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E-Marketplace Platform Adoption in the Construction Industry

A Qualitative Study on Adoption Barriers

TU Delft

Stabiplan
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E-marketplace Platform Adoption in the Construction Industry: A Qualitative Study on Adoption Barriers

Master Thesis

By

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EXECUTIVE SUMMARY

The construction industry is widely known as laggard in terms of productivity growth. Literature repeatedly identified the fragmented supply chain of the construction industry as one of the main causes. These studies argue that supply chain integration could significantly improve supply chain efficiency and productivity of the industry. Multiple studies within and outside of the construction industry context, mention electronic marketplaces as an enabler for supply chain integration. By aggregating buyers and sellers in a single contact point, e-marketplaces can integrate the fragmented construction supply chain and increase supply chain efficiency and contribute to productivity growth. Despite the promising contribution of e-marketplaces, and the attention of academic literature, the construction industry falls behind on e-marketplace adoption compared to other industries. Industries like retail, agriculture and even heavy industries, show an accelerated adoption of e-marketplaces.

The discrepancy between academic literature and the current market situation in the construction industry, motivated this research project. After a brief literature review it was concluded that academia paid little attention to the lack of e-marketplace adoption in the construction industry. Preliminary literature does not provide a sufficient explanation for the low adoption of e-marketplaces. Since this knowledge is missing, the construction industry cannot benefit from the expected contribution of e-marketplaces to productivity improvement. A research project is initiated to address this knowledge gap within a defined scope. The problem definition is scoped according to five dimensions resulting in the following research question: how are European building services manufacturers, wholesalers and engineers obstructed to adopt BIM-based e-marketplace platforms? This research project answered the research question by eliciting barriers, explaining why these barriers exist, and explaining how these barriers obstruct adoption.

The research project is conducted as an inductive research within the Dutch software developer Stabiplan B.V. First a literature review is conducted to develop a theoretical framework and collect related work on the adoption of e-commerce and BIM. This theoretical framework is built using five building blocks: Diffusion of Innovation (DOI), Technology, Organization, Environment (TOE), information transparency theory, interoperability theory, and technology trust theory. Using the theoretical framework, and related work, a list of nine hypothetical barriers is defined. During three rounds of data collection, the hypothetical barriers are evaluated, and emergent barriers elicited. First seven unstructured interviews with industry experts are conducted to elicit emergent barriers. Second a focus group with a similar group of industry experts is organized to elicit more barriers. The third round of data collection tests the hypothetical and emergent barriers in 12 interviews with stakeholders from the European building services industry. The participants included manufacturers of building services components, building services engineers and specialized wholesalers. In semi structured interviews the list of adoption barriers is evaluated and extended, and insight is gained on the causal relationships between those barriers.

The results answered the research question by eliciting and confirming 11 technical, organizational and environmental adoption barriers that obstruct manufacturers, wholesalers and engineers to adopt a BIM-based e-marketplace. A conceptual model is developed that shows to a certain extent why these barriers exist, and how they obstruct marketplace adoption. (1) First the industry is characterized by a lack of interorganizational cooperation. Related work already mentioned this barrier from a technical perspective, but this research also identified a cultural aspect of cooperation. (2) Second the results mention that vertical information transparency on a BIM-based e-marketplace can obstruct adoption by wholesalers and engineers. Preliminary literature already recognized that wholesalers fear margin erosion when prices become transparent in the supply chain. But this research shows that vertical information

transparency is also expected the obstruct adoption by engineers. Engineers fear margin erosion when BIM models are shared in a price transparent supply chain. (3) Furthermore, this research identified the lack of interoperability as a barrier for the adoption of BIM-based e-marketplaces. Related work already recognized horizontal interoperability issues as a barrier, but the results also identified vertical interoperability related to BIM content. In contrast to related work the results deny a lack of standards in commercial information representation. (4) The fourth barrier substantiated by the results, is incompatibility of internal business processes. Incompatibility of engineering processes aligns with related work, but in addition, this research also recognized a competitive aspect of incompatibility. The internal business processes of manufacturers are unable to compete with wholesale. This obstructs direct manufacturer-engineer transactions on an e-marketplace. (5) The next confirmed barrier shows that engineering companies lack skilled BIM designers and are therefore not able to adapt business processes to BIM. This obstructing factor aligns with related work. (6) Barrier six shows that manufacturers and engineers perceive high technological investment costs. The results complement related work because on top of BIM content development costs, engineers perceive high costs of developing complete BIM-models. Since engineers develop incomplete BIM models, procurement processes are still partly manual. (7) The seventh barrier identified by this research is resistance to change. This cultural aspect aligns with related literature. (8) The eighth barrier that results from this research, suggest that the traditional construction delivery method inhibits the adoption of a BIM-based e-marketplace. The role of the scope of work limits decision power of the engineer and might reduce adoption intention of suppliers. (9) The results mention a lack of awareness of the functionality and added value of a BIM-based e-marketplace. This finding complements related work that addressed the lack of BIM awareness but did not mention a lack of awareness among manufacturers of the commercial value of e-marketplaces. (10) The tenth barrier identified by this research and not recognized by related work, is the lack of BIM software functionality. Specific software functionalities can enable engineers to adapt business processes to BIM and allow manufacturers to compete with wholesale services and do direct manufacturer-engineer transactions. (11) The last result of this research is the obstructing role of wholesale on e-marketplace adoption by manufacturers. Related work never mentioned the powerful position of wholesale that actively applies defensive strategies to slow down the adoption of e-marketplaces.

The results are affected by a number of limitations. The most important limitations result from the sampling procedure and interview structure. Sampling for the stakeholder interviews selected mainly Dutch local oriented innovative companies. This limits the generalizability of the results. Besides, the interviews were less structured than intended. This caused time shortage and weakened the base of evidence in multiple cases. Because of these limitations, the findings need to be verified in further, more rigor, research.
The results of this research can be regarded as a research agenda on the topic of BIM and e-marketplace adoption for the construction industry. But furthermore, it can trigger a chain of research projects that contribute to the adoption of BIM-based e-marketplaces. Design researchers can use the results to develop design requirements that eliminate the obstructing influence of adoption barriers.

Recommendations for practice are made to entrepreneurs and market stakeholders. First entrepreneurs that aspire to develop a BIM-based e-marketplace or non-BIM e-marketplace, can use the results of this thesis in platform design. The recommendations for entrepreneurs focus on the importance of information disclosure rules, to limit vertical transparency. Furthermore, entrepreneurs should consider adapting the e-marketplace to existing business processes of engineers. The results identified a chicken-egg problem in the availability of interoperable BIM content and BIM software. We suggest that entrepreneurs should consider subsidizing manufacturers to lower the costs of developing BIM content and increase network externalities for engineers. The results suggest that an e-marketplace might add more value in the context of a design & build construction delivery method. Finally, the findings recognized that manufacturers are not able to conduct direct manufacturer-engineer transactions, because engineers rely on wholesale services. Entrepreneurs should consider inviting third party service providers on an e-marketplace.

The recommendations for marketplace stakeholders first emphasize on the interoperability issues. Organizations in the construction industry should aim for a European standard to accelerate the BIM adoption. Governmental efforts or initiatives from non-profit organizations should be embraced. The results also recognize the critical role of construction clients in the adoption of BIM. We emphasize that clients are expected to perceive significant benefits from BIM initiatives. Clients, which includes governments, should consider stimulating BIM adoption in projects. Finally, the results recognize the problems in direct manufacturer-engineer transactions. Manufacturers should consider looking into outsourcing services to compete with the added value of wholesale.

PREFACE

This thesis report describes a journey through unexplored scientific territory. The building services industry, and overarching construction industry, received little attention from the academic world. This limited theoretical basis made this project challenging, but even more interesting. As mentioned several times in the report, this research project evolved from a design research project. Inherently to qualitative theory building research, the researcher can reflect on the research question as the project proceeds. It is important to know the evolution of this research project to understand the choices that are made.

Initially, Stabiplan consulted me to examine the possibilities of an e-marketplace for the building services industry. Stabiplan recognized a business opportunity in the value of data as a platform owner. My initial proposal aimed to design a BIM-based e-marketplace for the building services industry. With industry expert interviews and a workshop, I intended to determine the core design parameters of a BIM-based e-marketplace. Then, stakeholder interviews were prepared to test and improve the initial design proposal. Unfortunately, during the stakeholder interviews I concluded that this design research project was not feasible. The interviews failed to explain the logic behind a BIM-based e-marketplace and participants were not able to get a full grasp of the concept. Interview time was mostly occupied with discussing the barriers for adoption of a BIM-based e-marketplace. After completing all 12 interviews, I decided to adjust the scope and change the objective of the research. Although this unusual change of course affected the results, I am convinced of the academic and practical contribution.

After all, I am very proud of my work and thankful to everybody that contributed to my journey. I would like to thank two persons in particular. First, I thank Mark de Reuver, my first supervisor. His academic experience and support were very helpful. Second, I would like to thank Gijs Willem Sloof, my external supervisor. He inspired me with his entrepreneurial energy. Last but not least, I would like to thank my colleagues at Stabiplan. It was a pleasure working with you.

I hope you appreciate my efforts. Enjoy reading!

Niels Koeman

Delft, March 17, 2018

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1 RESEARCH INTRODUCTION

1.1 Introduction

The construction industry is widely known to fall behind on productivity compared to other industries (Loosemore, 2014). Based on the broad definition by Pearce (2003), the construction industry is defined as: all economic activity that directly depend on producing and maintaining the building environment. For more than a decade, academic literature emphasized the need to improve the industries productivity (Council, 2006; Rojas & Aramvareekul, 2003). Productivity is measured as the value of goods and services produced by the construction industry, as a proportion of the value of input resources required to produce it. Also recent non-academic institutions payed considerable interest in the construction industry productivity problems. Barbosa et al. (2017) from McKinsey Global Institute estimate the productivity growth of the global construction industry to average around 1% per year compared to 2.8% per year of the global economy and 3.8% per year for global manufacturing businesses.

According to multiple studies, this lack of construction industry productivity is partially caused by the fragmented supply chain (Briscoe & Dainty, 2005; Fulford & Standing, 2014; R.J., J., & H., 2001). Supply chain fragmentation refers to a relatively high number of specialized suppliers in the supply chain. A typical supply chain for a large building or infrastructure involves hundreds of specialized small companies supplying materials, components or services (Briscoe & Dainty, 2005). Aforementioned researchers argue that supply chain fragmentation reduces productivity because it obstructs coordination of supply chain processes. Coordination of supply chain processes, such as design, planning and product delivery, is critical in achieving supply chain efficiency and productivity (Fulford & Standing, 2014). Researchers like Briscoe and Dainty (2005) and R.J. et al. (2001), argue that supply chain integration could significantly improve the construction industry productivity. Supply chain integration refers to increasing the coordination of supply chain processes by partnering or collaborative working (Briscoe & Dainty, 2005).

Electronic marketplace platforms (e-marketplaces) are generally recognized as enablers for supply chain integration (Eng, 2004; Luc, Pierre-Majorique, & Pierre, 2005; Mola & Russo, 2016). An e-marketplace, also referred to as transaction platform, is a special category of platforms, supporting transactions between buyers and sellers (P. C. Evans & Gawer, 2016). Platforms are defined as businesses based on enabling value-creating interactions between external producers and consumers (Parker, Van Alstyne, & Choudary, 2016). Eng (2004) and Mola and Russo (2016) explained how e-marketplaces are able to aggregate suppliers and buyers in a single contact point, to increase coordination and efficiency. Luc et al. (2005) explain how e-marketplaces integrated the telecommunication supply chain by regrouping suppliers. de Mattos and Barbin Laurindo (2015), argue that transparency of an e-marketplace provides insight for repositioning in the chain.
By aggregating buyers and sellers in a single contact point, e-marketplaces can integrate the fragmented construction supply chain and increase supply chain coordination and efficiency. Figure 1 gives an overview of how e-marketplaces are able to improve the construction industry productivity. Some researchers already mentioned the role of e-marketplaces in the context of the construction industry (Laine, Alhava, Peltokorpi, & Seppänen, 2017; Li, Cao, Castro-Lacouture, & Skibniewski, 2003). E-marketplace can take different positions in construction supply chains. B2B e-marketplaces can mediate general contractors and sub-contractors, or sub-contractors and suppliers (Li et al., 2003). B2C e-marketplaces can mediate clients and general contractors (Laine et al., 2017).

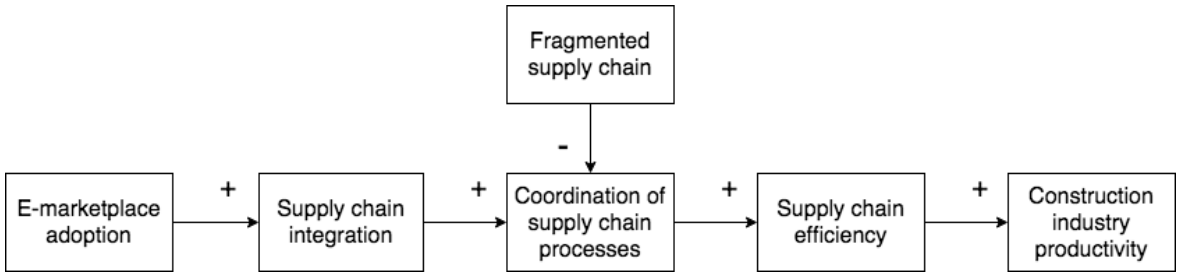

Figure 1 Research problem, conceptual model

Despite the promising contribution of e-marketplaces, and the attention of academic literature, the construction industry falls behind on e-marketplace adoption compared to other industries (Antonio Grilo & Jardim-Goncalves, 2013; Laine et al., 2017). Industries like agriculture, logistics, energy, petroleum, automobile, aerospace and even heavy industries experienced less trouble in adopting e-marketplaces (Parker et al., 2016; Zhu, 2002).

Concluding, this section identified a discrepancy between the current market situation in the construction industry and recent academic literature. Although preliminary research explains the role of e-marketplaces in improving the construction industry productivity, the construction industry falls behind on e-marketplace adoption. Prior academia argue that e-marketplaces can contribute to productivity growth of the construction industry by enabling supply chain integration. Section 1.2 will elaborate on this discrepancy by identifying a theoretical gap in the academic knowledge landscape. When a research gap is identified, section 1.3 will define a research scope and research problem. To solve the research problem, section 1.4 defines a research objective and question. Section 1.5 elaborates on the contribution of this research project. Finally, section 1.6 gives an overview of the structure of this report. Table 1 gives an overview of the core concepts used in section 1.1.

Table 1 Definition of core concepts used in section 1.1.

Concept	Definition
Construction industry	All economic activity that directly depend on producing and maintaining the building environment. Based on the broad definition proposed by Pearce (2003).
Productivity	The value of goods and services produced by an entity, as a proportion of the value of input resources required to produce it (Loosemore, 2014)
Supply chain fragmentation	A supply chain that consists of a relatively high number of specialized suppliers (Briscoe & Dainty, 2005).
Supply chain integration	Supply chain integration refers to increasing the coordination of supply chain processes by partnering or collaborative working (Briscoe & Dainty, 2005).
Platform	A business based on enabling value-creating interactions between external producers and consumers (Parker et al., 2016). Often referred to as multi-sided platform or two-sided market.
Electronic marketplace platform (e-marketplace)	An e-marketplace is a platform supporting transactions between buyers and sellers (Täuscher & Laudien, 2017). Often referred to as transaction platform or online marketplace.

1.2 Problem Formulation

The previous section introduced the broad problem area of this research by identifying a discrepancy between the current market situation in the construction industry and recent academic literature. This section will identify if this discrepancy can be explained using existing literature. If not, a research gap can be defined using a formal problem statement. A

brief literature review is conducted to map the available knowledge related to the problem.

The construction industry receives limited attention from academic literature. Most studies address technical problems or measure industry macro trends. There are a handful studies that address the adoption of e-marketplaces in the construction industry. For example Issa, Flood, and Caglasin (2003) did an extensive survey on the current adoption of e-business that includes among others e-commerce, e-procurement and e-marketplaces. The study concludes that although the construction industry is known for its conservative attitude towards innovation, the U.S. construction industry adopts e-business processes rapidly. The study doesn't conclude on the adoption of e-marketplaces. Alarcón, Maturana, and Schonherr (2009) studied the adoption and implementation of e-marketplaces in the Chilean construction industry. They concluded upon the current state of adoption, and the perceived advantages and barriers of e-marketplaces. According to the results , Alarcón et al. (2009), concluded that many Chilean construction companies adopted e-marketplaces and experienced significant benefits. The study does not apply on the European industry that is structurally different. Casaseca (2005) measured the adoption of e-marketplaces in the European construction industry. Among construction companies in France, Spain, Italy, Germany and the UK, 83% is using one-to-many e-commerce channels, and 21% uses e-marketplaces in their procurement processes. The author mentions several unsubstantiated explanations for the limited adoption of e-marketplaces. First marketplace transactions lack security, transparency and legal support. Companies tend to have a regional interest and there is lack of uniformity in industry products. And the construction industry contains many SME's that are often more skeptical towards the adoption of digital technologies. The study by Casaseca (2005) does not substantiate these adoption barriers and does not provide insight in how they obstruct the construction market.
Other relevant literature studies the adoption of e-commerce in the construction industry. For example Bhutto, Thorpe, and Stephenson (2005) argue that the attitude of the construction industry towards e-commerce is positive but the complex nature of construction project hinders adoption. Wang, Yang, and Shen (2007) mentions that literature is clear about the opportunities and advantages of e-commerce for the construction industry, but the adoption of e-commerce is slow compared to other industries. This aligns with the conservative character of the industry (Bhutto et al., 2005). One of the major barriers is the lack of industry standards for communication and data management (Wang et al., 2007; Zou & Seo, 2005). And in many conservative companies, leadership and organizational culture is not oriented towards e-commerce (Wang et al., 2007; Zou & Seo, 2005). Also the construction supply chain, security, law and policies are not adapted to e-commerce yet (Wang et al., 2007).
Finally, there exists an extensive list of literature on general or B2B marketplace adoption and design. For example Jelassi and Enders (2005) provide business actors with strategies to design and launch an b2b e-marketplace. Upadhyaya, Mohan, and Karantha (2017) studied the determinants for the adoption rate of b2b e-marketplaces by stakeholders. Weiblen, Giessmann, Bonakdar, and Eisert (2012) give an overview of the available business model templates to provide business model innovation guidelines for e-marketplaces.

The relevant academic literature related to the adoption of e-marketplaces in the construction industry is limited and cannot give a sufficient explanation for the low e-marketplace adoption in the construction industry. Since section 1.1 showed that e-marketplaces can contribute to productivity growth, one of the most urgent problems in the construction industry, a research project is justified. The problem statement of this research project is: Academic literature does not provide a sufficient explanation for the low adoption of e-marketplaces in the construction industry. Since this knowledge is missing, the construction industry cannot benefit from the expected contribution of e-marketplaces to productivity. The following section will lay the foundation for a research project by defining the scope and a research problem.

1.3 Research Scope

The problem statement of section 1.2 identified a research gap that applies on a broad population of stakeholders and highly complex concepts. Since the capacity of this research project is limited, a clear scope should limit the problem this research will address. The scope is limited based on five different parameters and assumptions. The conclusion of this section will use the research scope to redefine the research problem and population of stakeholders. Section 8.4 and 8.5 will reflect on these limitations.

The problem definition of this research involves the concept of e-marketplaces. This concept is highly complex and can have many different implementations. Recent literature by Antonio Grilo and Jardim-Goncalves (2013) and Aguiar Costa and Grilo (2015) suggest a specific type of e-marketplace based on the information technology (IT) 'Building Information Modelling' (BIM). BIM is an IT approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository (Gu & London, 2010). A BIM model centralizes all the data of a construction process, to connect all stakeholders throughout design, construction, maintenance and disposal of a building (Succar, 2009). BIM was already proposed in the late 80's, but the adoption in the construction industry accelerated over the last decade. Currently BIM is implemented in many projects worldwide (Walasek & Barszcz, 2017). To centralize data and connect all stakeholders of a construction process, multiple BIM-based collaborative platforms were developed and adopted (Ghaffarianhoseini et al., 2016).
Antonio Grilo and Jardim-Goncalves (2013) and Aguiar Costa and Grilo (2015) argue that, if BIM mediates stakeholders on a collaborative platform, it can also mediate buyers and sellers on a transaction platform. In two publications, they proposed a BIM-based e-marketplace design, that allows buyers and sellers to collaborate and do transactions. Recent non-academic institutions also recognized the role of BIM in enabling platform transactions. Strategy consultant Roland Berger referred to BIM as: "When BIM really takes of as a platform, it could do to the construction industry what the Amazon platform has done to retail" (Schober, Hoff, Lecat, Thieulloy, & Siepen, 2017). Despite the promising work of research and the attention of non-academic literature, BIM-based e-marketplaces are not adopted yet.
This research project will focus on the adoption of BIM-based e-marketplaces. Evidently the adoption of BIM-based e-marketplaces will show similarities to the adoption of non-BIM e-marketplaces. Subsection 8.5 will reflect on the generalizability of the results to non-BIM e-marketplaces. This results in the first scope limitation.

1. The scope of this research is limited to the adoption of BIM-based e-marketplaces.

The construction industry is one of the largest industries in the world and involves a wide variety of activities and markets. Section 3.1 will give more detailed insight in the industry characteristics. Since this study involves an in-depth analysis of business processes, supply chains and culture, the results cannot be easily generalized to the entire construction industry. Therefore, the second dimension that determines the scope of this research is industry category.
A major problem in the adoption of digital procurement technologies like e-marketplaces in the construction industry, is the high levels of unstructured goods and services (António Grilo & Jardim-Goncalves, 2011). Goods and services need to be structured and represented in a digital format before electronic procurement technologies can be implemented. An industry that involves high levels of structured goods and services is the building services industry. The building services industry is a segment within the construction industry that implements engineering for the internal environment and environmental impact of a building. In contrast to other construction industry segments, building services systems use less raw materials and more modular and standardized components. Because of this advantageous characteristic, the industrial scope is limited to the building services industry. This results in the second scope limitation.

2. This industrial scope of this research is limited to the building services industry.

The third dimension that limits the scope of this research is geography. The building services industry is a world industry and market characteristic vary per region. Because of the location of the researcher, and the geographical reach of his network, the geographical scope is limited to the European building services industry. This results in the third scope limitation.

3. The geographical scope of this research project is limited to Europe.

The first sections of this research emphasized the added value of e-marketplaces for the construction industry. Based on literature like Zhu (2002) and Alarcón et al. (2009), this research assumes there exist incentives for the adoption of e-marketplaces in the construction industry. Two stakeholder groups can be identified that are responsible for the adoption of an innovation. First entrepreneurs need to develop e-marketplaces, and second market stakeholders need to adopt e-marketplaces. Since entrepreneurs generally follow market demand, and e-marketplace technology is not completely new, this research will focus on the market stakeholders that need to adopt the e-marketplace. This results in the fourth scope limitation.

