the construction industry make a lot of effort in order to possess, preserve and improve this kind of knowledge process by for example looking back at previous projects and learn from them. Moreover, working with the BIM concept means that each one of the disciplines involved in a project works on their own native model and afterwards put the final version of their model in a common location so that all others can access, see if everything they need is there and start working with it. This requires that some disciplines send some feedback in order to modify and complete the models. That’s why the existence of well-defined and well-structured feedback systems are essential in order to improve the process of knowledge and learning and minimize the movement of files.
In addition, the importance of as-built models lies in the fact that such models can facilitate the maintenance work which facility management execute after the delivery of each project. Moreover, the benefit of such model can even be seen in the demolition phase at the end of the lifecycle of the project. The benefits of having an as-built model might compensate the fact that it is infrequently required and it is expensive to have.

IV. Our study shows that having a well-structured Information Management Strategy where the purpose of creating information is clear, where laws and legalizations are established and where responsibilities are clearly assigned, and having a well-defined feedback system where lessons can be learned from previous experiences, leads to minimize if not eliminate the distrust issue. However, this is easily said than done because of the fact that even if companies have a good structured process and a lot of experiences, blindly trusting the information can be a double-edged sword. The question companies should find answer to regarding this issue is not whether to trust the information or not, but to what extent should they trust the information in models.
The theory of Information Resource Management (IRM) implies that information can be considered as a tangible resource thereby can be treated as one, see 2.2.1. However, there are some major differences between information and other resources e.g. the value of a tangible resource can be determined easily unlike the value of information in which it is affected by its context and usage. This special nature of information is what confuses those who are engaged with BIM and it is the foundation of several types of waste within the concept.
According to our literature review and the analysis of the findings extracted from the interviews, value-adding information can be defined as the information that is required by the client and is going to be used by other

partners for a purpose. This information should be structured, correct and relatively easy to find and use. On the other hand, non-value-adding information can be defined as the information that is neither needed nor requested or is difficult to develop and get. Moreover, all kind of activities before the start of erecting a project and information that is added automatically are considered being non-value-adding.

The latter two abovementioned definitions are taken from the combination of answers from the 7 deferent companies in the building industry which are also connected to the different types of waste identified in the study. These results can be summarized as presented in Table 2 below. In the first column of the table below the seven wastes, defined by the Lean Theory, are presented. The most probable causes of these wastes are listed in the second column and are mapped under each related waste. Worth to mention here is that these causes are very close in nature to each other and it's hard in some cases to separate them. In the third column, those indicators which were used to map the existing wastes according to Messner and Dubler's information exchange translation can be observed. Finally, the fourth column shows different impacts on the Building Information Model or information treatment caused by these wastes.

Table 2 Summary of the identified wastes, their indicators and their impacts on BIM

Type of waste	Causes	Indicators	Impact on the BIM /information
Overproduction	BIM philosophy, value and non-value adding, information sharing, communication	Too much information, automatically added information	Slowdown in the functionality of the model
Inventory	BIM philosophy, required information, information sharing, feedback system, standardization	Missing information, extra information inquiry	Incomplete model
Extra Processing Steps	Information sharing, communication, feedback system, as-built model, trust	Eliminating, adding and changing information	Information inquiry and manipulation

Motion	Information sharing, value and non-value information, Information Management Strategy, trust	Too much information, changing file format a lot, rework, recalculation	The process takes longer time.
Defects	Non-value-adding, Information Management Strategy, trust	Not requested information, a lot of non-reliable information, the precision of the model, re-measuring	Unstructured information and incorrect model
waiting	Non-value adding, information sharing, too many involved, Information Management Strategy, feedback system, as-built model	Difficult to get and develop the information, too many actors involve, longer time to solve problems	Delay in delivering the model
Transportation	Technology, communication, shortage of a better IFC	A lot of interfaces, no agreed way of communication	Loss of information, a lot of models

By studying Table 2 carefully, we noticed that there are some causes that are more repetitive than others. The most repetitive ones are (sequentially arranged from most to least):

1. Information sharing and communication (5 times)
2. Value and non-value adding information (4 times)
3. Information Management Strategy (3 times)
4. Trust (3 times)
5. Feedback system (3 times)
6. As-built model and BIM philosophy (2 times)

By identifying these causes as the most common and repetitive reasons for information waste, the process of eliminating wastes associated to each of these causes will be much easier. Consequently, the information flow will be much smoother and the efficiency of BIM will increase.

4.2.3 Towards a more value-adding state

In order to resolve the existing challenges in the current state of information flow in the BIM approach and also add more value to this information particularly by eliminating the types of wastes discussed in this study, the requirements or gaps expressed by different disciplines should be considered. In addition to satisfying these requirements and filling the gaps in the short run, long-term strategic change plans should be designed and implemented in order to deal with future contingencies.