4. This research assumes there are incentives for adoption of e-marketplaces in the construction industry, but market stakeholders are obstructed.

As mentioned in the first section of this research, an e-marketplace for the construction industry can take multiple positions in the supply chain industry (Laine et al., 2017; Li et al., 2003). For example, a B2C e-marketplace can mediate clients and general contractors. Or a B2B e-marketplace can mediate general contractors, subcontractors and suppliers. This research will focus on e-marketplaces mediating subcontractors and suppliers. Subcontractors in the building services industry are generally called ‘engineer’. Suppliers can be wholesalers, or manufacturers that conduct direct engineer-manufacturer transactions. This document will refer to manufacturers and wholesalers as ‘suppliers’. This document will refer to manufacturers, wholesalers and engineers as ‘market stakeholders’. This results in the fifth scope limitation.

5. This research will focus on BIM-based e-marketplace mediating engineers as buyers, and manufacturers or wholesale as sellers.

The aforementioned five scope limitations narrowed down the problem and population this research will address. The formal research problem is defined as:

Academic literature lacks knowledge on how European building services manufacturers, wholesalers and engineers are obstructed to adopt BIM-based e-marketplace platforms.

This research problem affects the following population: European building services manufacturers, wholesalers and engineers. The following section will define a research question to solve the scoped research problem.

1.4 Research Question

To solve the research problem defined in the previous section, this research aims to explain how European building services manufacturers, wholesalers and engineers are obstructed to adopt BIM-based e-marketplaces. The research

question that relates to this objective is defined as:

How are European building services manufacturers, wholesalers and engineers obstructed to adopt BIM-based e-marketplace platforms?

Three sub-questions are defined:

1. *What are the barriers that obstruct European building services manufacturers, wholesalers and engineers to adopt a BIM-based e-marketplace?*
2. *Why do these barriers exist?*
3. *How do these barriers obstruct the adoption of e-marketplaces by European building services manufacturers, wholesalers and engineers?*

1.5 Research Contribution

The contribution of this research project is two-fold. First this research contributes to the academic knowledge landscape, and second it provides business stakeholders with relevant knowledge for the design and adoption of a BIM-based e-marketplace. This section will discuss both contributions.

The findings of this research can initiate a chain of research projects. The broad problem formulation of section 1.1 and 1.2 emphasize the contribution of e-marketplaces to the construction industry productivity. In three steps this research project can contribute to this problem formulation within the defined scope. These three steps are given in the conceptual model of Figure 2.

The first step corresponds to the research question of this study. By explaining how European building services manufacturers, wholesalers and engineers are obstructed to adopt BIM-based e-marketplaces, the relationship between adoption barriers and adoption intention is determined. The findings of this theory-building research should be validated by hypothesis-testing research. Using a larger sample and more rigor analysis, conclusions can be drawn on the validity and generalizability of the results.

The second step should be a theory building study on the moderating effect of e-marketplace design on the relationship between of adoption barriers and adoption intention. Research step 2 results in a set of design guidelines that minimize the influence of adoption barriers and maximize the adoption intention. These design guidelines should be validated in hypothesis testing research. An example of such a hypothesis testing research could be an experiment with different e-marketplace design and measuring the adoption intention of stakeholders.

In the third step, the design guidelines should be used to design and develop a BIM-based e-marketplace and measure the actual adoption rate.

Furthermore, the results can be used for other theory building research projects with a similar problem statement but a different scope. For example, the results of this research can be used for studies on e-marketplace adoption in the American construction industry. The discussion section will evaluate the extent the results are generalizable to a different scope.

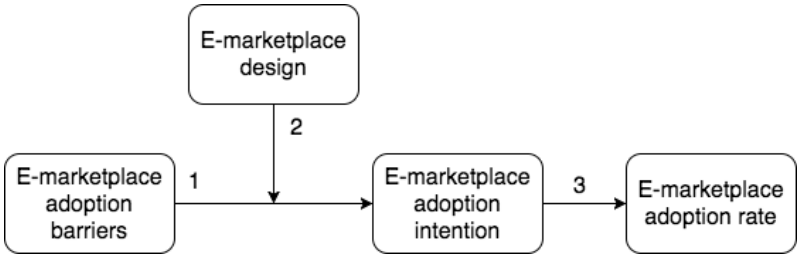

Figure 2 Further research, conceptual model

The relevance for business actors has two components. First the results provide entrepreneurs with knowledge on the adoption barriers of a BIM-based e-marketplace by market stakeholders. All tough this knowledge is still hypothetical; problem owners can anticipate for adoption barriers in the design of a BIM-based e-marketplace. Second the results can make manufacturers, wholesalers and engineers in the building services industry aware of the potential of a BIM-based e-marketplace and the existence of adoption barriers. This awareness might decrease the adoption barriers.

1.6 Document Structure

Chapter 1 introduced and substantiated this research project. Section 1.1 to 1.5 described what problem this research aims to address, why this problem is relevant, how this research aims to solve the problem, and what the contributions of the results are to research and to business. The following chapters will cover the research process as it results from the research methodology. Chapter 2 proposes and substantiates a suitable research method to answer the research question. Chapter 3 will give a description of the problem domain. In chapter 4 the researcher takes a deep dive into available literature to develop a list of hypothetical adoption barriers. Chapter 5 presents the data collection method, analysis and results of the industry expert interviews. Chapter 6 presents the data collection method, analysis and results of the industry expert focus group. Chapter 7 presents the data collection method, analysis and results of the stakeholder interviews. Chapter 8 will discuss the main findings, discuss the limitations and make recommendations for research and practice.

2 METHODOLOGY

The first chapter of this report substantiated the need for a research project by identifying a relevant problem and corresponding research gap. After defining the scope in section 1.3, a research question is defined that covers the scoped research gap. This chapter will describe and substantiate an appropriate research method to answer the research question. Note that this chapter will only describe the methodology related decisions that were made before the data collection process started. The implementation of this methodology is reported in chapter 5, 6 and 7.

This chapter is structured as follows. Section 2.1 will propose a suitable research approach. Section 2.2 develops a research structure based on the chose research approach. Finally section 2.3 will describe the data collection methods used.

2.1 Research Approach

The research question defined in the first chapter of this research, can be answered by exploring and understanding the meaning market stakeholders ascribe to a BIM-based e-marketplace. These perceptions are subjective and cannot be objectively measured. According to Creswell and Creswell (2017), the best research approach to explore and understand a subjective meaning of individuals or groups is qualitative research.
A qualitative research project that aims to fill a research gap follows the hypothetico-deductive method proposed by Sekaran (2013). The seven steps of this method are given in Table 2. First the researcher identifies a broad problem area by observation. This first step is covered by section 1.1 of this report. The second step is the preliminary information gathering and defining a problem statement. Section 1.2 and 1.3 defined a clear and relevant research problem. Step three involves conceptualizing all the concepts related to the problem formulation and identify relevant related work for hypotheses development. Step four defines a set of hypothesizes that provide a sufficient answer to the research question. But as described in section 1.2, the construction industry received limited attention from academia. No academic literature has been found that proposes a sufficient explanation for the limited adoption of e-marketplaces in the construction industry. Since the problem definition lacks preliminary research, no complete set of hypotheses can be derived from literature and this research can be called inductive research. This means further steps will not only involve hypothesis testing, but also hypothesis development. In step 5 data is collected to test, and in this case induct, hypotheses. Step 6 analyzes the data to support, reject or define hypotheses. Finally step 7 develops a final solution to the research problem and recommends upon the findings. The following section will use the hypothetico-deductive method to propose a research structure.

Table 2 Hypothetico-deductive method (Sekaran, 2013)

Step	Name
1	Observation
2	Preliminary information gathering
3	Theory formulation
4	Hypothesizing
5	Further scientific data collection
6	Data analysis
7	Deduction

2.2 Research Structure

The structure of this theory-building research is based on the hypothetico-deductive method but is extended with an iterative element. This research is structured into four phases. First the introduction covers the observation and preliminary information gathering step. The research project is introduced and substantiated, the problem statement is defined, the research question is defined, and a suitable research approach is substantiated. This first phase is covered by the first two chapters of this report.

In the second phase the researcher takes a deep dive into relevant academic literature. A theoretical framework is developed around the concepts related to the problem definition and an initial set of hypothetical barriers is derived. These hypothetical barriers can be derived from a theoretical framework or related work. Phase two includes step 3 and 4 of the hypothetico-deductive method and is documented in chapter 3 and 4 of this report.

The third phase, data collection and analysis, is a cyclical phase involving step 4, 5 and 6 of the hypothetico-deductive method. Since the problem lacks preliminary research, new adoption barriers will likely emerge from the data analysis step. These emergent barriers need further confirmation. By executing multiple data collection and analysis rounds, the emergent barriers can be tested. Figure 3 gives an overview of this iterative research structure including all the step from the hypothetico-deductive method. The data collection and analysis round can be repeated until no more emergent barriers are elicited. Phase 3 is documented by chapter 5, 6 and 7 of this report.

The fourth phase, evaluation, develops a final answer to the research question based on the results. Furthermore, it reflects upon the limitations of the results and recommends for further research and practice. This phase covers step 7 of the hypothetico-deductive method and is reported in chapter 8. Table 3 gives an overview of the research structure and Figure 3 shows how these phases relate to the hypothetico-deductive method. The next section will choose suitable data collection methods for the data collection phase.

Table 3 Research structure

Phase		Activities	Chapter
1	Research introduction	Introduce and substantiate the research project; define a problem statement; define a research question; propose a suitable research approach.	1, 2
2	Literature review	The researcher takes a deep dive into prior literature, describing the research domain and related work. The goal of this literature review is to develop a set of hypothetical adoption barriers that are expected to obstruct BIM-based e-marketplace adoption by market stakeholders.	3, 4
3	Data collection & analysis	Three rounds of data collection and analysis are conducted. Each round will test hypotheses and elicit emergent hypotheses.	5, 6, 7
4	Evaluation	Conclude upon the findings. Discuss the implications for science, limitations, and recommend for further research and business. Discuss process of the project and report additional insights.	8

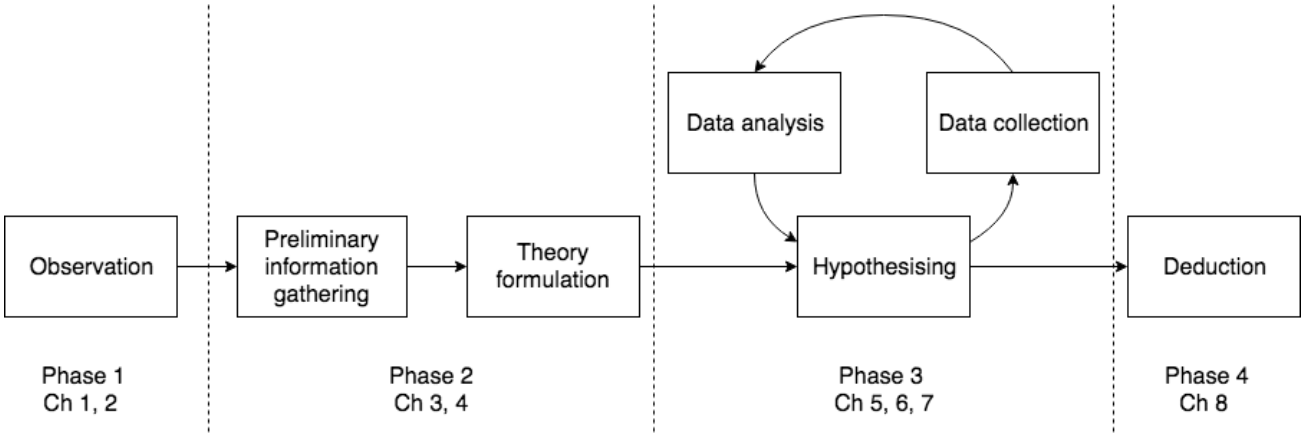

Figure 3 Research structure

2.3 Data Collection

The third phase of this research project involves a number of data collection rounds. This subsection will explain and substantiate the data collection methods and data sources that were chosen in every round. First the suitable data collection methods are identified from research design literature. Then three data collection rounds are proposed and substantiated. Followed by the selection of a suitable sampling method for every round. Finally, the preparation off interviews will be discussed.

2.3.1 Data Collection Methods

Bhattacherjee (2012) divides primary data collection methods in four categories: experimental research, case research, interpretive research and survey research. First experimental research needs a set of predefined independent variables to design experimental conditions. Since inductive research lacks these hypotheses, experimental research is not suitable. Case research, studies a case specific phenomenon within a specific organizational context. Since this research aims to study an industry wide phenomenon, case research is not suitable. Interpretive research involves the interference of the researcher while this project tries to minimize the role of the researcher. The fourth category is survey research. Survey research is ideally suited to measure unobservable data in a population that is too large to observe directly. Since this research aims to measure adoption barriers, which are unobservable, in a large population, the building services industry, survey research has found to be suitable for this project. Survey research can be conducted using two different methods: questionnaire survey, and interview survey. Questionnaire survey methods are suitable when the researcher knows exactly what information is required and how to measure the variables of interest (Sekaran, 2013). Interview survey is more flexible and can adapt to the answers of the researcher. Interview survey methods described by Bhattacherjee (2012) are: face-to-face interviews, focus groups, and telephone interviews.

The degree of structure in an interview can be structured, unstructured, or semi-structured. Structured interviews use a standard list of questions that are asked in a fixed order. A structured approach is used when the researcher knows what information is needed (Sekaran, 2013). Unstructured interviews use flexible open questions without a standard sequence. An unstructured approach is chosen when the researcher aims to bring preliminary issues to the surface (Sekaran, 2013), and does not exactly know what information is relevant to the problem. A semi-structured approach contains both structured and unstructured parts.

2.3.2 Data Collection Rounds

To answer the research question, the data collection phase aims to develop a sufficient list of adoption barriers, explain why these barriers exist, and how these barriers obstruct marketplace adoption. To meet that objective this subsection will propose three data collection rounds.

The first data collection round aims to elicit adoption barriers that were not identified during the literature review. Since the nature of these barriers is still unknown, the data collection method should be flexible. Unstructured interviews are chosen to allow the researcher to adapt his questions to factors that prove to be important. Since the results of the first data collection round will be evaluated in subsequent rounds, the data collection for the first round does not have to be very rigor. Besides, the first round should not cost much time because the following rounds are more rigor and therefore more time consuming. According to Dorussen, Lenz, and Blavoukos (2005), experts are a relatively reliable data source when a low sample size is used. Therefore, to save time and achieve sufficient representativeness, five to ten industry experts are chosen as data source for the first round. Representativeness refers to the extent a sample represents the population. Industry experts are expected to represent the population. Therefore, it is important that these industry experts have extensive experience with both engineers, manufacturers and wholesalers. To limit processing time, interviews should take no longer than 30 minutes. Depending on the geographic location of the industry expert, both face-to-face and telephone interviews can be used. To increase the efficiency of the interviews, industry experts are prepared for the interview with a preparation document (appendix A.1). An interview protocol is developed that can help the researcher in keeping the interview on topic (appendix A.2). The data is analyzed using a simple color coding method with codes corresponding to the elicited barriers and previously known barriers (appendix A.3). The implementation and results of the first round are discussed in chapter 5.

As mentioned in the previous section, the second survey method suitable for measuring unobservable data, is a focus group. According to Bhattacherjee (2012), focus groups allow for deeper examination of complex issues compared to interviews. The unstructured and spontaneous nature of the focus group often triggers responses or ideas that participants did not think about before. Since the adoption of e-marketplaces is a complex process, a focus group is expected to elicit additional barriers that could not be revealed in the industry expert interviews. Therefore, the second data collection round aims to elicit additional adoption barriers using a focus group. To increase the time efficiency of the focus group, the same industry experts used for the first round are also invited for the focus group. After all, they are already familiar with the concept. To increase interaction and idea generation, also some innovative thinkers are invited. The participants are prepared with a preparation document and questionnaire (appendix B.1). The questionnaire is distributed one week up front to gain insight in the background of the participants, prepare the participants for the subject, and to collect initial opinions. The questionnaire contains personal questions to map out the professional context of a participant, questions with regards to the added value of a BIM-based e-marketplace, and questions related to the design of a BIM-based e-marketplace. To steer the discussion in the right direction an introduction presentation is given (appendix B.2). The researcher uses a timed agenda and protocol to keep the discussion on topic. To evaluate the data collection method, participants fill in an evaluation questionnaire (appendix B.3). The focus group is recorded, and the transcripts are coded with codes corresponding to previously known and emergent barriers (appendix B.4). The implementation and results of the second round are discussed in chapter 6.

The third and last data collection round has three objectives. First it aims to test the hypothetical barriers developed in the literature review and emergent barriers elicited in previous data collection rounds. Second it should explain why these barriers exist. And third knowledge should be developed that explains how these barriers obstruct adoption. Since the conclusion of this research will be based on the results of this final round, data collection and analysis should be

more rigor compared to the previous rounds. In contrast to previous rounds, this round will address actual market stakeholders within the population. This will result in a more reliable result. Although the aim of this round is to test adoption barriers, new barrier might emerge. To elicit barriers and knowledge of the origin and relationship with marketplace adoption, the data collection method should be flexible. To test barriers, the data collection method needs to be focused. Therefore, semi-structured face-to-face or telephone interviews are suitable for this purpose. Face-to-face is preferred over telephone because of the complexity of the concept. The concept of a BIM-based e-marketplace is expected to be relatively new to most stakeholders in the building services industry. Especially the more conservative stakeholders that are not familiar with BIM or electronic procurement yet, are not expected to get a full grasp of the concept of a BIM-based e-marketplace. Therefore, it makes sense to interview the more innovative early adopting stakeholders. Besides early adopters are the first to adopt a new innovation like a BIM-based e-marketplace. Since the unit of analysis is a whole company, the interview participants should represent the company. Decision makers that oversee both the technical and commercial activities of a company are most representative. To prepare the participants, a preparation document is sent one week before the interview (appendix B.1) Interview protocols are used to structure the interviews and ensure all barriers are tested (C.2). Since not every barrier will affect every stakeholder and there may not be enough time in every interview to test all barriers, three different protocols are made. One for engineers, one for manufacturers and one for wholesalers. Every protocol will test different barriers but together all the barriers are covered. The interviews are recorded, and the transcripts are coded with codes corresponding to previously known and emergent barriers (appendix C.3 and C.4). The implementation and results of the third round are discussed in chapter 7.

2.3.3 Sampling

The three data collection methods proposed in the previous sections cannot target the entire population. Therefore, this section will select a suitable sampling method for every round. The goal of this subsection is to choose a sampling method that represents the population within the practical boundaries. Sekaran (2013) mentions six probability- and three non-probability sampling methods. The probability sampling methods are: simple random sampling, systematic sampling, stratified random sampling, cluster sampling, area sampling and double sampling. The non-probability sampling methods are: convenience sampling, judgement sampling, quota sampling.

For the first and second data collection round, a sample of industry experts that represent the population need to be selected. The major practical boundary for the first round is time. To access suitable industry experts, this research is conducted in cooperation with the Dutch software developer Stabiplan B.V. Stabiplan delivers products and services to both engineers, manufacturers and wholesalers in the building services industry for more than 25 years. Section 3.4 will describe the company Stabiplan in more detail. The sample of industry experts used for the first and second data collection rounds are all working for Stabiplan and have extensive experience in the building services industry. Convenience sampling based on accessibility and judgement sampling based on expert reputation is used to select a sample of industry experts. To ensure representativeness of the sample, proportionate stratified sampling is used based on knowledge of engineers, manufacturers and wholesalers.
For the second data collection round the sample is extended with innovative thinkers that are familiar to the building services industry. Convenience sampling based on accessibility and judgement sampling based on reputation is used to select a sample.
For the third data collection round a sample should be selected from the population. The population is defined as ‘European building services manufacturers, wholesalers and engineers’. The sample should select only relative innovative companies from the population. Since Stabiplan distributes innovative BIM solutions, their customer base is expected to consist mostly first adopting companies with extensive experience with BIM. Therefore, the sample is drawn

from a sample unit that equals the customer base of Stabiplan.
Market stakeholders in the building services industry can roughly be categorized based on two characteristics. The first characteristic is the position in the supply chain. Market stakeholders can be manufacturers, engineers or wholesalers. The second characteristic is the discipline of the stakeholder. Three discipline categories can be recognized in the building services industry: mechanical, electrical and plumbing. Section 3.1 will define these disciplines in more detail. Based on the combinations between these two characteristics, six strata are defined. To ensure representativeness, proportionate random stratified sampling is applied. Evidently there are other characteristics like company size and age that can influence representativeness. Section 8.4 will reflect on other factors that might have affected representativeness. The sampling procedure is graphically presented in Figure 4.

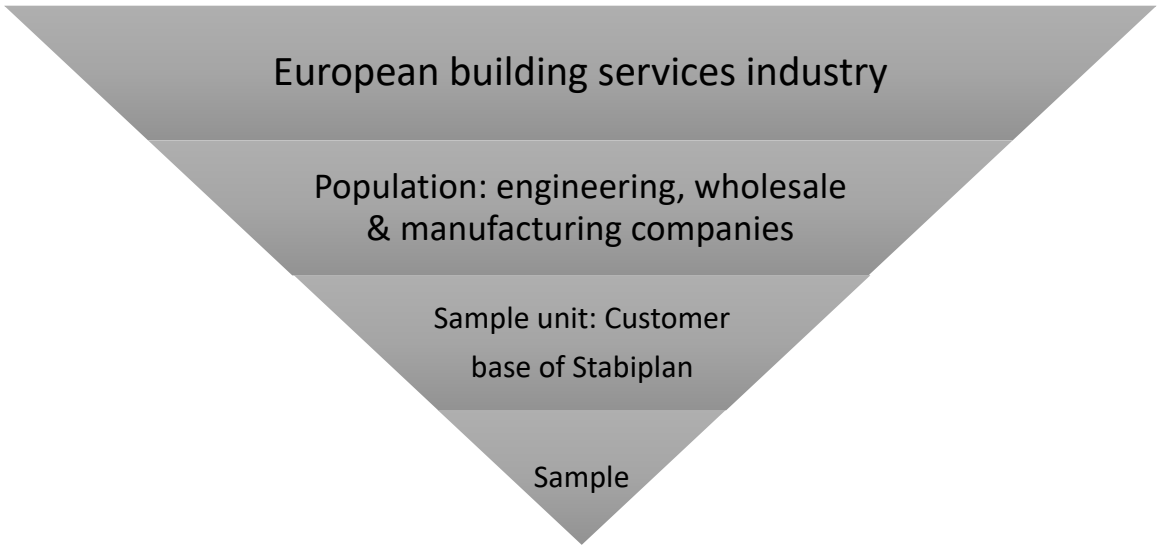

Figure 4 Sampling procedure, stakeholder interviews

These three rounds of data collection are expected to elicit the most important adoption barriers and gain insight in why these barriers exist, and how they obstruct the adoption of market stakeholders. In addition, Table 4 gives an overview of the data collection methods per round.