Standardization was mentioned to be highly required by the disciplines in the general findings. By considering the different viewpoints expressed by the interviewees, there is a wide range of need for standardization i.e. from a higher level covering all BIM processes to more specific types of standardization in a project level. Altogether, this standardization can be applied in both levels and in order to conform to the principals of Lean Thinking, the construction industry can adopt and adapt from the manufacturing industry, esp. the car industry, which has been successful in implementing Lean. By having more standardization, the models will contain all the significant information that the disciplines need and thus they waste less time and money to try to find the information they require. Moreover, standardization will make the information flow among actors smoother i.e. the models will not be slow and heavy and information will be handed to the right person in time. Another result will be achieving a common understanding through a project-based definition of the Building Information Model.

Furthermore, the findings also showed the demand for integration in the way of working and also having a single file. For the latter issue, i.e. working in a single file, the idealistic idea should be more considered because of the potential risk of overproduction or even other types of discussed wastes like waiting because of too much information, thereby reaching a negative result instead of improvement.

The level of satisfaction among the disciplines showed that they are rather satisfied despite the existing shortages and challenges. Furthermore, BIM is observed to be contributing in quality improvement of the projects most importantly in the accuracy of the calculations, quantities, etc. and clash detections. From these results, it is observed that almost all companies do believe that we are still in early stages of implementing BIM and therefore the level of expectation should not be very high. However, in order to move towards an improved value-adding information state, a long-term thinking is needed. This is due to the fact that even if the technological challenges resolve in a few years, the value and waste issues -if unaddressed- will always reside as on-going challenges unsolved.

Since, strategic issues such as Information Management Strategies, Information Sharing and Communication Strategies/Protocols and feedback systems were identified to be among the main causes of waste, the main course of action should be taken in the direction towards creating more standardization and structure in these areas. To reach this goal in the most efficient way, it is recommended to concentrate on employing the principals of Lean Thinking. In this way, the concepts of Lean can be used to have a more accurate framework in order to define what is value and waste depending on each project's needs and purposes. By using this framework, the main components of Information Logistics theory will be more effectively applied to the main Information Management Strategies. This is because the definition of value is directly related to the *right* information. Therefore, applying the principals of Information Logistics to the information flow should be able to overcome the gap of information sharing by improving protocols and strategies to govern this flow. Although companies are implementing this theory in their strategies, since information is not a tangible resource as other resources, they seem to not paying enough attention to applying the theory on information flow. Moreover, the trajectory of Information Management according to Lean will drive the sector's status to the proximity of *continuous improvement*.

As stated earlier, the positions of BIM Manager and Information Manager are of high importance in order to implement and manage the abovementioned ideas. The role of BIM Manager will be more than just modifying CAD drawings. This role should include the task of checking and assuring the accuracy of information as well as updating it. Further, among the respondents, one of the interviewees talked about having the role of CIO (Chief Information Officer) to be added to their hierarchy. Such an action can help to structure, design and implement Information Management Strategies in a focused and professional way. There is no doubt that responsibilities such as defining information sharing protocols, functional feedback systems in accordance to Information Logistics and also efficient communication routes can be managed by such collaborative team. Additionally, by implementing these strategies towards more efficiency and productivity of information, the model will be updated frequently with regards to an optimal file size. The result will be the aforementioned as-built model both during and in the end of the project that can be most importantly utilized for operations and maintenance. This is a significant help to more engage the Facility Management party to BIM, which was expressed to be lacking by most of the interviewees. However, executing these actions, esp. having the as-built model, can incur extra costs and seem not efficient to the clients at the first glance. Therefore, information Life Cycle Cost Analysis (LCCA) is highly recommended to be executed. Moreover, both executive disciplines and clients should be fully aware of the importance in the differences between an as-built model and geometrical as-built drawings.

Having these well-structured feedback systems and as-built models will accordingly increase the level of trust in the information. Furthermore, there are other factors to raise the level of trust which should be taken into consideration by actors, for instance, the reliability of the source of information i.e. who puts the information in the model in the first place and why, the relationship among the actors i.e. do they have history of collaboration with each other, and efficient communication e.g. through continuous formal and informal meetings in order to strengthen the bindings among actors as well as workers.

To sum up, applying the Information Logistics theory and the Lean Theory will ultimately lead to have well-defined and structured Information Management Strategies with clear purposes. Further, these information strategies should make it obvious why and by whom information is being created. The importance of information should be evaluated and shown as well i.e. assigning value to information. Strategies should also cover law and legal issues related to information. Finally, the responsibilities such as inquiring, obtaining, maintaining and updating information should be specified, which can be facilitated by the role of CIO as discussed earlier.