Table 4 Data collection per round

Round	Method	Structure	Sampling unit	Main purpose
1	Interviews	Unstructured	Industry experts in the European building services industry employed by Stabiplan.	Elicit emergent adoption barriers
2	Focus group	Semi-structured	Industry experts in the European building services industry, and innovative thinkers employed by Stabiplan.	Elicit emergent adoption barriers
3	Interviews	Semi-structured	Engineering, wholesale and manufacturing companies in the European building services industry from the customer base of Stabiplan.	Test hypothetical and emergent adoption barriers

2.3.4 Interview Preparation

Previous sections proposed interview surveys as data collection methods for this research. Since the topic of these interviews, BIM-based e-marketplaces is new to the participants, preparation is necessary. Especially because this research aims to elicit adoption barriers, it is critical that participants understand the concept of a BIM-based e-marketplace and the possible functionalities. Therefore, preparation documents are developed and distributed one week

before the interview and focus group (appendix A.1, B.1 and C.1). In the preparation documents, the concepts are explained using a generic model and two different design examples of a BIM-based e-marketplace. This section will first develop a generic model of a BIM-based e-marketplace and then propose two different marketplace design examples. The generic model is used in all data collection rounds. The two design examples are only used in the focus group and stakeholder interviews.

According to Weiblen et al. (2012), a basic e-marketplace includes four functionalities: (1) presentation of products, (2) negotiating the price and conditions, (3) setting up contracts, (4) arrange payment and delivery. A BIM-based e-marketplace is an extension of this basic model that brings buyers and seller together through a BIM model. The functionalities of a BIM-based e-marketplace are based on the functionalities suggested by Weiblen et al. (2012) and extended with a functionality to manage the BIM model. Figure 5 gives a graphic presentation of the generic functional model. Suppliers can be wholesale companies or manufacturers of products. Buyers are engineering companies that develop the BIM model. All interaction between supplier and buyer takes place via the platform. The model distinguishes three functionality classes. First 'communication' is based on the first and second functionalities mentioned by Weiblen et al. (2012). It supports all communication between buyer and seller before a transaction. First the seller needs to present a product to the buyer and a buyer needs to be informed on all relevant product information Then a buyer and seller negotiate a price and conditions. The second functionality class, referred to as a 'transaction', is based on the third and fourth functionality mentioned by Weiblen et al. (2012). This functionality class includes all transaction related activities like arranging contracts, terms and conditions, payment and delivery. The third functionality is BIM model management. The e-marketplace needs a cloud environment to store the BIM model and BIM content. In addition, the marketplace needs to extract a bill of materials (BOM) from a BIM model.

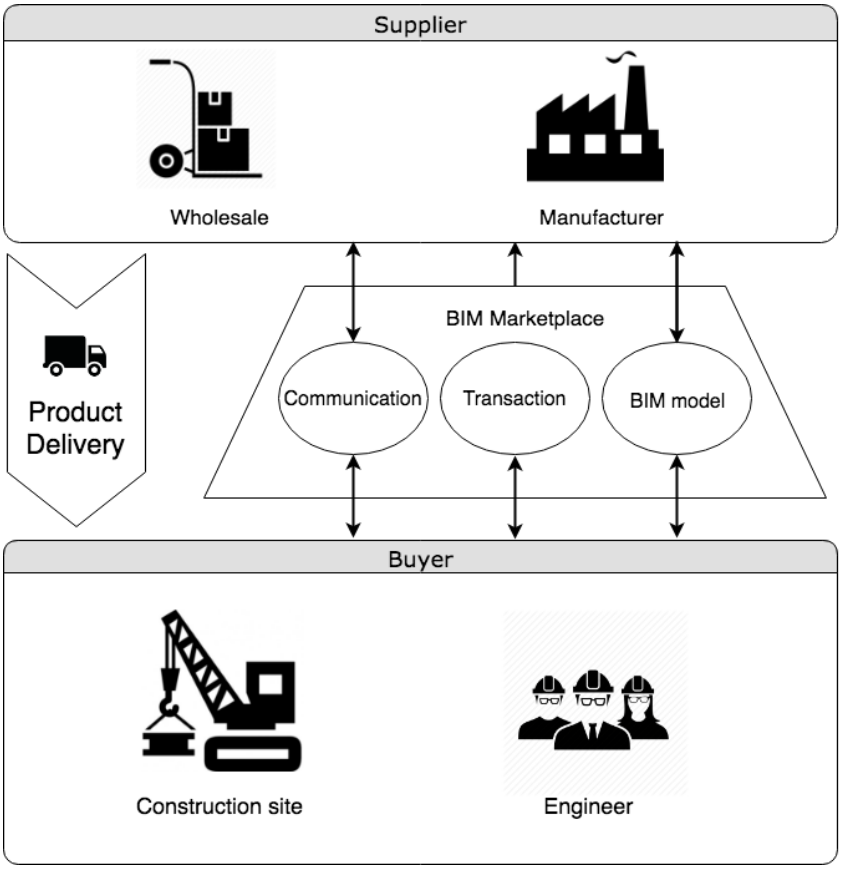

Figure 5 Generic functional model of a BIM-based e-marketplace

The generic model of Figure 5 is highly conceptual. Evidently there are many different design possibilities of a BIM-based e-marketplace. It is expected that the interview participants are not able to operationalize the generic model. Therefore, two different design examples are proposed to the focus group and stakeholder interview participants. The goal of using these two examples is to stimulate participants to think about the concept and get a better understanding of the possibilities and functionalities of a BIM-based e-marketplace.
The first design that is used in the interviews is based on the design by Aguiar Costa and Grilo (2015). They suggested a marketplace design were the engineer uploads a BIM model in the cloud, and suppliers make price offers. The first design example is given in Figure 6. All different engineers contribute to the complete BIM model that is managed by the general contractor. From the BIM model a bill of materials (BOM) is calculated. In this design, the engineer first designs a BIM model, and then makes a supplier choice.

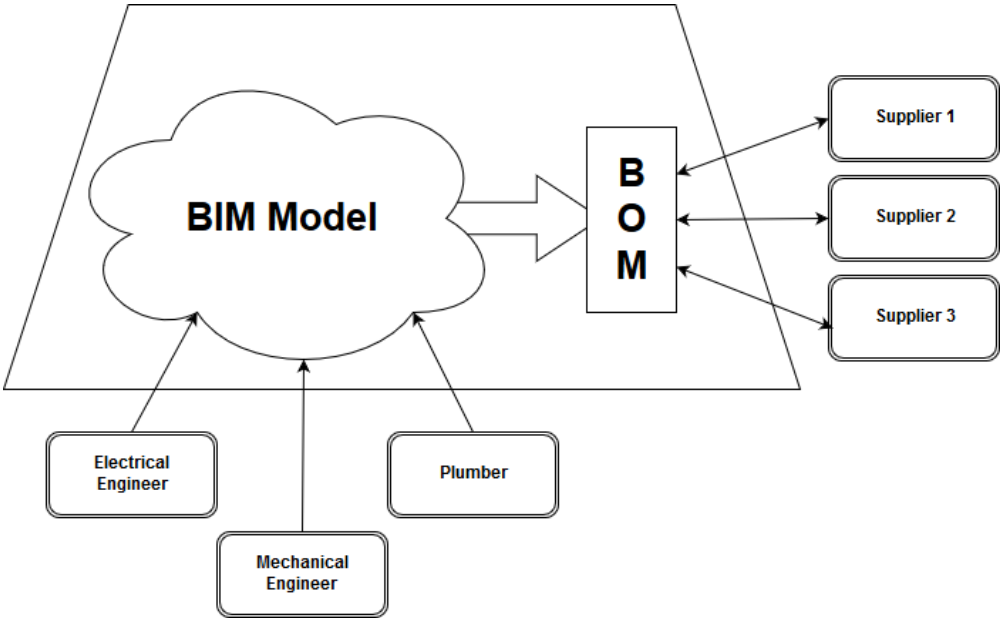

Figure 6 BIM-based e-marketplace design example 1

The second design example, given in Figure 7, is based on a product from Stabiplan called a Product Line Placer (PLiP). The marketplace, denoted by the large square in the figure, contains multiple independent PLiP applications. A PLiP is a BIM application to design a specific building services system in the cloud. A PLiP only supports components of one specific manufacturer or wholesale supplier and often contains special functionalities to support the designer. When an engineer enters the marketplace, he chooses a supplier PLiP and designs a system of components from that supplier. When the design is finished, the marketplace calculates a BOM. Using individual of staff discounts the price is calculated and a financial transaction is arranged. After the transaction is completed, the supplier delivers the components. The major difference compared to the first design example of Figure 6, is that engineer chooses a supplier before he designs a BIM model.

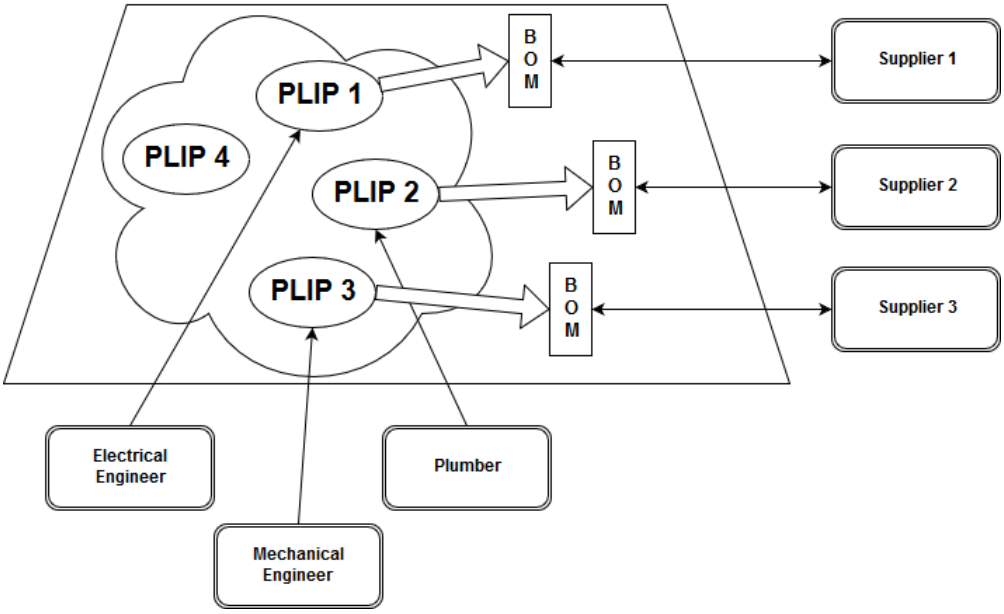

Figure 7 BIM-based e-marketplace design example II

3 DOMAIN DESCRIPTION

This research project will be conducted in an industry that is not well known to the academic world. Besides, the scoped research problem defined at the end of section 1.3, contains complex concepts that need further explanation. This chapter describes the most important aspects of the research domain.

This chapter is structured as follows. Section 3.1 gives an overview of the building services industry and the overarching construction industry. Section 3.2 describes the technology BIM. Section 3.3 describes the theoretical concepts around e-marketplaces. Finally, section 3.4 will give an introduction to the company Stabiplan, that funded this research.

3.1 Industry Profile

3.1.1 Construction industry

As mentioned in the chapter 1, this research will be conducted in the building services industry. The Building services a segment of the overarching construction industry. The construction industry, often referred to as Architecture Engineering and Construction (AEC) industry, is one of the largest industries in the world. With six to nine percent of gross domestic product in the developed countries, it makes a significant contribution to the world economy (Chitkara, 1998). The construction industry employs seven percent of the world working population and every year around $10 trillion is spent worldwide on construction related goods and services (Barbosa et al., 2017).

Defining the construction industry is not straightforward. The industry is highly complex and involves many interactive levels, production stages that contribute to the construction of a building or infrastructure (Foulkes & Ruddock, 2007). Besides, the construction industry increasingly diversified so the definition is changing over time. Pearce (2003) defined the construction industry based on a narrow or a broad focus. First the narrow definition includes only the on-site activities that contribute to the construction of a building or infrastructure. This includes site preparation, construction, installation and building completion. The broad definition includes all economic activities that directly depend on the construction of a building or infrastructure. This includes the wholes supply chain of construction but also maintenance and demolition. The previously mentioned six to nine percent contribution to GDP only holds for the narrow definition. According to Foulkes and Ruddock (2007), the construction industry in the broad definition contributes up to 20% of GDP in the UK. This research will use the broad view of Pearce (2003), and define the construction industry as: all economic activity that directly depend on producing and maintaining the building environment.

The construction industry is characterized by fluctuating demand cycles, project-specific product demands, uncertain production conditions, has to combine diverse range of specialized skills, geographically dispersed short-term project environments. These attributes make the industry highly diverse and unstable (R.J. et al., 2001). One of the research topics in construction related literature is productivity growth. Multiple market research companies and academic researchers conclude that the construction industry achieves low productivity growth compared to other industries (Barbosa et al., 2017; Leo, Samuel, James, Jennifer, & Arthur, 2016). The productivity lag can be explained by a variety of factors but among others Fulford and Standing (2014) mention: fragmented supply chain, large number of SME's, unstable supply chains and unstable relationships.

3.1.2 Building Services Industry

The building services industry is a segment within the overarching construction industry. Using the broad view of Pearce (2003), the building services industry is defined as: all economic activities that directly depend on the engineering for producing and maintaining the internal environment and environmental impact of a building. The building services industry can roughly be divided into three disciplines: mechanical engineering, electrical engineering and plumbing (MEP). Due to this categorization, the building services industry is often referred to as MEP industry. Mechanical systems include heating, ventilation and air conditioning (HVAC) systems. Electrical systems include: power supply, information and telecommunications systems, control systems, security and access systems, alarm systems and lighting. Plumbing systems use the movement of fluids for heating and cooling, waste removal, water supply, water recovery and treatment systems, rainwater, water drainage and fuel gas piping. Building services systems generally consist of a collection of modular independent components. A building services engineer generally collects and combines components to create a functional system. Therefore, the construction of a building services system requires hardly any raw materials on the building site.

3.1.3 Construction Delivery Methods

The process of initiation, constructing and delivering a building or infrastructure varies between countries. A plethora of construction delivery methods can be recognized (Davis, Love, & Baccarini, 2008). A construction delivery method is the process selected to execute a construction project for the purpose of assigning responsibilities and risk to the project team. To understand the position of a BIM-based e-marketplace in the construction process and supply chain, the most important construction delivery methods will be discussed. According to Vellalos and Gordon (2012), the two most used construction delivery methods are: Design-Bid-Build, and Design and Build.

The Design-Bid-Build (DBB) method, often referred to as the traditional method, is dominant in the European construction industry. DBB is a project delivery method in which the client enters into a contract with an architect and consulting engineer that provide design services based on the requirements provided by the owner (Hale, Shrestha, Gibson, & Migliaccio, 2009). When a construction project is initiated, the client hires a design team. The design team consists of an architect, responsible for the geometrical design, and a consulting engineer, responsible for the technical design. Based on the requirements provided by the client, the design team develops a scope of work. A scope of work, also referred to as statement of works, is a general description of the work that is expected to be performed under a particular contract between the client and general contractor. The level of detail in a scope of work varies, but generally it contains a complete design of the building including all building services installations.
After the scope of work is developed, the client prepares to make a contract with a general contractor. Typically, a tender bidding process is used to select a general contractor to conduct the building process. Three different tender processes can be recognized. First in an open tender, every construction company can hand in a proposal and usually the proposal with the lowest price is assigned to the job. Second in a competitive tender, the client preselects some companies that can hand in their proposal. The third option is a European government procurement where all tenders from across Europe can tender. European government procurement is mandatory for public buildings and projects beyond a certain budget. The owner selects a construction company based on certain predetermined parameters.
After tendering, the general contractor will build the construction as the scope of work prescribes. In most cases, the general contractor does not have the expertise and the capacity to complete the project. Therefore, contractors put copies of the scope of work out to multiple specialized subcontractors for bids on the subcomponents of the project. Subcomponents like concrete work, electrical systems and ventilation, require special expertise. Similarly, to the first tendering process, the general contractor chooses subcontractors based on predetermined parameters.
Using the scope of work, the subcontractor develops a final design of the subcomponent of the construction. This final

design is generally developed in a CAD or BIM model. Subcontractors are completely responsible for the procurement of components and materials to construct the prescribed subcomponent.

The second project delivery method is called Design and Build (D&B). D&B is defined as the purchase of a building from a single contractor who is responsible for both design and construction (Akintoye & Fitzgerald, 1995). In contrast to the DBB method, the D&B project involves only one procurement step to select one entity to complete the project, and one contract between the owner and this entity (Hale et al., 2009).
When a construction project is initiated, the client goes into contract with a design-build contractor. The contract prescribes some general requirements and a budget. The design-build contractor is completely responsible for both the design and construction services. Generally, design-build contractors have architectural expertise and engineering expertise. To design and construct the building, the design-build contractor contracts multiple consulting engineers and subcontractors. Because of the integration of design and construction responsibilities, D&B project often outperform DBB projects on time and costs (Hale et al., 2009).

Figure 8 shows the differences in role distribution between DBB and D&B. Table 5 gives an overview of the concepts discussed in section 3.1.

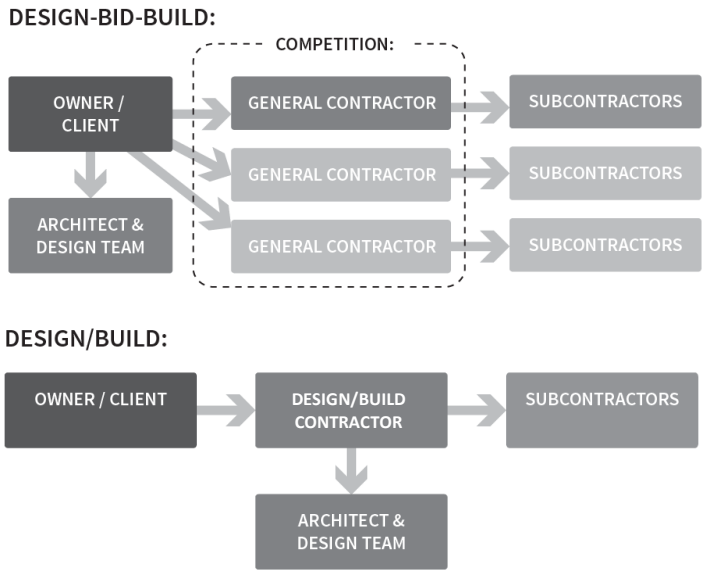

Figure 8 Construction delivery methods (Galloway, 2016)

Table 5 Definition of core concepts used in section 3.1

Concept	Definition
AEC industry	Architecture Engineering and Construction industry, also referred to as the construction industry.
Building services industry	All economic activities that directly depend on the engineering for producing and maintaining the internal environment and environmental impact of a building. This definition is based on the broad definition proposed by Pearce (2003).
MEP industry	Mechanical Electrical and Plumbing industry, also referred to as building services industry.
Mechanical engineering	In the MEP industry, mechanical engineering refers to heating, ventilation and air conditioning (HVAC) systems.
Electrical engineering	In the MEP industry, electrical engineering refers to: power supply, information and telecommunications systems, control systems, security and access systems, alarm systems and lighting.
Plumbing	In the MEP industry, plumbing refers to all systems that use the movement of fluids for heating and cooling, waste removal, water supply, water recovery and treatment systems, rainwater, water drainage and fuel gas piping.
Construction delivery method	The method to execute a construction project for the purpose of assigning responsibilities and risk to the project team. Also referred to as: project delivery method or procurement system.
Design-Bid-Build (DBB)	A construction delivery method in which the client enters into a contract with an architect and consulting engineer that provide design services based on the requirements provided by the owner (Hale et al., 2009). Often referred to as the traditional construction delivery method.
Scope of Work	A general description of the work that is expected to be performed under a particular contract between the client and contractor. Also referred to as scope of work or statement of work.
Design and Build (D&B)	A construction delivery method in which the client purchases a building from a single contractor who is responsible for both design and construction (Akintoye & Fitzgerald, 1995).

3.2 Building Information Modeling

The research problem defined in section 1.3 contains the concept ‘Building Information Modelling’ (BIM). BIM was already briefly introduced but this section will discuss the history and related concepts in more detail. The construction industry used 2D Computer Aided Design software since the 1970 to design buildings and installations and this evolved to 3D modelling in around 1985 (Weisberg). Computer Aided Design (CAD) is a software solution to aid in the de creation, modification, analysis, or optimization of a design (SARCAR, RAO, & NARAYAN, 2008). A CAD model contains only geometrical data about a building design and only plays a role in the design phase of a construction project. Since 2002 BIM received a lot of attention because market leader Autodesk promoted the term in their Revit software solution. BIM is not just a technology but an interacting set of policies, processes and technologies that manage the essential building design and project data in digital format throughout the building's life-cycle (Succar, 2009). BIM can be considered as the evolution of CAD because it extends the digital model with all non-geometrical that is relevant to a project. A BIM model centralizes all the data around a construction process to connect all stakeholders throughout design, construction, maintenance and disposal of an object. Often acknowledged advantages of BIM are: technical superiority, interoperability capabilities, early building information capture, use throughout the building lifecycle, integrated procurement, improved cost control mechanisms, reduced conflict and project team benefits (Ghaffarianhoseini et al., 2017). Besides the clear advantages of BIM, the new workflow is not fully adopted yet (Walasek & Barszcz, 2017). Often mentioned barriers for adoption are: the protection of data and the risk of cyber security, legal issues, contractual issues, responsibility issues (Ghaffarianhoseini et al., 2017).

Most of the data in BIM models is captured in ‘BIM content’. The industry refers to BIM content as modular digital representation of a specific component or object that can be imported in a BIM model. A BIM content file contains all

geometric and parametric data of a specific component. Most BIM content is developed by manufacturers to accompany their products. BIM content can be distributed decentralized via websites of manufacturers, but most BIM content is centralized on cloud BIM content platforms. Examples of these platforms are BIMobject.com, BIMstore.co.uk, and MEPcontent.com. These platforms mediate BIM designers and manufacturers. With the adoption of the BIM, centralization of data during a building project becomes more important. To manage and integrate all the BIM models from all stakeholders of a building project, collaborative BIM platforms are developed. Examples of collaborative platforms are Autodesk BIM360 and Trimble Connect.

Table 6 gives an overview of the concepts discussed in section 3.2.

Table 6 Definition of core concepts used in section 3.2

Concept	Definition
Computer Aided Design (CAD)	A software solution to aid in the de creation, modification, analysis, or optimization of a design (SARCAR et al., 2008)
Building Information Modeling (BIM)	IT approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository (Gu & London, 2010)
BIM content	Modular digital representation of a specific component or object that can be imported in a BIM model. BIM content is distributed decentralized via websites of manufacturers or centralized via BIM content platforms.
BIM content platform	Cloud-based platform that allows manufacturers and BIM designers to exchange BIM content. Often referred to as BIM content library.
Collaborative BIM platforms	Platform that integrates and manages multiple BIM models from all stakeholders of a building project.

3.3 E-marketplace platforms

The second concept addressed by the research problem are e-marketplaces. The first section of this research already briefly introduced e-marketplaces, but this section will discuss the related concepts in more detail. As mentioned earlier, e-marketplaces are a special category of platforms. This section will first define platforms more thoroughly, than discuss the platform business models, third discuss the value mechanisms on a platform, and finally discuss the characteristics of e-marketplaces.

Platforms are defined as businesses based on enabling value-creating interactions between external producers and consumers (Parker et al., 2016). But Hagiu (2007) recognized problems with this definition and extended it with two important features. First the platform must enable direct interactions between two or more distinct sides. Second each side must be affiliated with the platform. Direct interaction means that the two sides determine the key transaction terms instead of the mediator. This implies that for example a wholesale company, that enables value-creating interaction between external producers and consumers, cannot be regarded as platform. A classic example of an MSP is a village marketplace were merchants offer their products to buyers on a shared physical platform. With rise of the digital age, digital information technologies created new digital platforms that exist in various forms. Platforms can be potentially larger, more valuable and more powerful than non-digital platforms (Hagiu, 2007).

The adoption of platform business models can be regarded as one of the most impactful economic trends of the 21th. Parker et al. (2016) refer to it as the ‘platform revolution’. The platform business model is the opponent of the traditional pipeline business model. A pipeline business model seeks to create and transfer value in a step-by-step arrangement with producers on the one end, and consumers on the other end (Parker et al., 2016). Platforms business models tend

to beat traditional pipeline businesses because they scale more efficient, they unlock new sources of value creation, and they create data-based community feedback tools (Parker et al., 2016). Many of the most successful companies nowadays exploit a platform business model. For example, in the minds of many people, Apple is a hard- and software producer with a pipeline business model. But it is their platform business model, mediating external producers and consumers, that enabled Apple to beat Nokia in the top of the mobile phone market (Alex Moazed & Johnson, 2016)

One of the core concepts entailed by the definition of platforms is network externalities. Katz and Shapiro (1985) define network externalities as 'the utility that a user derives from consumption of the good increases with the number of other agents consuming the good'. When the added value depends on the same user group, the effect is called direct network externalities. When the added value depends on a different user group the effect is called indirect network externalities. Network externalities can generate a positive or a negative correlation between the number of users and the derived utility. Applying this concept to commercial digital platforms, positive indirect network externalities can be recognized between buyers and sellers. Sometimes a commercial platform trading scarce goods also entails negative direct network externalities for buyers and sellers. With more buyers on the platform, demand and prices will increase. With more sellers, supply and price pressure will increase.
The concept of network externalities introduces an important problem with the launch of platforms called the chicken-egg-problem. The chicken-egg-problem refers to the problem when the value proposition of both user groups depend on positive indirect network externalities between each other (D. Evans & Schmalensee, 2009). This causes a problem with launching a platform when both the sides are not complemented with users yet.

E-marketplaces, are a special category of platforms that allow for transactions (P. C. Evans & Gawer, 2016). Traditional marketplaces, for example warehouses, always operated parallel to pipeline businesses, brand stores in this example. But with the development and adoption of digital marketplaces, more and more traditional pipeline businesses get disrupted. Digital Marketplaces are able to reduce transaction costs, generate market liquidity, reduce costs of search and negotiation, add product and pricing transparency, reduce inventory and overhead costs, and facilitate bidding on the supplier side (Zhu, 2002). Especially the advantages related to search & negotiation, and transparency are expected to reduce the added value of intermediaries resulting in a shorter supply chain (Choudhury, Hartzel, & Konsynski, 1998). Although digital marketplaces are known for its disruptive force in b2c industries, think of eBay or Amazon, many b2b industries are adopting marketplaces rapidly (Lu & Antony, 2003). Most of the former traditional industries like agriculture, logistics, energy, petroleum, automobile, aerospace and even heavy industries adopted b2b marketplaces (Parker et al., 2016; Zhu, 2002). According to Weiblen et al. (2012), an e-marketplace platform has four basic functionalities. First an e-marketplace offers products and services in a structured manner as well as to select and find required products and services. Second it allows buyers and sellers to negotiate the price and conditions of a transaction. Third it allows buyers and sellers to arrange contracts. And fourth, it supports a financial transaction and delivery of the products and services.

Table 7 gives an overview of the concepts discussed in section 3.3.

Table 7 Definition of core concepts used in section 3.3.

Concept	Definition
Platform	Businesses based on enabling direct value-creating interactions between external producers and consumers that are affiliated with the platform (Hagiu, 2007; Parker et al., 2016).
Network externalities	The utility that a user derives from consumption of the good increases with the number of other users consuming the good (Katz & Shapiro, 1985).
Direct network externalities	Derived utility depends on the same user group on a platform
Indirect network externalities	Derived utility depends on another user group on a platform
Chicken-egg-problem	The problem where the value proposition of both user groups depend on positive indirect network externalities between each other (D. Evans & Schmalensee, 2009).

3.4 Company Profile: Stabiplan

This research is prepared and conducted in cooperation with the Dutch software developer Stabiplan B.V. Stabiplan, that recently became part of Trimble Inc., is active in the building services industry since 1990. The main office is located in Bodegraven (The Netherlands) and Stabiplan is also located in: Brasov (Romania), Paris (France) and Antwerp (Belgium). Stabiplan employs approximately 180 people. Stabiplan defines its mission as: 'Stabiplan helps its clients to develop better technical installations.' The vision of Stabiplan is to become the European market leader for Mechanical Electrical and Plumbing BIM software. Stabiplan promotes two distinct but interacting product groups: 'Stabicad' and 'MEPcontent' (Stabiplan, 2017).

The first and largest product in terms of revenue is Stabicad. Stabicad is a BIM software solution that allows engineers in the building services industry to design complete technical systems in a 3D model. Examples of these systems are ventilation, sprinkler and building power grid installations. Stabicad can be considered as an extension of the existing and popular software solutions 'AutoCAD' and 'Revit' developed by the American software developer Autodesk. In the last decade, Stabicad gained a market leader position in the Netherlands and Belgium. Approximately 80% of the Dutch building services engineers use Stabicad to design and calculate building services systems. The first version of Stabicad was development in the first years of Stabiplan and in 2017 the 11th version of Stabicad is introduced. Stabiplan also provides supporting activities for Stabicad as BIM consulting at projects and CAD training to engineers.

Stabiplan exploited a pipeline business model in the development and distribution of Stabicad for more than 25 years. Recently, Stabiplan innovated their business model to a platform business model with their platform MEPcontent.com. From the introduction of the Stabicad solution, Stabiplan has been developing BIM content to support Stabicad users. Engineers that use Stabicad need BIM content to fill their models and retrieve component specifications. In collaboration with manufacturers, Stabiplan develops BIM content and since 2013 this BIM content is freely available via the MEPcontent platform. MEPcontent distributes BIM content containing graphical data for CAD solutions and BIM content that also contains non-graphical data and component characteristics. The platform mediates engineers that need BIM content to fill their models and manufacturers that market their products. Recently, the MEPcontent platform also incorporates an app store. The app store distributes various small BIM applications. These applications add functionality or provide BIM designers with BIM content.

Stabiplan perceived the concept of a BIM-based e-marketplace as a potential business opportunity. Since their platform MEPcontent.com already mediates engineers (buyers) and manufacturers (sellers), Stabiplan might be in the strategic position to develop a BIM-based e-marketplace.

4 LITERATURE REVIEW

The first three chapters of this research formed the introduction phase of this research. This chapter will describe the second phase: literature review. This literature review aims to derive hypotheses from a theoretical framework and related work. These hypotheses try to make logical sense of how European building services manufacturers, wholesalers and engineers are obstructed to adopt BIM-based e-marketplace platforms. A theoretical framework is developed using theoretical literature that relates to the research problem. Related empirical work is collected that study the adoption of related technologies in the construction industry. The result of this literature review will be a list of hypothetical barriers for adoption of a BIM-based e-marketplace including theoretical explanations of why these barriers exist, and how they obstruct adoption. These hypotheses will be tested in the third data collection documented in chapter 7.

This chapter is structured as follows. Section 4.1 will describe the protocol used for this literature review. Section 4.2 develops a theoretical framework based on theoretical literature related to the research problem. Section 4.3 collects related work that study the adoption of related technologies. Section 4.4 combines the findings of the theoretical framework and empirical evidence, to define hypotheses that logically answer the research question.

4.1 Review Protocol

This section reports the systematic literature review approach that is used for this chapter. The goals of literature review and the keywords used per section are discussed.

Section 4.2 Theoretical Framework
A theoretical framework aims to conceptualize the relationships among factors relevant to the problem (Sekaran, 2013). The research question that this research aims to answer is: “How are European building services manufacturers, wholesalers and engineers obstructed to adopt BIM-based e-marketplace platforms?”. The core factor relevant to the research problems is: platform adoption. A theoretical framework should describe the factors that can slow down the adoption of platforms. Therefore, the following keywords were used in different AND combinations: technology, innovation, platform, multisided platform, digital platform, commercial platform, transaction platform, e-marketplace, online marketplace, B2B, barrier, adoption, diffusion, design, boundaries.

Section 4.3, Related Work
Section 4.3 collects empirical studies on the adoption of related technologies in the construction industry. The first technology is e-commerce. E-commerce is a collective name for all electronic technologies that support businesses and include among others e-commerce, e-marketplaces and Electronic Data Interchange. To find relevant literature the following keywords were used: E-procurement, E-commerce, E-business, EDI, Electronic Data Interchange, E-marketplace, online marketplace, construction, building services, sector, industry, barriers, adoption.
The second related technology is Building Information Modelling. To find literature that studies the adoption of BIM the following keywords were used: computer aided design, CAD, building information modelling, BIM, AEC, construction, building services, sector, industry, barriers, adoption.

This literature review will focus primarily on academic literature. In some cases, for example in section 1.1 non-academic literature was used to show the research problem is topical. Some of the subjects and technologies this research address, are relatively new and the construction industry is changing. Therefore, empirical literature related to the construction industry, BIM and e-commerce older than 15 years will be ignored and literature older than 5 years will be

reviewed critically. Literature describing theoretical studies can be older. Since recent literature is of higher value to this research, forward snowballing is generally preferred above backward snowballing. Backward snowballing is only used to find literature describing theoretical frameworks. Search engines Scopus, Web Of Science and Google Scholar are used to access academic literature. Endnote was used to download citations in the bibliography.

4.2 Theoretical Framework

This section will propose a theoretical framework that aims to explain how the adoption of e-marketplaces can be inhibited. This theoretical framework consists of five building blocks based on five independent theories that each provide a different perspective on the adoption of BIM-based e-marketplaces. Section 4.4 will operationalize these theories in the context of the construction industry, to develop hypotheses.

4.2.1 DOI

The first theory that not only holds for platforms, but for every innovation, is the 'Diffusion Of Innovations' (DOI) theory by Rogers (1962). The DOI theory describes why, how and at what rate innovations are adopted by a population. Rogers (1962) argues that adoption behavior is influenced by: relative advantage, complexity of technology, compatibility, trialability and observability. Diffusion is defined as the adoption of an innovation by a social system. Since this research is primarily interested in the factors that slow down the adoption of innovations, these barriers will be discussed.
According to Rogers (1962) a number of physical, social and economic factors can form barriers for adoption of innovations. These barriers can slow down the adoption rate by obstructing the flow of information or the movement of people. An example of a barrier can be distance. When information about an innovation is not able to cross certain geographical barriers, this will slow down the geographical diffusion. Another example is culture. Cultural or linguistic differences within a social system may hinder the flow of information and slow down the adoption of innovations.

4.2.2 TOE

The second theory that conceptualizes the adoption of innovations is the 'Technology-organization-environment' (TOE) framework by Depietro, Wiarda, and Fleischer (1990). The TOE framework suggests that the adoption of technological innovations by organizations is influenced by the technological, organizational and the environmental context of an organization. First the technological context consists of all internal and external technologies that are relevant to a firm. The organizational context describes all the characteristics and resources of the organization, and the environmental context is made up of the industry structure, competitors, macroeconomic context and the regulatory environment.
The TOE framework is extensively applied to the adoption of IT innovations. Examples of technological factors influencing the adoption of e-business by organizations are: technology readiness & integration (Oliveira & Martins, 2011), technological skills of human resources (Teo, Ranganathan, & Dhaliwal, 2006) and security applications (Oliveira & Martins, 2011). Examples of organizational factors are: firm size (Liu, 2008), perceived/expected benefits (Kuan & Chau, 2001), difficulties in organizational change (Teo et al., 2006) and international/global scope (Zhu & Kraemer, 2005). Examples of environmental factors are: regulatory support (Zhu & Kraemer, 2005), consumer readiness(Zhu, 2002), competition intensity (Zhu & Kraemer, 2005).

4.2.3 Transparency

The third building block of this theoretical framework is based on the concept of information transparency. Information

transparency is defined as the degree of visibility and accessibility of information. Electronic marketplaces generally make prices and product information more visible and accessible for buyers and other sellers (Zhu, 2002). This is considered to have a positive effect on supply chain efficiency (Mukhopadhyay, Kekre, & Kalathur, 1995). Online exchanges streamline the information flow in supply chains (Zhu, 2002) and re-balance information asymmetry between suppliers and buyers (Bakos, 1998). Zhu (2002) argues that information transmission on an online marketplace can be horizontally or vertically. Horizontal information transmission occurs among parties at the same level of the supply chain, while vertical information transmission occurs between parties sequential in the supply chain. This concept also applies on horizontal or vertical information transparency. E-marketplaces tend to increase horizontal as well as vertical transparency Zhu (2002).

Although information transparency is considered to increase supply chain efficiency, not every party is able to benefit from those gains. Nakayama (2000) studied the impact of vertical information transparency obtained by the implementation of Electronic Data Interchange systems. The results show empirical evidence for a shift in bargaining power from wholesaler to supplier. Vertical information transparency provides the supplier with more trading information and gain more marketing flexibility compared to wholesalers. For example, vertical information transparency gives buyers insight in the margins of wholesalers because both supplier price and buyer price are transparent. This puts significant pressure on margins of wholesalers. As argued in section 1.1, the construction industry supply chain is fragmented and wholesalers have a powerful position in the supply chain. Vertical information transparency can inhibit wholesalers to participate on a BIM-based e-commerce platform because their bargaining power and margin might decrease.

Horizontal information transparency determines the visibility and accessibility of information between parties on the same level in the supply chain. Zhu (2002) studied the influence of horizontal information transparency on competition in the supply chain. Empirical evidence shows that companies operating in B2B industries fear data exposure, pricing pressure, and margin erosion on a B2B e-marketplace. Especially the cost transparency of suppliers is highly relevant because a marketplace redistributes market share from high-cost suppliers to low-cost suppliers. Low-cost suppliers are expected to experience more advantage compared to high-cost suppliers. On the buyer side, high value (willingness-to-pay) buyers are expected to experience more advantage from a marketplace compared to low-value buyers.

4.2.4 Interoperability

The fourth building block of this theoretical framework is technological interoperability. This theory is provided by (Choi & Whinston, 2000). With the development of online commerce and especially with the adoption of e-marketplaces, interoperability and standardization became more important concepts. Interoperability is defined as the extent to which systems and devices can exchange data, and interpret that shared data. Choi and Whinston (2000) distinguish two types of interoperability: vertical and horizontal interoperability. Horizontal interoperability refers to the extent competing products can be used together. Vertical interoperability refers to the extent complementary products can be used with competing products. The economic benefits of interoperability were already significant for the physical economy. Standards and technological compatibility enabled industrial production which lowered cost and prices, increased competitiveness, improved customer benefits. But the digital, so called ‘networked’ economy benefits even more from interoperability. Interoperability is a fundamental requirement for network externalities among users. Network externalities, already discussed in section 3.3, is the value of a product that increases with the number of users.

Interoperability is even more important to BIM-based e-marketplaces than to other types of e-marketplaces because a BIM-based marketplace relies on both physical and digital standardization. The concept of horizontal interoperability

applies on products traded on a BIM-based e-marketplace in two ways. First the extent actual products can be combined in an technical system. And second the extent BIM content, the digital representation, of these products can be combined in a BIM model. The concept of vertical interoperability in the context of BIM-based e-marketplaces refers to the extent products can be presented on different BIM-based e-marketplace platforms. Both horizontal and vertical interoperability increase network externalities for suppliers and buyers.
The construction industry is generally known to struggle with standardization (Yousefzadeh, Spillane, Lamont, McFadden, & Lim, 2015). Especially the adoption of BIM is highly dependent on interoperability and data standardization. The problem of standardization is also related to the fragmented industry structure mentioned in the first section of this report. Choi and Whinston (2000) emphasize the importance of interorganizational cooperation in global standardization. Although governmental interventions are important, the process of standardization mainly relies on the efforts of market-players. A fragmented industry structure slows down the adoption of data standards and inhibits interoperability.

4.2.5 Technology Trust

The third theoretical concept that is highly relevant for e-marketplaces, is technology trust. The classic definition of trust, also referred to as 'trading trust', is relevant for every transaction. Trading trust is defined as: 'the subjective probability with which organizations assess that another organization will perform potential transactions according to their confident expectations' (Ratnasingam, Pavlou, & Tan, 2002). With the development of electronic transactions, an extra dimension of trust became relevant: technology trust. Ratnasingam et al. (2002) define technology trust as: 'the subjective probability by which organizations believe that the underlying technology infrastructure is capable of facilitating transactions according to their confident expectations'. Technology trust is an important factor in the perceived benefits and the performance of e-commerce platforms Ratnasingam et al. (2002).

The five theories described in this section form the building blocks of this theoretical framework and provide a broad theoretical basis of the factors that can obstruct the adoption of BIM-based e-marketplaces (Figure 9). Section 4.4 will use this theoretical framework to develop hypothetical barriers for the adoption of BIM-based e-marketplaces. But first section 4.3 will review related work and collect empirical evidence to support hypothesizing.

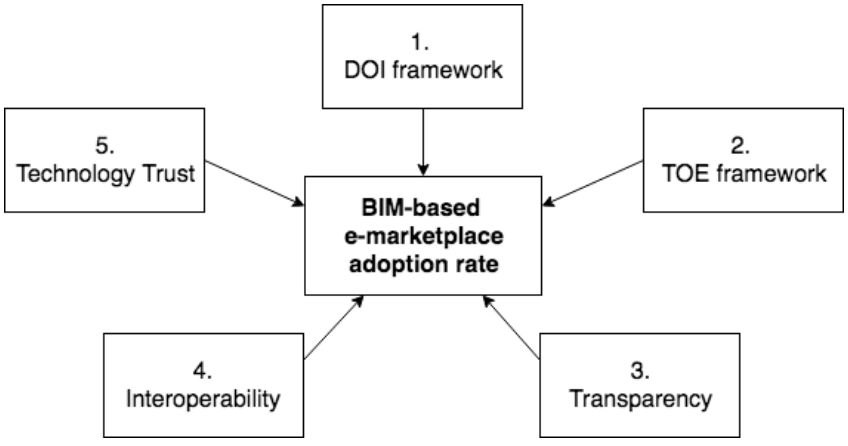

Figure 9 Theoretical framework, five building blocks

4.3 Related Work

This section will collect related work that study the adoption of related technologies in the construction industry. After a

first hunch in academic literature, a BIM-based e-marketplace can be assigned to two technology classes. The first technology class is electronic commerce (E-commerce). The second technology class is Building Information Modeling (BIM). Both technology classes receive extensive attention from academic literature in the context of the construction industry. The following subsections will first describe these technology classes and collect empirical evidence of factors that obstructed the adoption of these technologies in the construction industry.

4.3.1 E-commerce

Electronic commerce is defined from many different perspectives. Garrett and Skevington (1999) approach e-commerce in a comprehensive definition: “E-commerce is trading by means of new communication technology. It includes all aspects of trading, including commercial market making, ordering, supply chain management, and the transfer of money”. And in the time perspective ‘new communication technology’ covers every information technology beyond telephony, fax and telex.

The concept of e-commerce applies to the construction industry in different forms. Implementation of e-commerce results in the following business processes: e-marketing, e-selling and procurement of goods and services, e-collaboration, e-finance and e-customer services (Veeramani et al., 2002). According to literature research by Eom, Kim, and Jang (2015), there is little academic literature available on the role of e-commerce in the construction industry. There exists research that identifies barriers and drivers of e-commerce during its development phase.

Zou and Seo (2005), noticed significant e-commerce benefits to the construction industry. These drivers are: increasing productivity because of efficient creation, retrieval, delivery of information and more effective communication, inventory reduction and decrease in the number of rebuilding with accurate design information. Zou and Seo (2005), also mention the following barriers: fragmentation of information and lack of information management systems, the need to adapt organizational policies and management, lack of innovative culture and a lack of knowledge sharing.

Rankin, Chen, and Christian (2006) studied e-procurement in the Canadian construction industry. They analyzed the barriers and drivers that companies face when transforming the procurement process from the traditional tender biddings, to e-commerce. They identified the following barriers: cost appropriation, ambiguity of information ownership, ambiguity in responsibilities, lack of technological capabilities, challenge of integrating e-commerce solutions with internal processes, lack of standards, lack of trust in security and finally authentication of electronic documents. Rankin et al. (2006) also identified the following drivers for e-procurement: reduction of transaction costs, reduced paperwork, time saving in the procurement process, accuracy of data in transactions, higher productivity, greater market access.

Isikdag, Underwood, Ezcan, and Arslan (2011) studied the barriers and challenges of e-commerce in the Turkish construction industry. They identified the following key barriers: security issues with high value transactions, lack of legal mechanisms for digital contracts, lack of legal structures, lack of top management support, lack of best practice studies and capabilities, lack of knowledge about taxation for e-commerce, low availability of online marketing tools, low trust in digital marketing campaigns, low technical capabilities, low trust in security, lack of trust between parties in e-commerce, lack of training, and lack of integration with internal processes. Obviously, the availability of online marketing tools is outdated. Currently almost every company utilizes online marketing tools.

A paper from Bhutto et al. (2005) also studies barriers and drivers for the adoption of e-commerce. The following barriers are identified: point-to-point nature of communication, multiparty projects, high initial investments and lack of agreement on standards. Bhutto et al. (2005) also identified the following drivers: faster transaction timer, reduced costs, more up-to-date information, less paperwork, wider market and more information.

Finally Wang et al. (2007) studied the adoption of e-commerce in the construction industry and concluded the adoption speed was lower compared to other industries. They identify the following barriers: fragmented structure of the industry, lack of knowledge sharing and agreement on standards. An overview of the barriers for the adoption of e-commerce derived from literature is given in Table 8. The fourth column refers to the related hypothesis defined in (section 4.4).