5 Conclusions

This study investigated the hypothesis proposed in the introduction chapter and was structured according to a qualitative approach to answer the research questions about BIM and value-adding information by conducting a literature review alongside interviews. The hypothesis presumed that BIM workers are not looking at information from a value-adding point of view thereby risks exist in waste of resources. This is due to the fact that BIM is still in its early stages and no significant endeavours have been done to evaluate the status of information flow. The literature were divided into BIM-related, information-related and Lean-related.

In order to depict an image of the current state, the interview findings revealed gaps and shortages in the strategic level of Information Management on one hand, and a rather embedded understanding of the main concept of Building Information Modelling in comparison to the traditional 3D geometrical modelling on the other hand. Nonetheless, the scope of this study comprised mainly value-adding state of information from a non-technological perspective. To serve this scope, Messner and Dubler's "translation of wastes in the manufacturing industry into information waste" was employed in order to identify the main causes of information waste and non-value-adding information. The indicators for each type of waste were used to map the potential areas. As a result, the fields containing the most iterating wastes were presented.

Finally, based on the main concepts of Lean Thinking and Information Logistics, some recommendations were proposed in relation to the main identified causes of waste, as also discussed in sec 4.1.3 and further on in this chapter, in order to move towards a more value-adding state.

Consequently, these are the most important results in relation to the research questions regarding the current status of information and value in BIM:

1. We are still in the early phases of implementing and embedding the BIM approach in companies.
   In other words, companies are still focusing on utilizing the employment of BIM in their projects since it is a rather new concept. Therefore, there has not been enough opportunity to look into the information aspect and evaluate whether the information transmitted to BIM is value-adding or not.
2. The full capacities of BIM are not utilized.
   High expectations of BIM such as providing all bits of information related to the building or very low utilization like the lack of Facility Management's contribution for operation and maintenance exist.
3. The main causes of information waste exist both in a strategic level and also a system level.
   The actors' uncommon perspective on value-adding-information definition, unstructured Information Management Strategies, unstructured Information Sharing and Communication Strategies, the trust issue, unstructured feedback systems, lack of as-built models and finally the incompetence of technology were identified as the main causes of information waste.

4. Rethinking Information Management Strategies has the highest importance in order to transfer the current state into a more value-adding information state in BIM.
   The interviewed companies showed to have their focus mostly on having as much information as possible. However, they did not reflect to have established and structured Information Management Strategies in order to think more collaboratively. Lack of a common definition of value-adding information is also a challenge, esp. due to the nature of construction projects and non-iterative experiences in a single project. The Lean Construction theory can help to better define information waste and information value thereby more efficiently reach the goals of Information Logistics in projects.
5. Standardization has a high demand and can significantly impact BIM processes.
   It can improve the level of coordination among the contributing actors in a project. Moreover, it will add value to information and reduce waste thereby increase the level of trust among actors. The first step is to have a standardized common definition of BIM among actors in the beginning of projects. It is also highly beneficial to have overall BIM standards like general Information Delivery Manuals and working procedures.
6. The issue of trust is causing EPS waste in the form of recalculations, re-measurements and even remodeling.
   This can be also related with the important challenges of information sharing and communication. Moving towards more structured Information Sharing Strategies or protocols as well as moving away from depending on traditional routes of communication can significantly higher the level of trust. However, some of the quality assurance processes are inevitable and should not be considered as rework.
7. There is still a huge gap in the feedback systems that companies use in/among projects.
   The gap is identified by the absence of structured feedback systems. A structured feedback system will help future organizational learning as well as ongoing updates of information for the BIM workers. A type of *as-built* model will be the result of feeding back information to the Building Information Model itself.
8. The role of BIM/Information Manager is not still embedded in construction companies.
   The findings showed that even if there is such a role, it is mainly involved with intra-organizational coordination. These roles can significantly improve the interoperability, collaboration and coordination in information transmitted to BIM esp. from an inter-organizational perspective. Altogether, the main responsibility of these roles is to implement Information Management Strategies in the most efficient and value-adding way.
9. Even though the technology perspective was outside the scope of this study, it should be stated that the lack of technology competency is still very important,

especially when considering the interoperability issues and common interfaces of communication e.g. IFC.

In order to move towards a more value-adding state by overcoming the existing gaps/issues in the field of efficient information transmission and utilization in BIM, a set of recommendations were proposed in the end of the Discussion section. The core ideas of the proposal can be summarized as follows:

1. These recommendations are general strategic ideas designed by juxtaposing the principals of *Information Logistics*, i.e. delivering the right information at the right time to the right person, and *Lean Thinking*, i.e. reducing waste, increasing value and pursuing continuous improvement.

   This was based on the finding that even though these two concepts are known among companies, it did not seem to be applied in a structured way in regards of information transmission to BIM.