Table 8 Barriers for the adoption of e-commerce in the construction industry

Ref	Barriers	Sources	Hypothesis
8.1	Lack of information management. Companies are not able to manage the information overload that results from e-commerce operations.	Zou and Seo (2005)	4
8.2	A new digital infrastructure requires the adaption of core components of the organization in terms of policies and management.	Zou and Seo (2005)	4
8.3	Lack of innovative culture. Management and employees do not support innovative behavior.	Zou and Seo (2005), Isikdag et al. (2011)	10
8.4	Lack of knowledge sharing channels and organizations still rely on people-based transferring of information.	Zou and Seo (2005), Wang et al. (2007)	1
8.5	Companies face high perceived costs with the adoption of e-commerce technology.	Rankin et al. (2006), Bhutto et al. (2005)	6
8.6	Ambiguity of information ownership and property rights can occur.	Rankin et al. (2006)	7
8.7	During the e-commerce processes ambiguity in responsibilities can occur.	Rankin et al. (2006)	7
8.8	Companies face a lack of technological capabilities among employees.	Rankin et al. (2006), Isikdag et al. (2011)	5
8.9	Challenge of integrating e-commerce solutions with internal processes and software.	Rankin et al. (2006), Isikdag et al. (2011)	4
8.10	There is a lack of standards for information representation	Rankin et al. (2006), Bhutto et al. (2005), Wang et al. (2007)	3
8.11	There is lack of trust in the security of electronic transactions	Rankin et al. (2006), Isikdag et al. (2011)	8
8.12	Uncertainty about the legal status and authenticity of electronic contracts	Rankin et al. (2006), Isikdag et al. (2011)	7
8.13	Lack of legal structures to support e-procurement and provide certainty and trust	Isikdag et al. (2011)	7
8.14	Lack of knowledge about taxation regimes for e-commerce transactions.	Isikdag et al. (2011)	7
8.15	Fragmented structure of the construction industry.	Wang et al. (2007)	1

4.3.2 Building Information Modeling

The second technology class is Building Information Modeling. Since BIM is a much more recent concept compared to e-commerce, studies on BIM adoption are expected to identify more relevant barriers and drivers.

Walasek and Barszcz (2017) studied the adoption of BIM and recognized the following barriers to adoption: fragmented structure of the industry, incompatibility of standards, lack of consensus and awareness of BIM functionality, lack of inter-organizational knowledge management, risk of legal issues and lack of a legal framework, lack of training and the necessity to create new roles in an organization.

Ghaffarianhoseini et al. (2017) identified benefits and challenges of the implementation of BIM for the construction industry. The following challenges can be recognized: ambiguity of intellectual property and cybersecurity. The following drivers are associated with BIM: better CAD models, knowledge management, standardized data, management benefits, integration of roles and processes, lower error chance, costs savings, more efficient and reliable planning, life cycle management,

Chien, Wu, and Huang (2014) studied the technical, financial, management, environmental and legal risks of BIM projects. Chien et al. (2014) defined the following barriers in a literature study: low awareness of benefits, lack of software compatibility, knowledge management difficulties, low management support, lack of skilled employees, learning costs, financial costs and unclear legal liabilities. An overview of the barriers for the adoption of BIM in the construction industry

is given in Table 9. The fourth column refers to the related hypothesis defined in (section 4.4).

Table 9 Barriers for BIM adoption

Ref	Barriers	Sources	Hypothesis
9.1	Fragmented structure of the industry	Walasek and Barszcz (2017)	1
9.2	Incompatibility of standards	Walasek and Barszcz (2017), Chien et al. (2014)	3
9.3	Lack of consensus and awareness of BIM functionality	Walasek and Barszcz (2017), Chien et al. (2014)	1
9.4	Lack of inter-organizational knowledge management.	Walasek and Barszcz (2017), Chien et al. (2014)	1
9.5	Risk of legal issues and lack of a legal framework.	Walasek and Barszcz (2017), Ghaffarianhoseini et al. (2017), Chien et al. (2014)	7
9.6	Lack of skilled employees and training programs to acquire these skills	Walasek and Barszcz (2017), Chien et al. (2014)	5
9.7	Necessity to create new roles in an organization.	Walasek and Barszcz (2017)	4
9.8	Security and the risk of cybercrime	Ghaffarianhoseini et al. (2017)	8
9.9	Costs of investments and learning	Ghaffarianhoseini et al. (2017), Chien et al. (2014)	6

This section collected and interpreted related work on the adoption of e-commerce and BIM. Related work extensively describes factors that obstructed the adoption of BIM and e-commerce in the construction industry. The following section will use this related work and combine it with a theoretical framework to develop hypotheses.

4.4 Hypothesizing

This section will develop hypothetical barriers for the adoption of a BIM-based e-marketplace. Based on the theoretical framework and related work introduced in the previous sections, hypotheses are defined that explain the research problem. These hypothetical barriers will form the starting point of knowledge building in this research project.

1. Fragmented industry structure

The first building block of the theoretical framework, the DOI framework, explains that a requirement for diffusion of an innovation is the flow of information through a social system. Studies like Nawi, Nasrun, Baluch, and Bahaudin (2014) conclude that the structure of the construction industry is fragmented. The top 400 construction firms in the US account for less than 15% of industry volume (ENR, 2009). This fragmented structure obstructs the flow of information through the construction industry. According to Zou and Seo (2005) and Wang et al. (2007) the flow of information is obstructed because of a lack of knowledge sharing channels (table 8.4).

According to the DOI framework this fragmented structure will thus inhibit the diffusion of BIM-based e-marketplaces. This aligns with studies like Sheffer and Levitt (2010), who conclude that a fragmented industry structure slows down the diffusion of innovations. Related work also mentions that the fragmented structure of the industry obstructs the adoption of e-commerce and BIM (table 8.15 & 9.1). A fragmented industry can obstruct the adoption of a BIM-based e-marketplace in three ways.

First studies like Wang et al. (2007) and Walasek and Barszcz (2017) confirm that the fragmented structure of the construction industry inhibits interorganizational cooperation in the context of BIM adoption (table 9.4). Since interorganizational cooperation is critical to the adoption of BIM, the fragmented structure of the construction industry is expected to form a barrier for adoption of BIM-based e-marketplace.

Second Rogers (1962) argues that when information flow is obstructed, the awareness regarding a technology falls

behind. A lack of awareness about the functionality and added value of an innovation negatively affects the adoption intention. Empirical research by Walasek and Barszcz (2017) and Chien et al. (2014) show that the adoption of BIM is obstructed by a lack of consensus and awareness of the BIM functionality (table 9.3). Therefore, the adoption of a BIM-based e-marketplace is also expected to be obstructed by a lack of awareness.
Third Nawi et al. (2014) argue that the fragmented structure of the construction industry also obstructs the flow of information in supply chains. This reduces transparency and increases the influence of barrier 2.

2. Information transparency

The second adoption barrier resulting from the theoretical framework is information transparency. In the introduction of this research, transparency is approached as the most beneficial aspect of e-marketplaces. Transparency is expected to increase supply chain efficiency and increase productivity growth of the construction industry. Literature shows how not all stakeholders benefit from information transparency on an e-marketplace. Vertical information transparency is expected to shift bargaining power from wholesalers to suppliers. This puts pressure on the margin of wholesalers and they are therefore not expected to adopt e-marketplace solutions. Horizontal information transparency is expected to change competition among suppliers. Especially high cost suppliers are expected to lose market share and are therefore not expected to participate on an e-marketplace. Zhu (2002) also empirically confirmed the obstructing role of transparency in b2b e-marketplace adoption. They found that information disclosure rules critically affected the adoption intention of firms. Companies acknowledged to fear of data exposure, pricing pressure, and margin erosion on an open b2b marketplace. The role of information transparency is not mentioned by related work.

3. Lack of interoperability

The third adoption barrier resulting from the theoretical framework is interoperability. Interoperability is argued to be a fundamental requirement for network economies like e-marketplaces. Interoperability enables network externalities on an e-marketplace. Interoperability on a BIM-based e-marketplace refers to both the technical compatibility as the digital compatibility of products. A lack of interoperability is expected to reduce the added value for both buyers and sellers. The lack of standards in information representation is a widely known problem in the construction industry. This problem of interoperability is expected to be a barrier for the adoption of BIM-based e-marketplaces. Empirical literature confirmed the problem of data standards. Researchers like Rankin et al. (2006) and Walasek and Barszcz (2017) confirm the lack of data standards is a barrier for e-commerce and BIM (table 8.10 & 9.2)

4. Internal business processes

The TOE framework emphasizes the integration and compatibility of organizational structures and processes and an innovation. Organizational change and redistributing roles requires much effort to achieve. Related work identified multiple barriers to the adoption of e-commerce and BIM related to internal business processes and role distributions (table 8.1, 8.2, 8.9 and 9.7). For example Walasek and Barszcz (2017) mentioned the necessity to create new roles in an organization hinders BIM adoption, Zou and Seo (2005) mention that a new digital infrastructure requires the adaption of core components of the organization in terms of policies and management, and Rankin et al. (2006) mentioned the challenge of integrating e-commerce solutions with internal processes and software. The incompatibility of internal business processes and the need to change the internal role distribution is also expected to obstruct stakeholders to adopt BIM-based e-marketplaces. Examples of internal business processes that might not be compatible are procurement processes at engineers, and sales or logistic processes at manufacturers.

5. Human resources

The technological aspect of the TOE framework emphasizes the technological skills of human resources that need to adopt the innovation. Innovations often require specific knowledge to implement and organizations can have trouble to

acquire skilled human resources. Engineers participating on a BIM-based e-marketplace need to adopt the BIM process and work with specialized software. According to Ahuja, Jain, Sawhney, and Arif (2016), technological skills related to BIM and e-commerce are not very common in the construction industry. Multiple related studies like Isikdag et al. (2011) and Chien et al. (2014) confirm that skilled human resources are critical to the adoption of BIM or e-commerce in an organization (table 8.8 & 9.6). Since these skills are rare, acquiring skilled human resources can be difficult and costly. Therefore, a lack of human resources is expected to obstruct the adoption of BIM-based e-marketplaces.

6. Technological investment costs

According to the technological aspect of the TOE framework, available internal and external technologies are an important factor in the adoption of technological innovations. Compatibility with existing technologies is an important determinant of the costs to adopt an innovation. Rogers (1962) argues that compatibility with existing technology is positively correlated with the adoption rate of a new technological innovation. Related work on the adoption of e-commerce and BIM in the construction industry confirm the role of available technology and expertise (table 8.5 & 9.9). According to researcher like Rankin et al. (2006), companies face high costs with the adoption of e-commerce because they need to update their technological infrastructure and corresponding technical knowledge. Isikdag et al. (2011) refers to the integration between e-commerce solution and existing software. Ghaffarianhoseini et al. (2017) also confirms the costs of technological investments and learning decrease the adoption intention of BIM. Technological investments are also expected to obstruct the adoption of BIM-based e-marketplaces.

7. Lack of legal framework

According to the TOE framework, the adoption of an innovation is not only determined by firm specific characteristics but also by the environment. One of those environmental factors is the legal environment of an organization and the regulatory support of an innovation. Zhu and Kraemer (2005) emphasize the importance of regulatory support for online transactions. Online transactions bring new issues regarding business law, security and online transactions with parties that have no prior relationship (Zhu & Kraemer, 2005). When the support of this legal framework is incomplete, uncertainty will reduce the intention to adopt an innovation.

In the context of e-commerce and BIM, multiple studies refer to legal issues that obstruct adoption (table 8.6, 8.7, 8.12, 8.13, 8.14 and 9.5). Researchers like Rankin et al. (2006) and Isikdag et al. (2011), mention uncertainty on regulatory support as an adoption barrier for the construction industry. Examples of legal topics are: property rights, responsibility distribution, authenticity of digital contracts and taxation policy. Since the lack of a legal framework played a role in the adoption of BIM and e-commerce, it is also expected to obstruct the adoption of a BIM-based e-marketplace.

8. Lack of technology trust

The conceptualization of technology trust by Ratnasingam et al. (2002), showed an extra dimension of trust for electronic transactions. Apart from trading trust that applies on every transaction, technology trust significantly influences the performance and business value of an e-commerce platform. Multiple related studies mention the role of trust in the adoption of BIM and e-commerce technologies (table 8.11 & 9.8). Researchers like Rankin et al. (2006) and Isikdag et al. (2011) emphasize the lack of trust in the security of e-commerce transactions and the risk of cybercrime. According to Ghaffarianhoseini et al. (2017) trust is also an important adoption factor for BIM. Security is a very important topic when it comes to the living environment of people. BIM models of buildings can contain a lot of valuable information that cannot be made public. For example, criminals could use a BIM model to break into a building or to plan an attack. Since a lack of technology trust is an adoption factor for e-commerce and BIM, the adoption of BIM-based e-commerce platforms is also expected to be obstructed by a lack of technology trust.

9. Resistance to change

The DOI framework not only mentioned the flow of information that determines the adoption of an innovation, but also the nature of the social system. Rogers (1962) uses five categories to distinguish different actors in a social system: innovators, early adopters, early majority, late majority, and laggards. According to Rogers, cultural aspects of a social system is one of the determinants in the distribution of these five categories. Related studies like Zou and Seo (2005), Isikdag et al. (2011) mention a lack of innovative culture as a barrier for the adoption of e-commerce in the construction industry (table 8.3). This lack of innovative culture refers to a low number of innovators and early adopters compared to late adopters and laggards. Alarcón et al. (2009) also mentions this cultural aspect as 'resistance to change'. They argue that the rigid nature of the construction industry culture inhibits implementation of new initiatives and the changes of business processes. Since the adoption of a BIM-based e-marketplace will require changes in business processes of all stakeholders, resistance to change is expected to obstruct adoption of all stakeholders.

4.5 Conclusion

This literature review developed a theoretical framework, collected related work, and used this literature to develop a list of nine hypothetical barriers. The rest of this document will refer to this list as 'hypothetical barriers'. Newly elicited barriers will be referred to as 'emergent barriers'. Table 10 gives an overview of the hypothetical barriers. These hypotheses will be tested in third data collection round, stakeholder interviews.

Table 10 Hypothetical barriers for the adoption of a BIM-based e-marketplace

Barrier	Description	Literature support
1	The *fragmented structure* of the construction industry reduces interorganizational cooperation and awareness	DOI framework, multiple related studies
2	*Information transparency* inhibits the adoption by suppliers because they fear data exposure, pricing pressure, and margin erosion	Zhu (2002)
3	Technical *interoperability* and the lack of standardization in the construction industry reduces network externalities	Choi and Whinston (2000); multiple related studies
4	The *internal business processes* of stakeholders are not ready to integrate with an e-marketplace	TOE framework; multiple related studies
5	A lack of skilled *human resources* is expected to obstruct adoption by engineers and manufacturers	TOE framework; multiple related studies
6	Stakeholders face high *technological investment costs*, because the internal technological resources are not compatible	TOE framework; multiple related studies
7	A *lack of legal framework* creates uncertainty in transactions and reduces the added value	TOE framework; multiple related studies
8	A *lack of technology trust* reduces the perceived added value and obstructs adoption intention of all stakeholders	Ratnasingam et al. (2002); multiple related studies
9	The construction industry culture is characterized by a high *resistance to change*	DOI framework, multiple related studies

5 INDUSTRY EXPERT INTERVIEWS

Chapter 4 took a deep dive into prior literature and defined a first set of hypothetical barriers for the adoption of a BIM-based e-marketplace. This chapter will report the first round of the data collection and analysis phase. As discussed in section 2.3, the first data collection round involves industry expert interviews. The primary goal of these short interviews is to elicit emergent barriers that were not hypothesized by the literature review.

This chapter is structured as follows. Section 5.1 reports the applied data collection methodology. Chapter 2 already introduced the general methodology but this section will report the implementation. Section 5.2 will use the results to define emergent barriers and evaluate previously known barriers. Section 5.3 concludes upon the findings of the industry expert interviews. The detailed interview documents and data is attached in Appendix A.

5.1 Methodology

Section 2.3 proposed and substantiated a suitable method for this first data collection round. This section will report the implementation of this method and the choices that were made. This involves a sampling procedure described in subsection 5.1.1, the interview protocol described in subsection 5.1.2, and subsection 5.1.3 describes the applied data analysis method.

5.1.1 Sampling

As discussed in section 2.3, the first data collection round will target industry experts within the company Stabiplan. Both judgement sampling based on expert reputation, and proportionate stratified sampling is used based on knowledge of engineers, manufacturers and wholesalers. After inviting eight industry experts at Stabiplan, seven agreed to an interview meeting. One element did not respond to the invitation because he missed the invitation email. Since this person has a similar expertise to P7, this non-response is not expected to bias the result. Table 11 gives an overview of the participants for the industry expert interviews and the corresponding codes. The text in the report will refer to this code when a quote is used.

Table 11 Industry experts sample

Participant code	Function	Industry experience (years)
P1	Marketing Director Stabiplan	25
P2	Business process manager	23
P3	Senior account manager	30
P4	Manager product management	21
P5	Software architect	25
P6	Sales director	25+
P7	Senior account manager	25+

5.1.2 Interview Protocol

Since the focus of this round is more on eliciting barriers than on testing barriers, the interviews are unstructured and informal. To ensure the interview stays on-topic, the generic functional model of Figure 5 is printed and used during the interview. A list of questions (appendix A.2) is developed to provide the researcher with questions and given in appendix

5.1.3 Data Analysis

As mentioned in section 2.3, the first data collection round should not cost much time. The interviews are not fully transcripted but summarized. A color coding approach with codes corresponding to barriers is used to filter and categorize the data. The coding process started with nine codes corresponding to the nine hypothetical barriers that were defined after literature review. During the coding process four more emergent codes were used based on four emergent barriers.

To estimate the degree of influence of a barrier, a degree of confirmation indicator is defined. Based on the number of participants mention the existence of a barrier, or the emphasis participants put on the obstructing role of a barrier, the degree of confirmation is determined. Table 12 gives an overview of the definitions in degree of confirmation. This table also holds for the subsequent data collection rounds.

Table 12 Degree of confirmation

Degree of confirmation	Description	Sign
Explicitly denied	Denied by multiple participants or very emphatically denied by one participant.	--
Denied	Denied by one participant	-
Not denied, nor confirmed.	Not discussed or contradictory opinions of participants	0
Confirmed	Confirmed by one participant	+
Explicitly confirmed	Confirmed by multiple participants or very emphatically confirmed by one participant.	++

5.2 Results

After coding the unstructured data that resulted from the interviews, this section will present the results. Subsection 5.2.1 will first describe the emergent barriers that were elicited. Than subsection 5.2.2 will evaluate the hypothetical barriers that were spontaneously confirmed by the industry experts.

5.2.1 Emergent Barriers

The industry expert interviews elicited the following emergent barriers.

10. Traditional construction delivery method

The traditional Design-Bid-Build construction delivery method of the construction industry was a frequent topic during the interviews. Two industry experts mentioned that the scope of work reduces the added value of a marketplace. A scope of work, as discussed in subsection 3.1.3, is a general description of the work that is expected to be performed under a particular contract between the client and contractor. In the traditional construction delivery method, the architect and consulting engineer develop a scope of work for a building and installations. This scope of work prescribes design and component choices that the engineer needs to follow. Industry experts argue that the scope of work limits the decision power of engineers. For example, one of the interviewees stated: “The decision power of engineers is still limited by the details in a scope of work”. This shows that the design and procurement phase are partly chronologically and organizationally separated. Part of the incentive for suppliers to join an e-marketplace is the expected increase of sales and revenue. When the buyer on an e-marketplace is not the decision maker, and the decision maker is not participating on the e-marketplace, the e-marketplace will not increase sales for suppliers. This reduces the added value of a BIM-based e-marketplace for suppliers. The role of the scope of work is not mentioned as a barrier for adoption of e-marketplaces by related work. Nawi et al. (2014) did recognize the negative effects of the separated design and

construction phases on cooperation and productivity.

11. Negotiation culture

The second emergent barrier is the negotiation culture in the construction industry that limits price transparency. According to five industry experts, price negotiation is important in almost every step of the building process. Engineers receive fixed discounts based on year turnover, but also negotiate prices for individual projects. P7 states: “Suppliers apply discounts based on quantity and relationship but in some cases, engineers bypass the normal discount structures using tender bids.” According to Bichler, Kersten, and Strecker (2003), traditional negotiation suffers from limited price transparency. Negotiation implies that buyers generally receive an individually negotiated price agreement instead of transparent market price. Since price transparency can obstruct the adoption of wholesale and manufacturers (section 4.4, barrier 2), barrier 11 is also expected to obstruct adoption by wholesale and manufacturers. Procurement in construction is known to commonly require negotiation (Dzeng & Lin, 2004), but related work did not mention the negotiation culture as a barrier for e-marketplace adoption.

12. Lack of awareness

Two interviewees mentioned that manufacturers are expected to lack awareness of the added value of a BIM-based e-marketplace. Three industry experts mention the added value of customer data mined on a BIM-based e-marketplace. A BIM-based e-marketplace allows the marketplace owner to extract information from buyers and transfer it to suppliers or third parties. This can be buying behavior but also project information. Suppliers can use this information to anticipate for demand or to target marketing activities. If manufacturers and wholesalers are not aware of these opportunities, it is expected to affect their adoption intention. Industry experts only mention manufacturers to lack awareness of the data opportunity. Section 4.4 argued that a lack of awareness is a result of a fragmented industry structure. But since a lack of awareness can also have other causes, this analysis will regard it as a separate barrier.

13. Logistic services wholesale

Six out of seven industry experts emphasized the obstructing role of wholesale on e-marketplace adoption by manufacturers. Currently almost all transactions in the industry are mediated by wholesale. Wholesale protects this market position and obstructs direct manufacturer-engineer transactions by developing an essential logistic added value in the supply chain. Four interviewees mention that logistic processes of manufacturers cannot compete with wholesale and therefore manufacturers are obstructed to conduct direct manufacturer-engineer transactions. One industry expert thinks that third party logistic providers are not able to provide these logistic services because they are not familiar with the industry and clients.

5.2.2 Barrier Evaluation

Since the evaluation barriers is not the primary goal of the first data collection round, the previously known barriers were not tested in a structured manner. But although the researcher did not refer to the known barriers, interviewees did mention some spontaneously. The following previously known barriers were mentioned during the industry expert interviews.

1. Fragmented industry structure

Industry experts did not explicitly confirm the fragmented industry structure as a barrier. One industry expert mentioned that engineers are reluctant to share BIM models with other organizations. P6 states: “Actors in the building services and construction industry don’t easily share data and models because of the conservative exchange culture”. Since data sharing is a form of interorganizational cooperation, resistance to share can be related to the fragmented industry

structure. This relationship is explained in section 4.4.

2. Information transparency

One industry expert mentioned that wholesalers fear price transparency on an e-marketplace. Price transparency is a form of information transparency and is defined as: the degree to which market participants know the prevailing prices of goods or services on offer (Soh, Markus, & Goh, 2006). P3 thinks wholesale will never participate on an e-marketplace. Six participants believe that wholesalers implement defensive strategies to block the development of e-marketplaces. This fear of price transparency aligns with prior literature. According to Soh et al. (2006), e-marketplaces are widely assumed to increase price transparency and decrease prices. Especially suppliers with a high-cost strategy are expected to lose margin on an e-marketplace.