2. The requirement of assigning a role as *BIM managing* in collaboration with *information managing* role is motivated.

   The BIM managing role will have the control over the flow of information, identifying what is value-adding and what is not for the project as well as updating the model frequently in order to minimize wastes. Moreover, these responsibilities will lead to having an *as-built* model of the project with the least deviation from what has been built thereby highest accuracy. The output will be of high importance for the Facility Management companies for operation and maintenance tasks. This is relying, of course, on the level of trust from the Facility Management party on the information they get.

3. Two of the most important obstacles in the way of collaborating in order to move towards a better state are *model/component ownership* and *responsibility*.

   The fact that companies own or protect their self-created components/models can hinder information sharing among companies or even within projects. Aside from this obstacle, if there are commonly shared components or models, the responsibility taking of accuracy and value-adding state of the information still remains a challenge to prevail.

Further research:

Because of the shortage of time and resources, a case study was not carried out in order to closely monitor BIM-related information issues in a building project and produce quantitative results. Further, the already stated recommendations are still not implemented and tested in building construction projects. Therefore, there is a huge potential for expanding the realm of this research by exercising the ideas and evaluating the results. Particularly, separate case studies can be conducted on investigating each type of waste translated by Messner and Dubler (2010) presented in this thesis. Furthermore, since Messner and Dubler’s theory was among the very few existing translations to identify information waste, testing of other approaches, if existing, is here motivated to provide new results. On the other hand, new translation theories which can conform more to the information value and waste concepts can be created and tested.

In addition, the overviews of different actors were studied about the employment of information alongside their requirements in BIM. However, the study was not focusing on the *client* perspective which has a defining role in the strategy formation. This was identified by the stated fact that required information is “what the client requires” from different disciplines. Considering still being in the early stages of BIM implementation, we propose to have a further research on the client’s perspective in relation to the topic of the thesis. This will open more windows to identify clients’ perspectives on value-adding information thereby creates more opportunities to a common awareness among clients of the importance of this topic.

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7 Annex

7.1 The interview questions

1. What is your definition/philosophy of BIM and how long have you been using it?
    a) How do you compare it to 2D drawings?
    b) How do you distinguish BIM from 3D CAD (pure geometry)?
2. What are the needs and requirements that made the company use this BIM (definition/philosophy)?
3. Have you carried out any type of evaluation/survey about the value created in the business before and after using BIM?
    - Is allocating time and money to use BIM beneficial? If yes, how?
4. Who delivers the final BIM model to you? (FM)
5. From your point of view, what are the challenges that BIM have? (project- or whole organization- perspective)
6. Generating a BIM model means that a huge amount of information is being generated. What strategy do you have to manage this information?
7. What type of information in addition to geometrical information is added in your projects?
    - Is allocating time and money to use this type of additional information beneficial? How?
8. What is required information according to your perspective? Is it hard to get the required information from a BIM Model? Why?
9. To what extent does the current information in BIM fulfill your expectation/requirements?
10. What is value adding information to you? And how do you distinguish between value adding and non-value adding information?
11. Do you have feedback information system from previous projects in order to obtain organizational learning?
12. a) To what extent do you trust the information in the models? For instance, how often do you re-measure or reconsider the information in the model or do adjustments in order to execute a task/procedure? (Contractor)
    b) To what extent do you trust the information in the models? How often do you do adjustments/updates to information in the BIM in order to make it usable for operations and maintenance? (FM)
13. Do you forward any kind of feedback to have an *as-built model* in the end of every project to other actors? (Contractor)
14. a) Do you have a BIM coordinator/manager? (Contractor)
    b) Do you have an Information coordinator/manager? (FM)
15. How can the information added to BIM contribute to quality improvement according to your experience?
16. How do you currently share information in and between projects? Do you have strategies and established protocols for how information should be shared?

17. What are the main challenges you have faced in communication among different actors? How can the current state be improved?
18. Considering that the construction industry is a very conservative industry and it is resilient to change, can value-adding information facilitate innovation e.g. by smoothing the communication among actors?
19. What do you think that BIM should be better in, regarding information and information systems?

7.2 The interview question themes

Table 3 The main themes of the interview questions

Theme 1 (Current state)	**Theme 2 (information & value)**	**Theme 3 (Improvements)**
BIM definition/philosophy	Information Management Strategies	BIM improvements
BIM usage reasons/advantages	Value-adding information perspective	BIM expectations/level of satisfaction
General BIM challenges	Required information perspective	Quality improvement
Evaluation/Survey	Information Sharing Strategies/protocols	
	BIM/Information Manager	
	As-built model	
	Structured Feedback system	
	Trust in the model/in between actors	
	Communication challenges	