3. Interoperability

One industry experts confirmed a lack of data standards and BIM file compatibility in the construction industry. P6 stated: "developing one standard for data exchange is hard if not impossible. IFC has most potential to become the BIM standard but still there exist a lot of sub standards for niche markets and in different countries". Note that P6 refers to the data standards for the whole construction industry and does not mention interoperability issues within the building services industry.

4. Internal business processes

Three industry experts confirm that the internal role distribution of engineers is not compatible. Traditionally engineering companies separate the designer-, calculator- and buyer role. Often these roles are even separated between different departments. The design departments design a building services system based on the scope of work and develop a BIM model. The calculator develops a BOM based on the design and BIM model. Finally, the buying department negotiates with suppliers and arranges contracts. A BIM-based e-marketplace combines all these activities on one screen. According to two industry experts these roles are slowly merging. Besides the role of barrier 4 on engineers, four interviewees mention that logistic processes of manufacturers are not ready. This also relates to the emergent barrier 13.

5. Human resources

One interviewee confirmed the problem of human resources. P6 states: "Another barrier is that engineering companies expect that knowledge and skills of BIM is concentrated to a few engineers. These skilled people are very rare on the job market". This barrier relates to barrier 4 because a BIM-based e-marketplace concentrates design-, calculation- and buying activities and skills in one BIM designer.

6. Technological investment costs

Industry expert P2 confirmed the obstructing role of technological investments costs on the adoption intention of manufacturers. On the other hand, P4 and P5 deny that costs are a significant barrier for manufacturers. They state: "The costs for manufacturers are not a problem, a free platform would have a negative low-quality image".

9. Resistance to change

Four out of seven industry experts confirm the conservative culture. This resistance to change reflects in the adoption of innovations and in the procurement choices of engineers. For example, P6 states: "Business processes are hard to change and jobs of for example calculators and buyers are protected". P3 states: "Most engineers only use brands and components they feel familiar and comfortable with and their choices are based on trust and habit". Industry experts also indicate the emotional connection of engineers with wholesale companies. P4 believes this conservative culture can

change quickly due to the BIM adoption. BIM will put new people in charge that force cultural change.

5.3 Conclusion

The industry expert interviews elicited four emergent barriers and evaluated seven previously known barriers. Table 13 gives an overview of the list of barriers after the first data collection round. The fourth column gives the affected market stakeholders based on the following abbreviations: E = engineer, M = manufacturer and W = wholesale. The 13 barriers will be tested in the third data collection round, stakeholder interviews. But first the next chapter will report the second data collection round that will elicit more emergent barriers.

Table 13 Industry expert interview results

Barrier	Description	Confirmation	Affected market stakeholders
1	Fragmented industry structure	+	E
2	Information transparency	+	W
3	Lack of interoperability	+	E, M, W
4	Internal business processes	+	E, M
5	Human resources	+	E
6	Technological investment costs	0	M
7	Lack of legal framework	0	-
8	Lack of technology trust	0	-
9	Resistance to change	+	E, M, W
10	Traditional construction delivery method	n.a.	M, W
11	Negotiation culture	n.a.	W
12	Lack of awareness	n.a.	M, W
13	Logistic services wholesale	n.a.	M

6 INDUSTRY EXPERT FOCUS GROUP

The literature review and industry expert interviews developed a list of 13 hypothetical and emergent adoption barriers. This chapter will report the second data collection round. As described in the research design at section 2.3, the second data collection round involves a focus group. This focus group aims to elicit more emergent adoption barriers. The results will be tested in the third data collection round.

This chapter is structured as follows. Section 6.1 reports the applied sampling method, agenda and coding method for the focus group. Section 6.2 presents the results by defining emergent barriers and evaluating previously known barriers. Section 6.3 concludes upon the findings of the focus group. A detailed report of the focus group can be found in section B.

6.1 Methodology

Section 2.3 proposed and substantiated a suitable method for this second data collection round. This section will report the implementation of this method and the choices that were made. Subsection 6.1.1 reports the sampling procedure, subsection 6.1.2 gives the agenda for the focus group, subsection 6.1.3 described how the focus group was evaluated and finally subsection 6.1.4 describes the implementation of the data analysis method.

6.1.1 Sampling

As described in section 2.3, the sampling procedure for the focus group should select the same elements as for the first round, but also invite innovative thinkers that are familiar with the building services industry. After the agendas of the selected elements were compared, the focus group was planned on 22 September 2017 and six participants were invited. P4 declined the invitation because of an interfering appointment. This non-response is not expected to bias the results because P4 has similar expertise compared to P5. Table 14 shows the participants of focus group. According to the results of the preparation questionnaire, three out of five participants have between 23 and 30 years of experience with the building services industry and construction industry. Two participants have less than 1 year of experience in both industries. In general, the participants have a positive expectation of the focus group.

Table 14 Focus group sample

Participant code	Function	Experience (years)
P2	Business process manager	23
P3	Senior account manager	30
P5	Software architect	25
P8	Senior product manager	1
P9	Sales manager	1

6.1.2 Focus Group Agenda

The session is held at a conference room at Stabiplan and only uses a whiteboard to stimulate discussion and interaction. Since the availability of colleagues at Stabiplan was limited, a focus group of 90 minutes is organized. Table 15 gives the timed agenda of the BIM-based e-marketplace focus group. Note that the agenda contains elements of marketplace design that fall outside of the scope of this research. These elements are crossed out in the table and will not be discussed in this report. The preface of this research report explains how the scope of this research changed during the project.

In the introduction, the participants are welcomed first. The introduction is supported with a PowerPoint presentation

(appendix B.2). The researcher collects the filled in preparation questionnaires. The researcher explains the intention of the research as a whole, and the role of the focus group in this project. The researcher emphasizes that this focus group is audio and video recorded but these recordings stay with the researcher inside Stabiplan. Only the coded results are used in the research project. Second the concept of a BIM-based e-marketplace is explained using the functional generic model of Figure 5. The researcher explains that the focus group is not about practical design choices like software packages, but more about the fundamental adoption problems and design aspects. Questions and discussion about the practical implementation will reduce the efficiency of the focus group. Third the initial barriers for adoption are reviewed. Explain how these barriers are identified and how stakeholders are affected. Then to make the participants aware of the design possibilities, the researcher proposes the two design examples from Figure 6 and Figure 7.

Table 15 Focus group agenda

Phase	Step	Description	Material	Time est.
Preparation (2 weeks)	1 Invitation	Invite participants to the workshop and prepare them for the	Invitation (appendix B.1)	2 weeks upfront
	2 Questionnaire	Questionnaires to the initiator and participants of the workshop	Preparation questionnaire (appendix B.1)	1 week upfront
Introduction (10 min)	1 Welcome	Welcome and introduction to the structure of this workshop	Introduction presentation (appendix B.2)	1 min
	2 BIM Marketplace	Recap the concept of a BIM Marketplace and platform theory.	Figure 5	3 min
	3 Introduce the adoption barriers	Summarize the adoption barriers that resulted from literature and interviews.		3 min
	4 Introduce to platform design	Briefly introduce the role of platform design (generic to specific), and how they may solve the adoption barriers.	Scheme with design parameters	3 min
Platform Design (75 min)	1 Generic> Specific	Introduce and discuss the different practical approaches of a BIM Marketplace. Discuss additional options.	Figure 6 Figure 7	15 min
	2 Modularity	Discuss modularity with regards to suppliers and barrier 13	Modularity trade-off diagram	10 min
		Discuss modularity-in-use from the engineer perspective. Introduce the idea of an RFx or configurator model	Modularity trade-off diagram	10 min
	3 Platform control	Discuss gatekeeping with regards to barrier 8 and 13	Control diagram	10 min
		Discuss process control with regards to barrier 8	Control diagram	10 min
	4 Pricing	Discuss platform pricing strategy with regards to barriers 3, 7, 8 and 15	Decision diagram platform pricing	10 min
	5 Complementary services	Discuss complementary services with regards to barriers 3, 4, 6 and 15	Overview of complementary services	10 min
Conclusion (5 min)	1 Recap barriers	Recap to the barriers for adoption	Scheme with adoption barriers	2 min
	2 Align barriers with the design	Which barrier could be solved with which parameter	Scheme with adoption barriers and design parameters	2 min
	3 Conclusion	Conclude upon the results		1 min
Evaluation (1 week)	1 Questionnaire	A questionnaire is used to evaluate the workshop	Evaluation questionnaire (appendix B.3)	1 week after

6.1.3 Evaluation

To evaluate the focus group method a questionnaire is distributed right after the focus group. The questionnaire is completed by four out of five participants. The questionnaire and results are given in appendix B.3.
All participants think the focus group was useful and efficiently organized. All participants mention that not every participant had an equal contribution to the discussion. This aligns with the results because participant P3 had a dominant contribution. Every participant felt that he had the chance to participate in the discussion. Three participants mentioned that a better preparation could have increased the output of the focus group. Three participants mentioned that due to timing problems, the last discussion points received less attention.
The researcher noticed that the focus group was less effective than expected. Little interaction took place and participants generally expressed their individual thoughts. Participants often agreed and little discussion took place. Most of the discussion time was spent on design aspects that are outside of the scope of this research. Section 8.4 will reflect on the limitations of the focus group.

6.1.4 Data Analysis

First the audio file of the focus group is transcribed. Since the responses of every participant on a certain subject are important to determine the 'group opinion', the recordings are transcripted word by word. The focus group resulted in 15 pages of transcript data that needs to be reduced and organized. The transcripts are coded in the program Atlas.ti using 13 codes based on the 13 previously known adoption barriers. During the coding process, three new barriers were identified, and three corresponding emergent codes were assigned. After coding, the data reduced to 33 quotations. Appendix B.4 shows screenshots of the coding process. The 33 quotations are analyzed to elicit emergent barriers and confirm previously known barriers. During the focus group, participants often responded on statements of other participants verbally or non-verbally. The analysis will focus on whether participants agree or disagree. Using Table 12, a degree of confirmation is determined per barrier.

6.2 Results

After coding the unstructured data from the focus group, this section will present the results. Subsection 6.2.1 will first describe the emergent barriers that were elicited. Than subsection 6.2.2 will evaluate the previously known barriers that were mentioned spontaneously during the focus group.

6.2.1 Emergent Barriers

The following two emergent barriers were mentioned during the focus group.

14. Relational oriented market

The relationship between engineer and supplier became a topic of discussion during the focus group. Participant P5 explicitly mentioned that engineers procure based on long term relationships and corresponding agreements. Het states: "An open marketplace will completely change the relationship and arrangements of an engineer with his supplier". This implies that engineers are more relational oriented than transactional oriented buyers. Relational orientation of buyers have been an extensive subject of study. Benamour and Prim-Allaz (1999) define relational oriented buyers as long-term affective oriented buyers. Transactional oriented buyers have a more short-term and function-oriented focus.
A relational oriented market can increase the entry barriers for new suppliers (Fahri, 2002). This contrast with e-marketplace that lower the barriers for suppliers to enter new markets (P. C. Evans & Gawer, 2016). Since the latter is generally recognized as an advantage of e-marketplaces, relational oriented buyers decrease the added value of an e-marketplace for suppliers. The relational oriented procurement culture is also expected to obstruct adoption intention of

engineers because engineers will only enter after their preferred supplier entered the marketplace.

15. Consultancy services wholesale

As mentioned by industry experts in subsection 5.2.1, wholesalers try to block direct manufacturer-engineer transactions by providing extensive logistic services. The results of the focus group show that wholesale also use consultancy services to protect their market position. This barrier came to light when discussing complementary services that could be integrated in the platform. P3 stated: “You could undermine the position of wholesale by providing consultancy as a complementary service on the marketplace”. Wholesale provides consultancy services to the engineer on system design with different manufacturers. Barrier 15 obstructs the adoption of manufacturers similarly to barrier 13. Manufacturers are not able to compete with the consultancy services of wholesale. Manufacturers should heavily invest in consultancy practices before direct manufacturer-engineer transactions can be conducted.

6.2.2 Barrier Evaluation

Since the evaluation of barriers is not the primary goal of the second data collection round, the focus group agenda does not contain a barrier testing element. But nevertheless, some previously known barriers were spontaneously mentioned by the focus group participants. The following five previously known barriers were confirmed.

2. Information transparency

The role of information transparency received a lot of attention during the focus group session. Three different aspects of information transparency were mentioned. First product transparency might allow foreign manufacturers to compete with established brands. When product information becomes transparent, new manufacturers can e.g. develop cheaper alternative to expensive brands. Besides, when project and customer information become transparent, new manufacturers can actively promote alternatives. This product transparency can form a competitive threat for established manufacturer and therefore form an adoption barrier.

The second aspect of information transparency is price transparency that puts pressure on the margins of wholesale. All participants agreed that wholesale fear price transparency on an e-marketplace. P3 stated: “The only party that will profit from marketplace transparency is the client.”

The focus group also elicited a third aspect of information transparency that was not recognized in the first data collection round. The results suggest that BIM Model transparency obstructs the marketplace adoption intention of engineers. BIM Model transparency is defined as the degree of visibility and accessibility of BIM Models in the supply chain. Results indicate that on an open BIM-based e-marketplace, engineers are reluctant to share a BIM model or BOM because of transparency. Engineer are part of the supply chain and capture some margin on components. When the BIM model is transparent to the contractor or client, engineers fear to be bypassed or lose margin. Especially participant P3 emphasized the barrier of BIM model transparency. P3 states: “Engineers sell a project for a fixed price to the client or contractor. Using sharp procurement, he tries to increase his margins. These margins will reduce when the BIM model becomes transparent”. On the other hand, engineers also fear that on a transparent marketplace, other parties will influence their choices. P3 states: “If an engineer has the slightest suspicion that someone influences his choices in design, he will distrust the marketplace”. Some participants agree with P3, nobody denies.

3. Interoperability

P3 confirms the problem of interoperability. He states that different actors in a building process can use different software solutions. Barrier 3 was no prominent topic during the focus group.

4. Internal business processes

P2 confirmed that engineers use ERP order systems that are not compatible with a BIM-based e-marketplace. He

suggested that this forms a barrier for adoption of engineers. Besides one industry expert mentioned that the consultancy processes might be underdeveloped to compete with wholesale. This relates to the emergent barrier 15. Barrier 4 received little attention during the focus group.

9. Resistance to Change

P4 mentioned the role of resistance to change in supplier choice. P5 states: "Many engineers always work with the same manufacturers and wholesalers because they have good arrangement." This statement also shows that barrier 9 relates to barrier 14. Resistance to change seems to be common sense among the participants.

11. Negotiation culture

Two participants confirmed the role of the negotiation culture. P2 states: "Engineers prefer to buy high volumes at one supplier because of volume discount". All participants agreed that negotiation decreases price transparency and there was little discussion

13. Logistic services wholesale

Three quotations of two participants confirm the high logistic added value of wholesale. Wholesale can achieve fast delivery because they have their own logistic network. P2 stated: "Wholesalers are everywhere, same-day delivery because they have so many warehouses". P3 is convinced that external logistic service providers are not able to organize logistics in the construction industry. P3 states: "Wholesale truck drivers know the logistic processes on a building site".

6.3 Conclusion

The focus group elicited two emergent barriers and evaluated six previously known barriers. The focus group results confirm only one barrier that was not confirmed in the previous round. Table 16 gives an overview of the results of the focus group. The third column gives the extent of confirmation per barrier in the first data collection round. The fourth column gives the extent of confirmation per barrier in the second data collection round. The fifth column gives the affected market stakeholders based on the first two round. The new list of 15 barriers will be tested and extended in the next data collection round, stakeholder interviews.

Table 16 Focus group results

Barrier	Description	Confirmation Round 1	Confirmation Round 2	Affected market stakeholders
1	Fragmented industry structure	+	0	E
2	Information transparency	+	++	E, W
3	Lack of interoperability	+	+	E, M, W
4	Internal business processes	+	+	E, M
5	Human resources	+	0	E
6	Technological investment costs	0	0	M
7	Lack of legal framework	0	0	-
8	Lack of technology trust	0	0	-
9	Resistance to change	+	+	E, M, W
10	Traditional construction delivery method	n.a.	0	M, W
11	Negotiation culture	n.a.	++	E, W
12	Lack of awareness	n.a.	0	M, W
13	Logistic services wholesale	n.a.	++	M
14	Relational oriented market	n.a.	n.a.	M, W
15	Consultancy services wholesale	n.a.	n.a.	M

7 STAKEHOLDER INTERVIEWS

The previous sections developed a list of 15 hypothetical and emergent adoption barriers of a BIM-based e-marketplace. This chapter will describe the third and final data collection round that involves stakeholder interviews. This round aims to test the hypothetical and emergent adoption barriers, explain why these barriers exist, and explain how they obstruct the adoption of a BIM-based e-marketplace.

This chapter is structured as follows. First section 7.1 will report the applied methodology of the interviews. Section 7.2 presents the results by evaluating previously known barriers and eliciting emergent barriers. The results are also used to explain why these barriers exist and how they obstruct adoption. Section 7.3 concludes upon the findings of the stakeholder interviews. A detailed report of the focus group can be found in appendix C.

7.1 Methodology

Section 2.3 proposed and substantiated a suitable method for this third data collection round. This section will report the implementation of this method and the choices that were made. Subsection 7.1.1 reports the sampling procedure, subsection 7.1.2 gives the interview protocol, and finally subsection 7.1.3 describes the implementation of the data analysis method.

7.1.1 Sampling

As substantiated in section 2.3, the sample of market stakeholders will be taken from the network of Stabiplan. All the participants have a relationship with Stabiplan and use their products. Based on supply chain position and discipline of market stakeholders, random stratified sampling is conducted within the customer based of Stabiplan. The researcher asked several colleagues of Stabiplan to submit a list of two companies per stratum. The sampling procedure listed 16 companies and contact persons. All contact persons were invited using the invitation (appendix B.1) and called to increase response rates. 12 Of the 16 contact persons agreed to participate and made an appointment. One contact person refused to participate because of a busy agenda, and three participants did not respond and could not be reached. Table 17 gives an overview of the sample that is interviewed. Some participants agreed to be mentioned by the company name. The report will refer to participants with an M (manufacturer), E (engineer) or W (wholesaler) code that is given in the second column. The third column gives the company size based on the definition of the European Union (EUR-lex, 2003).

Table 17 Sample for stakeholder interviews

Company name	Company code	Company Size	Supply chain position (stratum 1)	Discipline (stratum 2)	Function of interviewee(s)
Anonymous	M1	Large	Manufacturer	Electrical	(1) Product specialist, BIM specialist (2) Project manager e-business
Spelsberg B.V.	M2	Large	Manufacturer	Electrical	Managing director
Mitsubishi Electric	M3	Large	Manufacturer	Mechanical	Technical sales manager, BIM manager
SANHA GmbH & Co. KG	M4	Large	Manufacturer	Plumbing	Product manager
Mark Climate Technology	M5	Medium	Manufacturer	Mechanical	Managing director
Anonymous	E1	Large	Engineer	Mechanical	Manager Information Management & ICT
Anonymous	E2	Medium	Engineer	Mechanical	(1) Technical planner (2) Project manager
Megens Installaties	E3	Medium	Engineer	Plumbing	Technical director
Anonymous	E4	Small	Engineer	Electrical	Technical planner
Rexel The Netherlands	W1	Large	Wholesale	Electrical	Manager Product Data & Management
ERIKS B.V.	W2	Large	Wholesale	Plumbing	Business development manager
Ubel	W3	Medium	Wholesale	Mechanical	Business manager

7.1.2 Interview Protocol

The stakeholders were interviewed using a standard interview protocol. As explained in section 2.3, the interviews are semi-structured. That means the interview is structured with a list of questions, but the researcher can deviate from the standard interview protocol when he feels necessary. Also, the order of questions can be changed due to input from the interviewee. Since interview time with managers was limited, and not every barrier affects every market stakeholder, three different interview protocols were developed. Based on Table 16, this section explains what barriers are tested in which of the three interview protocols. The interview protocol for manufacturers is given in appendix C.2.

1. Fragmented industry structure

The industry expert interviews in the first data collection round, mentioned a lack of interorganizational cooperation and a reluctance to share BIM models among engineers. Section 4.4 relates this lack of cooperation to the fragmented industry structure. To test the lack of interorganizational cooperation, the engineers are asked how BIM models are shared with other engineers or main contractors.

2. Information transparency

The industry expert interviews and focus group showed three different aspects of information transparency. First information transparency can form a thread for manufacturers. This aspect is tested by discussing the status quo in product transparency (appendix C.2: question 7). Second price transparency can obstruct wholesalers from adopting e-marketplaces. This aspect is tested in the interview protocol for wholesale by measuring the status quo in price transparency. The third aspect is BIM model transparency that obstructs adoption of engineers. This aspect will be measured in the engineer interviews with questions related to how engineers share BIM models in the supply chain.

3. Lack of interoperability

The first two data collection rounds only discussed interoperability related to BIM software and BIM content. Related

work discussed in section 4.4 showed that standards related to commercial information representation also play a role in e-commerce. Since manufacturers and engineers develop and use BIM content, questions that measure interoperability of BIM data are included in the manufacturer and engineer interview protocols (appendix C.2: question 5). Since wholesalers are more experienced with e-commerce, questions that measure interoperability of non-BIM data commercial information representation are included in the wholesale interview protocol.

4. Internal business processes

Industry experts mention that the internal role distribution and procurement systems of engineers might not be ready to adopt an e-marketplace. To measure barrier 4 the interview protocol for engineers contains questions about the internal role distribution and the procurement processes. Besides industry experts also mention that the internal business processes of manufacturers might not be ready to conduct direct manufacturer-engineer transactions. Therefore, the interview protocol for manufacturers contains questions that measure the readiness of logistic, sales and consultancy processes of manufacturers to conduct direct manufacturer-engineer transactions (appendix C.2: question 1, 2, 3, 6, 17).

5. Human resources

The lack of human resources received little attention from industry experts. Only in the first data collection round the lack of skilled BIM designers is mentioned. To measure barrier 5, the engineer interview protocol tests if engineers lack skilled BIM designers. Besides, the industry expert interviews show that manufacturers hardly conduct direct manufacturer-engineer transactions. This could be an indication that manufacturers lack salespersons that can target engineers. To measure how barrier 5 affects manufacturers the manufacturer interview protocol asks how the manufacturer influences sales to the engineer (appendix C.2: question 3).

6. Technological investment costs

The industry experts did not agree about the role of technological investment costs but suggest that manufacturers might perceive high costs of developing BIM content. Barrier 6 is only included in the manufacturer interview protocol. Barrier 6 is measured by asking what factors influence the decision to develop BIM content (appendix C.2: question 4, 13).

7. Lack of legal framework

Industry experts did not mention legal issues as an adoption barrier. Due to limited interview time, barrier 7 receives less priority and is not included in the interview protocols. If barrier 7 turns out to be important, stakeholders are assumed to mention it during the unstructured parts of the interview. The coding process will use a code that corresponds to barrier 7.

8. Lack of technology trust

Industry experts did not mention technology trust as an adoption barrier. Due to limited interview time, barrier 8 receives less priority and is not included in the interview protocols. If barrier 8 turns out to be important, stakeholders are assumed to mention it during the unstructured parts of the interview. The coding process will use a code that corresponds to barrier 8.

9. Resistance to change

Although industry experts confirm resistance to change among all market stakeholders, barrier 9 is not actively tested during the interviews. This choice is made because questions about resistance to change are expected to be biased by self-interest. Market stakeholders are not expected to admit a conservative culture because their innovative reputation is important these days. It is assumed that if resistance to change plays an important role, it will appear from quotes

during the discussion. Questions like: “What procurement processes do you use and how do they change?” are assumed to unearth conservative motivations.

10. Traditional construction delivery method

The traditional construction delivery method and in particular the role of the scope of work, emerged as a barrier in the first round but was not confirmed in the second round. To test the influence of barrier 10, the interview protocol for engineers contain questions that measure the role of the scope of work and how it influences their decision power.

11. Negotiation culture

Barrier 11 emerged in the first data collection round and was confirmed in the second. Industry experts mention that negotiation and individual price agreements are a common practice between wholesalers and engineers. Therefore, the interview protocols for engineers and wholesale contain questions that discuss negotiation and how it influences price transparency.

12. Lack of awareness

The lack of awareness related to the added value of a BIM-based e-marketplace is only mentioned in the first data collection round. Industry experts mention barrier 12 in relation to awareness of the data opportunity by manufacturers. Therefore, questions that measure the awareness of the data opportunity are added to the manufacturer interview protocol (appendix C.2: question 18).

13. Logistic services wholesale

The obstructing role of wholesale is strongly emphasized by industry experts. Engineers depend on the logistic services of wholesale and manufacturers are not able to compete. The interview protocol of engineers contain questions that measure the dependence of engineers on wholesale logistics. The interview protocol of wholesale contains questions that measure how developed these logistic services. The manufacturer interview protocol contains questions that measure if manufacturers are able to compete with these logistic services (appendix C.2: question 6, 17). Besides, all market stakeholders are asked their opinion on third party logistic services (appendix C.2: question 16).

14. Relational oriented market

The barrier of relational oriented procurement is elicited during the focus group. The stakeholder interview should test if engineers are relational buyers and whether they are more emotionally connected to manufacturers or wholesale. Therefore, the engineer interview protocol contains questions that discussed the relationship of engineers with suppliers. Barrier 14 is also measured from the perspective of supplier by including questions about buyer supplier relationships in the manufacturer and wholesaler interview protocols (appendix C.2: question 7).

15. Consultancy services wholesale

The focus group recognized a barrier in the consultancy services delivered by wholesale. Engineers depend on the consultancy services of wholesale and manufacturers are not able to compete. Barrier 15 is measured by asking engineers who they contact in case of technical advice. Barrier 15 cannot be tested in the supplier interviews because the answers will be biased by self-interest. It can be assumed that manufacturers and wholesalers are inclined to overrate their consultancy capacity.

Table 18 shows the barriers that are testes in the three different protocols.

Table 18 Stakeholder interviews, barrier testing distribution

Barrier	Description	Engineer protocol	Manufacturer protocol	Wholesale protocol
1	Fragmented industry structure	x		
2	Information transparency	x	x	x
3	Lack of interoperability	x	x	x
4	Internal business processes	x	x	
5	Human resources	x	x	
6	Technological investment costs		x	x
7	Lack of legal framework			
8	Lack of technology trust			
9	Resistance to change			
10	Traditional construction delivery method	x		
11	Negotiation culture	x		x
12	Lack of awareness		x	x
13	Logistic services wholesale		x	
14	Relational oriented market	x	x	x
15	Consultancy services wholesale	x		

7.1.3 Data Analysis

After the twelve interviews were recorded, the spoken text is transcribed. To limit the amount of data, the interviews were not transcribed word by word. The transcript should contain every opinion or statement and every important quote. This process resulted in transcripts of 3 to 5 pages per interview. Using the program Atlas.ti all the transcripts were coded in relation to the barriers. The coding process started with 15 codes related to the 15 barriers developed in the first and second data collection round. Three emergent codes were defined based on three barriers that emerged during the coding process. Screenshots of the coding process in Atlas.ti are given in appendix C.3.

After the coding process, all relevant quotes were categorized per barrier. During analysis, many barriers turned out to consist of multiple independent aspects that affect different stakeholders. To determine the origin of barriers, and to explain how these barriers obstruct adoption, these different aspects need to be analyzed independently. For example, barrier 5, the lack of human resources, can be split up in two aspects. First manufacturers lack skilled sales people. And second engineers lack skilled BIM engineers. Both aspects need to be analyzed to determine the origin of barrier 5 and to determine how barrier 5 obstructs adoption. To separate these different aspects, a second coding round is conducted in Excel. Excel sheets were made that contain all the quotes per barrier. The data in every quotation is interpreted and reflected upon every aspect. An example of this coding procedure is given in appendix C.4. Using the results of the coding round and Table 12, a degree of confirmation is determined.

7.2 Results

After coding the unstructured interview data, this section will present the results. Subsection 7.2.1 will first describe the emergent barriers that were elicited. Than subsection 7.2.2 will evaluate the previously known barriers that were confirmed during stakeholder interviews, conclude upon the origin of those barriers, and explain how these barriers obstruct the adoption. The relationships between barriers and adoption are visualized in small causal diagrams. These causal diagrams combine the results of this research with literature findings of chapter 4, to give sufficient explanations for causal relationships. These explanations are used in the conclusion of this research to answer the research question. Coloring is used to separate confirmed and non-confirmed concepts and relationships. The green concepts and relationships are empirically confirmed in this research. The blue concepts and relationships are based on literature. The black/white relationships and concepts not supported by evidence but based on logic reasoning.

7.2.1 Emergent Barriers

This section presents the emergent barriers that were mentioned during the stakeholder interviews. Causal relationships are identified to explain why these emergent barriers exist, and how every barrier obstructs adoption. The analysis mentions different aspects which refer to the second level coding round.

16. Commercial services wholesale

Wholesale provide sales and marketing activities for manufacturers that generates turnover. This withholds manufacturers from developing a direct supply chain on a BIM-based e-marketplace. 4 out of 5 manufacturers mention that wholesale is able to generate turnover. No stakeholder denied the commercial added value of wholesale. For example, M5, that does not use wholesale states: “But we also notice that competitors that use wholesale can sell more individual products”. M4 recognizes a decline in generated turnover by wholesale. "In the early days, we only pointed our sales activities to wholesale but nowadays we need to follow up project leads and join the building process from the beginning." 2 out of 5 manufacturers also mention that wholesale provides marketing activities for their brand. M1 for example states: “Wholesale also offers us some marketing activities like promotions. Wholesale offers us a marketing channel to reach the engineer". Since sales processes are internal business processes of manufacturers, barrier 16 can be related to barrier 4. Since wholesale provides commercial services, the sales processes of manufacturers are underdeveloped. Figure 10 gives a causal diagram of barrier 16.

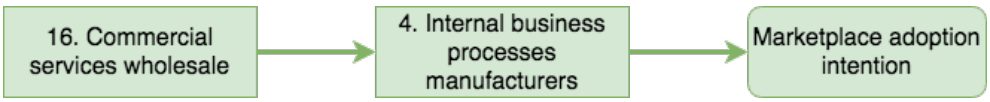

Figure 10 Causal diagram barrier 16

17. Technical limitations

A lack of BIM software intelligence slows down the BIM adoption and are expected to slow down the adoption of a BIM-based e-marketplace. 2 out of 12 stakeholders mention the obstructing barrier 17. This report will evaluate this as a barrier, but software intelligence can also be evaluated as an opportunity to take over the consulting role of wholesale. BIM software should be able to advise engineers on component choices within a certain system or warn the engineer for design errors. W3 states: "I think the intelligence is still missing in BIM models. Software is still not able to advise designers on component choices or detect mistakes. You should combine software like Vabi with BIM software to integrate technical knowledge in the model”. Engineer E3 takes a similar standpoint: " Also the software is not intelligent yet. BIM software should be able to suggest the right component for a specific system without manual choice of the designer. Or warn the designer if a component is not compatible or meets the specs of the system”. Barrier 17 is related to barrier 4, because due to the lack of software intelligence, engineers are not able to adopt BIM business processes. Barrier 17 can also be related to barrier 15 because the lack of software intelligence increases the consultancy added value of wholesale. This relationship is not measured in this research. Figure 11 shows how the lack of software intelligence influence the marketplace adoption of manufacturers and engineers.

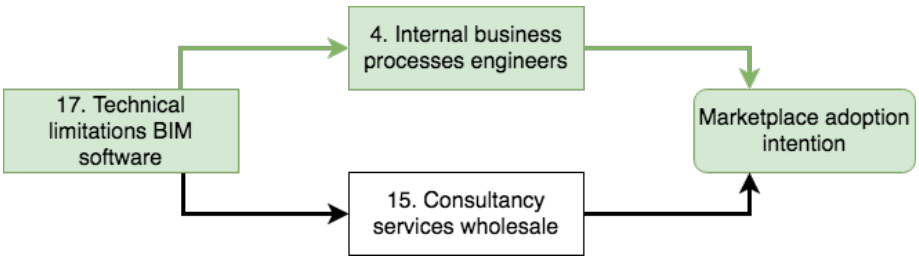

Figure 11 Causal diagram barrier 17

18. Financial services wholesale

Financial services provided by wholesale, inhibit manufacturers and engineers from doing direct transactions. Engineers expect long payoff terms and guarantee, and manufacturers expect to get payed immediately. 2 out of 5 manufacturers mention the financial added value of wholesale. Manufacturer M2 states: “One added value of wholesale is financial services. We don’t have anything to do with credit limits, payment terms etc.". Since financial services are internal business processes of manufacturers, barrier 18 can be related to barrier 4. When wholesale provides financial services, the financial processes of manufacturers are underdeveloped. The relationship between barrier 18 and the adoption intention is not measured. Figure 12 gives a causal diagram of barrier 18.

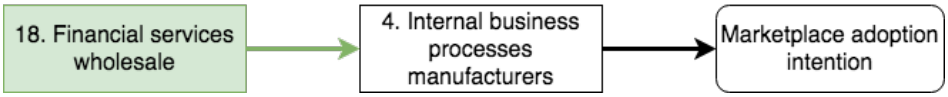

Figure 12 Causal diagram barrier 18

7.2.2 Barrier Evaluation

This section will evaluate previously known barriers and describe the different aspects that were recognized after second level coding. A deeper analysis will detect causal relationships to explain the origin of barriers. Finally, a causal diagram will show how the confirmed barriers are expected to affect marketplace adoption.

1. Fragmented industry structure

After the second level coding process, two aspects of barrier 1 were identified.

1.1 The fragmented industry structure causes a resistance to share BIM models among engineers.

4 Out of 12 stakeholders mention the resistance to share BIM models. E1 states: “A central BIM model in the cloud is not going to work because engineers try to protect their model and will not share is easily". Statements of engineers also prove that the reluctance to share business models is generally caused by the fear of model/BOM transparency described by barrier 2. A4 did not experience the reluctance to share BIM models within a building team cooperation. A building team is a form of construction delivery method that similarly to the design & build method (section 3.1.3), integrates the design and construction responsibilities in one entity.

1.2 The fragmented industry structure causes a lack of interorganizational cooperation. This hinders the BIM adoption and will form a barrier for the adoption of a BIM-based e-marketplace.

Two stakeholders mentioned the lack of interorganizational cooperation as key barriers to BIM adoption and expect it

will form a key barrier for the adoption of a BIM-based e-marketplace. W2 uses the European Union as an analogy for the fragmented culture within the industry: "Exactly like in the BIM model, all countries came together with a beautiful common goal. But because all the countries only think of themselves and don't want to pay for other problems, this union is slowly falling apart". E2 mentions that interorganizational cooperation is essential in the adoption of BIM. The data shows a causal relationship between interorganizational cooperation and barrier 3. Interorganizational cooperation reflects in the willingness of companies to comply to industry standards. E2 states: "One of the largest problems is that many different organizations try to develop a standard with their own brand". Literature discussed in section 4.4 also relates the fragmented industry to vertical information transparency (barrier 2), and to the lack of awareness (barrier 12). These relationships cannot be evaluated based on the data.

Figure 13 shows how a fragmented industry culture can affect BIM-based e-marketplace adoption.

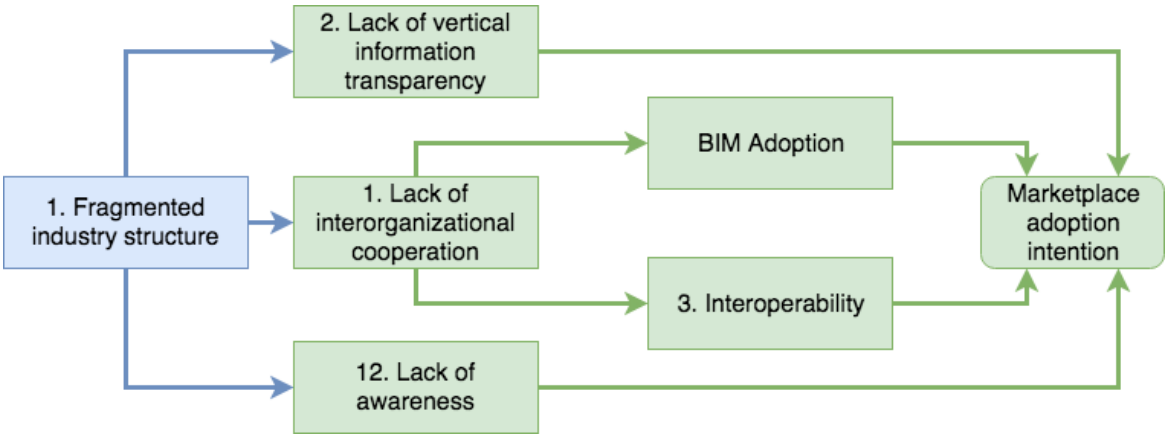

Figure 13 Causal diagram barrier 1

2. Information transparency

After the second level coding process, three aspects of barrier 2 were identified.

2.1 Information transparency reflects in increased product transparency. Wholesale companies are obstructed to adopt a BIM-based e-marketplace because product transparency increases.

2 out of 3 wholesale companies mentioned that product transparency does not form a barrier. W1 and W3 even promote transparency and view it as one of their added values. W1 states: "Since transparency and data standardization is important to W1, we only work with manufacturers that support the ETIM standard". According to 10 out of 12 stakeholders, product transparency in the building services industry is already high and an e-marketplace will not change this. Technologies like ERP and 2BA, and standards like Eurovent and EAN, created high transparency on product characteristics and gross prices. M5 states: "I feel the market is quite transparent. Due to classifications like Eurovent, the engineer can check the quality and capacity of our products and the competitor". E1 states: "Using an EAN number and 2BA we can exactly see were a component is cheapest".

2.2 Information transparency reflects in vertical price transparency. Manufacturers and wholesaler fear margin erosion because prices become transparent to engineers.

Vertical price transparency determines how easily engineers can compare prices different buyers pay for a certain product. According to all 4 participating engineers, price transparency is low. Price transparency is decreased because

all buyers negotiate individual price arrangements (barrier 11). For example, E4 states: “This BOM is manually checked and then manually emailed to some standard wholesale partners. They return a quotation and we choose the supplier based on price or other aspects”.
2 Out of 3 wholesale companies confirmed barrier 2 in relation to aspect 2.2. W2 and W3 fear that a completely open marketplace will result in transactional buying behavior. This decreases their added value. 3 Out of 4 engineers mention the negative attitude of wholesale towards transparency. No engineer denied this. Net price transparency are expected to decrease the margins and thus adoption intention of wholesale.
1 out of 5 manufacturers confirmed barrier 2 in relation to aspect 2.2. 4 out of 5 manufacturers deny barrier 2 in relation to aspect 2.2. M3 fears that a transparent marketplace will be a ‘race to the bottom’. The majority of M3’s transactions are relational and made to measure solutions. M3 states: “For us every product is different because every project is different. This also holds for pricing. We always make a price for specifically for certain project”. Other manufacturers mention that they are used to price transparency because wholesale offers products of different manufacturers side by side.

Literature shows a causal relationship between barrier 2 and barrier 1. A fragmented industry can decreases vertical information transparency because the supply chain is fragmented (Nawi et al., 2014). This causality is not confirmed by the results.

2.3 Information transparency reflects in BIM model transparency in the supply chain. Engineers fear margin erosion when BIM models and BOM’s become transparent to contractors and clients.
The BIM model transparency aspect of barrier 2, has been confirmed by all 4 engineers. All engineers fear to lose added value when BIM models and BOM’s become transparent to the contractor. For example, E1 states: “The risk for us is that the contractor himself will start to buy components and we lose the markup on the materials we use”. E2 also mentions that the ‘risk’ of direct supplier-contractor transaction is high when prefab methods are applied. E2 states: "Especially with prefab the concepts are very modular and the technical expertise of the engineer is not demanded anymore. In those cases, the role of the engineer reduces to an installer." Two engineers, E1 and E4, mention that direct supplier-contractor transactions are already happening. E4 states: "We already notice this trend in for example the acquisition of solar panels. Contractors want to buy the panels themselves to save the markup of the engineer."

Figure 14 gives a causal diagram that explains the origin of barrier two, and how it affects marketplace adoption.

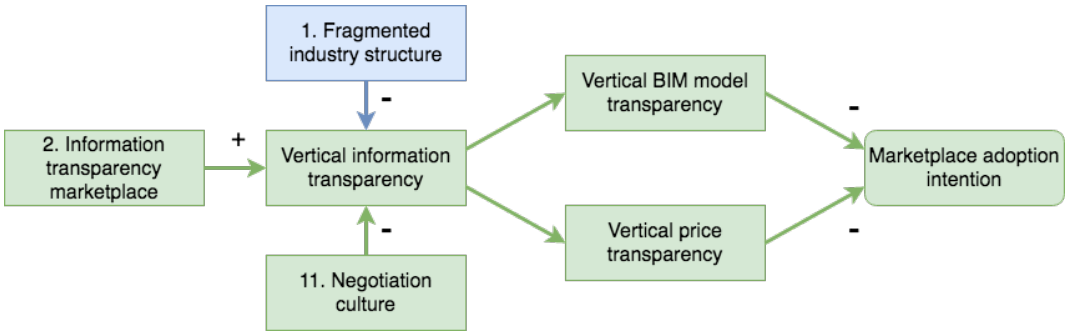

Figure 14 Causal diagram barrier 2

3. Lack of interoperability
After second level coding, three different aspects of barrier 3 were defined.

3.1 The industry faces a lack of horizontal interoperability, because there exist many different incompatible software platforms for BIM design, with different file types.

6 Out of 12 stakeholders confirmed barrier 3 in relation to software platforms. 2 stakeholders did not recognize the incompatibility of BIM models. E3 states: “Different BIM software solutions at different organizations can hardly communicate”. Other organizations specifically mention that interdisciplinary sharing of BIM models is hindered by the lack of compatible software. Incompatibility of BIM software slows down the adoption of BIM.

3.2 There exists a lack of vertical interoperability because there is no consensus or standard for the detail level and data representation of BIM content.

5 Out of 12 stakeholders confirmed barrier 3 in relation to BIM content. Especially E2 thinks barrier 3 is one of the dominant barriers in BIM adoption. E2 states: “But still there exists a large variety of opinions on BIM content so a standard will be a long way. First there need to be a common understanding of the level of detail and data contents of a BIM content family”.

3.3 There exists a lack of vertical interoperability because of the limited availability of high quality BIM content.

2 out of 4 engineers mention the low quality and limited availability of BIM content. According to engineers E2 and E3, content is often not correct, up-to-date, authorized, detailed, complete or not available at all. It costs much time to change or create content. Engineer E4 does not experience that problem: “we are experience enough to change content or add information to general content". Barrier 3 relates to barrier 6 because manufacturers need to invest to develop BIM content, and the perceived costs for engineers of developing BIM models increase with low quality content.

Literature discussed in section 4.4 relates barrier 3 causally to barrier 1. Stakeholder W2 mentions the relation between barriers 3 and 1. W2 states: "One of the largest problems is that many different organizations try to develop a standard with their own brand". This statement refers to a lack of interorganizational cooperation. Literature argues that interorganizational cooperation is hindered by the fragmented structure of the industry.

The influence of barrier 3 on the marketplace adoption intention is visualized in Figure 15.

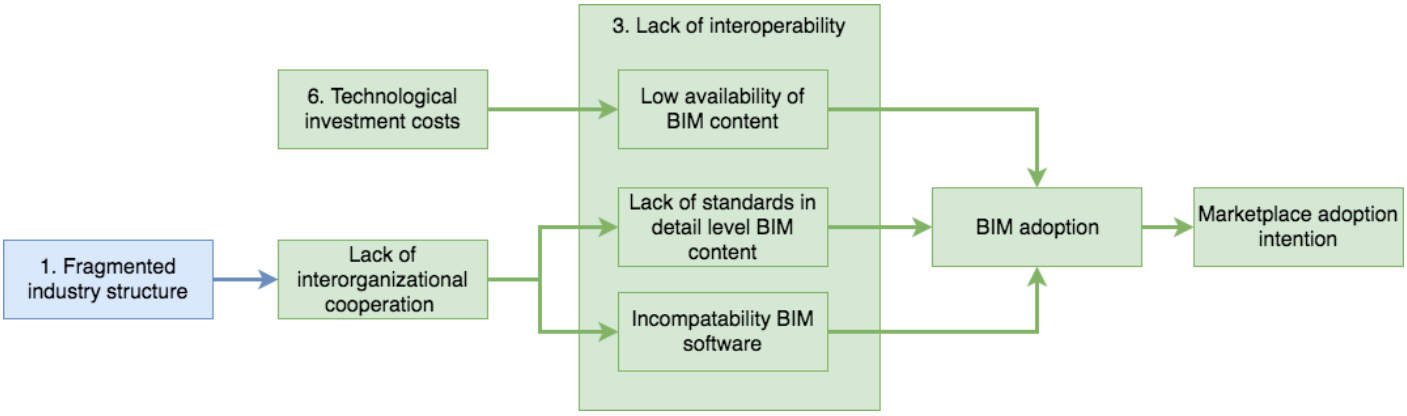

Figure 15 Causal diagram barrier 3

4. Internal business processes stakeholders

After second level coding, seven different aspects of barrier 4 can be identified. These aspects are based on the different business processes at stakeholders that need to be adjusted before participating on a BIM-based e-marketplace.

4.1. Engineers do not develop complete BIM models, so the BOM derived from a BIM model does not contain the complete order.

All 4 engineers confirmed barrier 4 in relation to complete business models. E2 states: “All components smaller than 5x5x5 cm are not modelled and those components form a large share of the value of an installation”. The completeness of models depends on the discipline and application. E1 states: “Especially in prefab the models as very complete”. E4, an electrical engineer, states: “Everything visible is modeled, but cabling are not modeled”. The reason aspect 4.1 exists seems to be costs. E2 states: “Let's say that currently we model 80% of components which costs us 100 manhours. To model that extra 20%, we need an extra 100 manhours". So, barrier 4 is causally related to barrier 6.

4.2. Engineers still use traditional order channels such as email and telephone. The step from traditional channels to a BIM-based e-marketplace, is larger than from ERP to a BIM-based e-marketplace.

All 4 engineers confirm barrier 4 in relation to traditional order channels. E1 states: “Off coarse ERP but also the traditional telephone is used and we visit wholesale themselves". E3 almost only uses ERP software to order against standard price agreements. But in case of large quantities they still call wholesale to make a price arrangement. Barrier 4 has been found to be causally related to barrier 11. Engineers negotiate on the price of a complete BOM and this can only be done using traditional procurement channels.

4.3. The calculation process at engineers is still partly manual. Engineers don’t completely calculate quantities from the BIM model.

All 4 engineers confirmed barrier 4 in relation to aspect 4.3. Some engineers perform completely manual calculations like E2: “Calculation is done by hand and the results are entered in ERP software”. Others use calculation functionalities of BIM software and manually complete the BOM. E4 states: “After the design is completed we extract a BOM of the model. This BOM is manually checked and completed”. Aspect 4.3 has been found to be causally related to aspect 4.1. Since BIM models are not complete, the BOM needs to be completed manually which involves manual calculation.

4.4. Manufacturers don’t have experience with direct manufacturer-engineer transactions.

3 Out of 5 manufacturers denied barrier 4 in relation to aspect 4.4. For 2 out of 5 manufacturers, M3 and M5, the majority of transactions are direct manufacturer-engineer transactions.

4.5. Manufacturers don’t have experience with direct delivery to the building site.

All 5 manufacturers denied barrier 4 in relation to aspect 4.5. For example, M2 states: “Sometimes wholesale provides the transport and sometimes we deliver straight to the building site. It depends on the size and nature of the project”.

4.6. Manufacturers don’t develop BIM content for all their products.

All 5 participating manufacturers develop BIM content for their products but not for their complete assortment. The development of BIM content depends on the BIM adoption in the specific reason. For example, M1 states: “We are developing content and applications for Revit, but the rest of M1 still lacks behind. A trend can be recognized that more and more manufacturers develop BIM content for their products. Aspect 4.6 relates to barrier 6 because manufacturers don’t develop BIM content partly because of the high perceived costs. Multiple stakeholders mention the ‘market pull’ effect of the development of BIM content. M1, an international large company states: “Those who don’t adopt BIM will get left behind. Manufacturers follow the wishes of their clients”.

4.7. The design, calculation and procurement activities at engineers are still separated.

3 out of 4 engineers confirmed barrier 4 in relation to the role distribution. For example, E2 states: “Our internal processes are organized using four departments: procurement, orders, calculation and design”. The separation of these activities means the BIM designer behind the screen do not have decision power on component or brand choice. This decreases

the added value of a BIM-based e-marketplace for suppliers because brand and component decisions are already made by the technical planner before the BIM-model is developed. The traditional role distribution is hard to change because of resistance to change among employees. E2 states: “We have a certain corporate structure and we are used to a certain business process. Many employees work here for 20 to 25 years and fear change. We shouldn’t change too much because that will decrease productivity”. Barrier 4 also relates to barrier 5, because without skilled BIM designers, engineers are not able to transform their business processes.

Barrier 4 affects the adoption intention of stakeholders via perceived costs. When internal business processes of engineers and manufacturers don’t match the requirements, this increases the perceived entry costs. This relationship, mediated by resistance to change, is given in Figure 16.

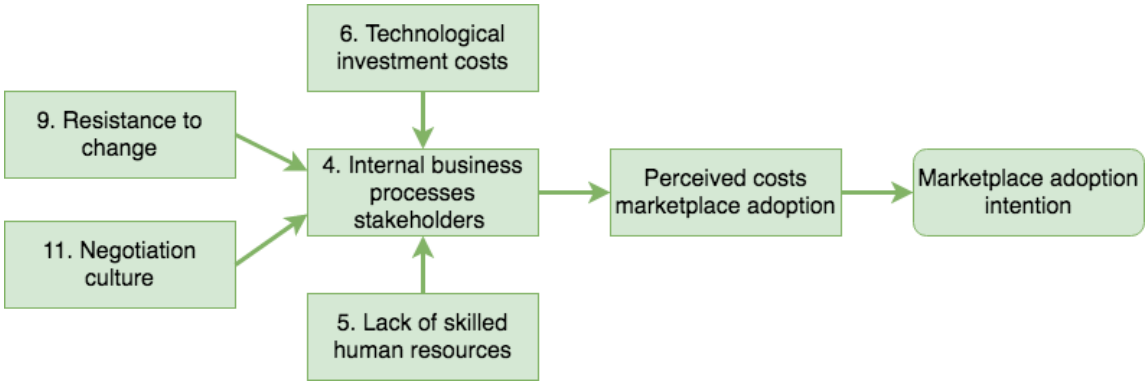

Figure 16 Causal diagram barrier 4

5. Lack of skilled human resources

After second level coding, two aspects of barrier 4 were defined.

5.1 Manufacturers do not have an experienced sales team to target the engineer on a BIM-based e-marketplace.

All 5 manufacturers denied barrier 5. For example, M4 states: “In the early days we only pointed our sales activities to wholesale but nowadays we need to follow up project leads and join the building process from the beginning”. One wholesaler, W2, stated that manufacturers often lack the sales capacity to target the engineer. "But manufacturers generally focus on their technical development instead of sales capacity. Therefore, manufacturers often lack the sales capacity to sell large quantities to engineers."

5.2. Engineers face a lack of skilled people to adopt BIM.

Barrier 5 is confirmed by 2 out of 4 engineers, no engineer denied. E3 states: “The most important part is that it doesn’t matter what people want, it’s what your employees are able to do”. E2 also mentioned that the supply of skilled people on the job market is currently small. Since engineers lack skilled BIM designers, they cannot change business processes (barrier 4) and are obstructed to adopt BIM.

The influence of barrier 5 on the marketplace adoption intention is visualized in Figure 17.

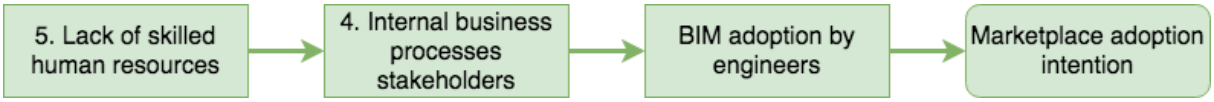

Figure 17 Causal diagram barrier 5

6. Technological investment costs

After second level coding, two different aspects of barrier 6 were defined.

6.1 Manufacturers perceive high costs in the development of BIM content for their products.

One manufacturer confirmed barrier 6, no manufacturer denied. Barrier 6 can be related to barrier 2. Since the technological investment costs are high, the availability of BIM content is limited. This relationship is not confirmed.

6.2 Engineers face high costs in developing complete BIM models.

One engineer confirms barrier 6. E2 perceive high costs in building complete BIM models. "The costs of completing the BIM model to the last component are very high.". Barrier 6 is related to barrier 3. Engineers perceive high cost of developing complete BIM models because of the limited availability of BIM content. E2 states: "The manufacturer is not willing to develop good BIM content and therefore we are not able to develop complete models." Barrier 6 has found to be causally related to barrier 4. Without available content, the costs of developing complete models are high, and engineers will be reluctant to develop complete models.

The influence of barrier 6 on the marketplace adoption intention is visualized in Figure 18.

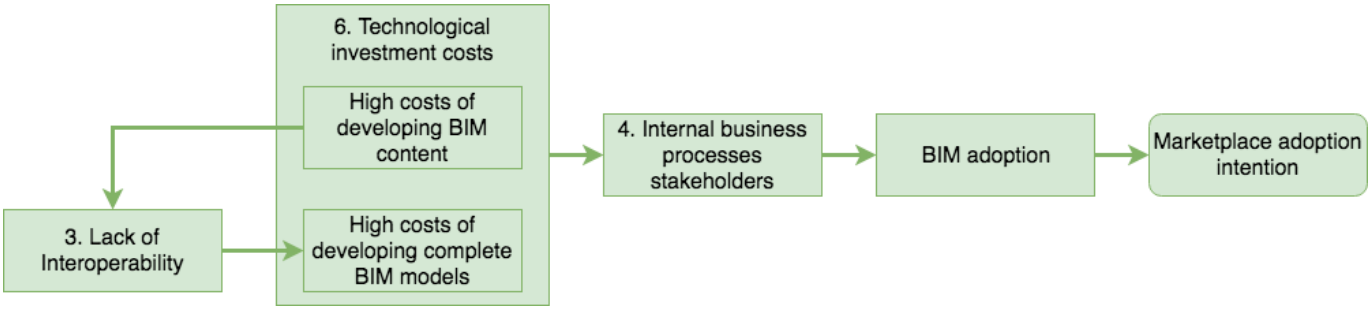

Figure 18 Causal diagram barrier 6

7. Lack of legal framework

Barrier 7 has been confirmed by 1 out of 12 stakeholders, nobody denied. E3 experiences a lack of legal support with regards to the division of responsibilities. E3 states: “We also experience a lack of a legal framework to support the sharing of BIM model. Who is responsible for the results of a BIM model?”. Since barrier 7 seems to have a minor obstructing role it will be omitted from the list of barriers in the conclusion.

8. Lack of technology trust

Barrier 8 is moderately confirmed by one stakeholder. M1 promotes the adoption of BIM among engineers but experiences resistance. “When a customer notices that the BIM content doesn’t look like the real product because of a low level of detail, he distrusts the model and the BIM methodology. There is little trust in developments like BIM.” No stakeholder mentioned that the industry is characterized by a lack of technology trust. Since barrier 8 seems to have a

minor obstructing role it will be omitted from the list of barriers in the conclusion.

9. Resistance to change

Barrier 9 is measured in two ways, stakeholders that made statements implying resistance to change, and stakeholders that mentioned to recognized resistance to change at other actors. 3 out of 8 non-engineer stakeholders mentioned the resistance to change at engineering organizations. For example, industry expert at M2 states: “Engineers try to hold on the old way for as long as possible". 3 out of 4 participating engineers made statements that indicate resistance to change. For example, E2 states: “We have a certain corporate structure and we are used to a certain business process. Many employees work here for 20 to 25 years and fear change. We shouldn’t change too much because that will decrease productivity”. One manufacturer, M1, made statements indicating resistance to change.

Barrier 9 affects the marketplace adoption intention in two ways. First barrier 9 has found to be related to barrier 13, 15, 16, and 18. Barrier 13, 15, 16 and 18 relate to the added value of wholesale. A statement of M1 indicates this relationship: “As long as wholesale achieves added value, nothing will change”. No stakeholders recognized resistance to change at manufacturers or wholesale as a barrier.

The second way barrier 9 affects marketplace adoption intention is via barrier 4. In case of resistance to change, the resistance depends on the amount of change. Barrier 4 reflects on the changes in internal business processes at stakeholders. Especially manufacturers and engineers are expected to experience major changes in their business processes. Barrier 9 is only confirmed for engineers. These relationship is visualized in Figure 19.

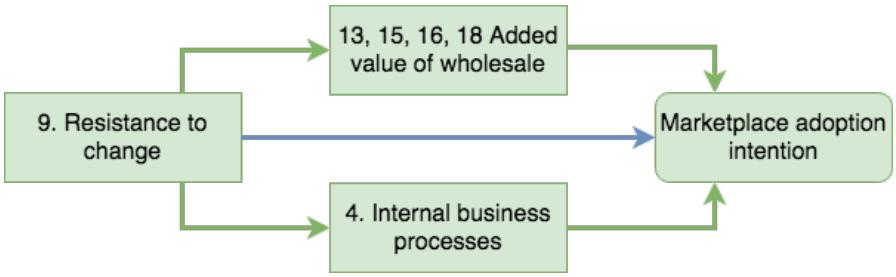

Figure 19 Causal diagram barrier 9

10. Traditional construction delivery method

5 Out of the 12 stakeholders confirm that the scope of work decreases decision power of the engineer. 1 stakeholder denied the role of the scope of work. In some cases, the scope of work strictly prescribes certain brand choices, and in other cases it suggests choices. For example, M1 states "Consulting engineers often contact me for technical specifications of M1 products. They write the scope of work and determine the freedom of choice for the engineer. Sometimes they strictly prescribe M1, sometimes they prescribe ‘M1 or equivalent’" One engineer, E4, does not work in the traditional building process but practices a building team cooperation. In a building team every subcontractor co-writes the scope of work and therefore experience full decision power in component and manufacturer choice. The interviews did not measure the influence of decision-making power of engineers, on the adoption intention. But since industry experts explicitly emphasized the obstructing role of barrier 10, and the influence on adoption intention is understandable, barrier 10 is retained as a barrier in the conclusion of this research.

Figure 20 gives a visual representation of the causal relationships between barrier 10 and marketplace adoption intention by stakeholders.

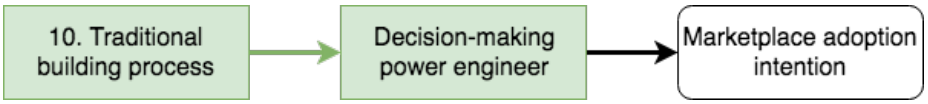

Figure 20 Causal diagram barrier 10

11. Negotiation culture

Barrier 11 is confirmed by 4 out of 4 participating engineers. Small orders are bought against a negotiated standard price reduction, and large orders are individually negotiated. Some engineers negotiate more, others less, but they never order against the standard market price. For example, E4 states: “Standard material like light switches are ordered against standard prices”, “But for larger orders individual price negotiations and price comparison is used to minimize prices”. Price negotiation can reduce vertical net price transparency in the market and increase the influence of barrier 2. Barrier 11 can also be related to barrier 4. Engineers that negotiate prices cannot automate their procurement processes. The relationship between barrier 11, 2 and 4 is not measured in this research. Therefore barrier 11 will be omitted as a barrier in the conclusion of this research. The conclusion will identify the negotiation culture as a potential cause for barrier 2 and 4. The relationship between barrier 11 and 4 is not measured. The causal relationship is given in Figure 21.

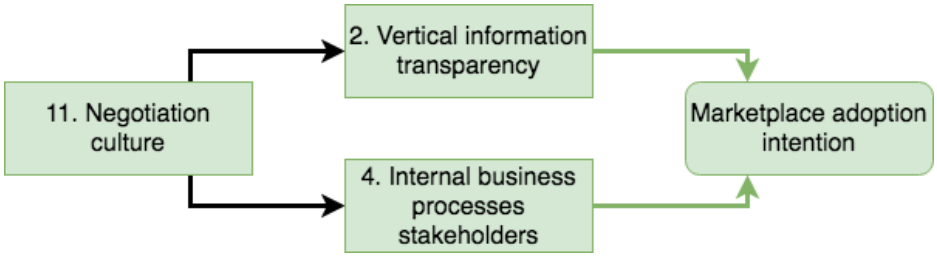

Figure 21 Causal diagram barrier 11

12. Lack of awareness

After second level coding, four different aspects of awareness can be recognized.

12.1 Manufacturers and wholesalers lack awareness of the added value of customer data

Barrier 12 has been denied by all of the 8 suppliers. All manufacturers (5 out of 5) are aware of the value of customer data and are able to utilize it. Manufacturers are all looking for quality leads and have experience with active sales techniques. Manufacturers all want to get involved in project as early as possible.

All wholesalers (3 out of 3) are aware of the value of customer data and are able to utilize it. Wholesalers are continuously looking for new projects leads and have experience with active sales techniques. The earlier wholesale is involved in a project, the higher their added value can be. W1 states: "W1 want to be involved in the building process from the earliest stage possible. We want to offer our logistic solutions and prices in an earlier stage of the cycle. We can anticipate on this demand by adapt our procurement activities to demand."

The following data is mentioned to be valuable: name engineering company, contact person engineering company, location/region engineer, contact information, project name, project size, project location and characteristics, system information, which content used and why, how do engineers make decisions and what aspects of our product influence that decision.

12.2 Manufacturers and wholesalers are not aware of the functionality of BIM and a BIM-based e-marketplace

Barrier 12 has been confirmed by 2 out of 5 suppliers that are not aware of the commercial opportunity. Suppliers view BIM as a service to their customers, the engineer. They don't recognize a commercial opportunity in BIM other than increasing added value to the engineer. For example, M4 states: "Activities that we support concerning BIM are meant to support the engineer but also wholesale." BIM awareness among manufacturers is related to the BIM adoption in that specific country. W2 states that: "Many manufacturers that we distribute are based in Italy were the BIM adoption is still behind. Therefore, these manufacturers don't have good content". This statement by W2 also shows a relationship between barrier 12 and 3.

12.3 Engineers are not aware of the functionality of BIM and a BIM-based e-marketplace

5 Out of 12 stakeholders confirmed barrier 12 in relation to aspect 12.3. W3 states: "In our experience BIM is still a game of modelling. Most engineers still work in a traditional way and only use BIM to design models". BIM awareness among engineers is found to be related to company size. W3 states: "Only the larger engineers with larger project are more advanced in transforming their business processes". The relationship between engineer awareness and adoption intention is not measured.

12.4 There exists a lack of BIM awareness among contractors.

Barrier 12 in relation to contractors is only mentioned by E1. Contractors or clients often demand a traditional working method. Stakeholders also mentioned that engineers often adapt their working method to demand of the contactor or client. Because of the described market pull effect, E1 is sometimes forced to work in traditional way. E1 states: "We are very much involved with BIM but also at E1 we still sometimes work in the old way. This sometimes is driven by the contractor as well". This lack of awareness among contractors can be related to a market pull effect in BIM development. Engineers will adopt BIM processes if the contractor or client demands.

Literature discussed in section 4.4 relates the lack of awareness to the fragmented structure of the industry.

The causal relationship between barrier 12 and the marketplace adoption intention is given in Figure 22.

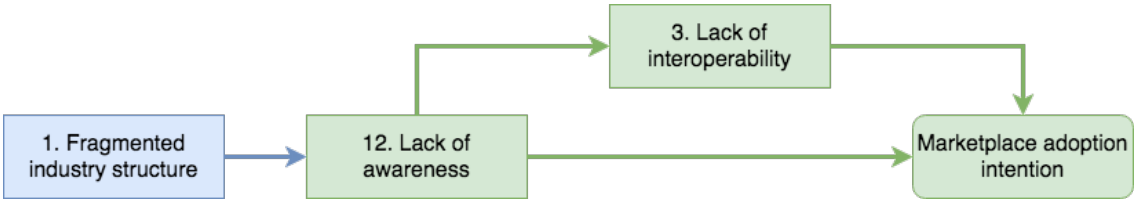

Figure 22 Causal diagram barrier 12

13. Logistic services wholesale

After second level coding, barrier 13 was split up into four aspects. These four aspects cover the total logistic added value of wholesale.

13.1 Stock keeping is an important added value of wholesale

3 out of 3 wholesalers, 4 out of 4 engineers and 4 out of 5 manufacturers confirm barrier 13 in relation to stock keeping. 2 out of 5 manufacturers mention a decreasing stock keeping at wholesale, no denied. Even M3 and M5, two companies that make little use of wholesale, sometimes benefit from stock keeping and logistic efficiency of wholesale.

13.2 The bundling of components from different manufacturers is an important added value of wholesale to ensure logistic efficiency.

3 Out of 3 wholesalers, 2 out of 4 engineers and 2 out of 5 manufacturers confirmed barrier 13 in relation to the bundling of components. 2 out of 3 wholesalers (W1, W3) mention that BIM increases the logistic added value of wholesale because of logistic innovations.

13.3 Wholesale provides building site logistic services to the engineer

3 Out of 12 stakeholders confirmed barrier 13 in relation to wholesale performs building site logistics. No stakeholder denied. W2 states: "We perform logistic tasks on the road and on the building site. These logistic operations need to be very efficient because time is money."

13.4 Delivery to the building site is an important added value of wholesale.

9 Out of 12 stakeholders denied barrier 13 in relation to aspect 13.4. Besides the fact that all stakeholders mention that wholesale delivers most of the products to the building site, 9 out of 12 stakeholders mention that an external logistic service provider could also provide logistic services. One engineer E4 thinks that external logistic service providers are not capable of delivering because they have no knowledge of building site logistics. Stakeholders emphasize that clear agreements are very important. M1 states: "If you make clear agreements it won't be a problem. Make sure that you clearly agree on the place and time. An external logistic service provider could also collect and bundle the different components" W3 states: "DHL already organized logistics around a few building projects. They use a building-hub to channel logistics from multiple suppliers. They will continue to develop these services".

Since logistic processes are internal business processes of manufacturers, barrier 13 can be related to barrier 4. Since wholesale provides logistic services, the logistic processes of manufacturers are underdeveloped. These relationships are given in Figure 23.

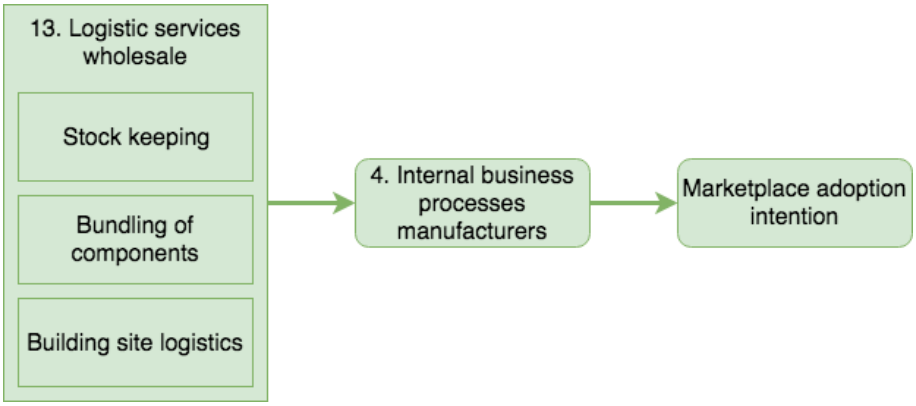

Figure 23 Causal diagram barrier 13

14. Relational oriented market

After second level coding, two aspects of barrier 14 were identified.

14.1 Engineers generally choose a manufacturer based on relational arguments.

4 out of 5 manufacturers confirm barrier 14 in relation to manufacturer choice. For example, manufacturer M1 states: "Most of our customers work with M1 for a long time. Engineers are loyal to their brands". 3 out of 4 engineers made statements that imply relational oriented procurement. For example, engineer E3 states: "We used to buy Grundfoss pumps but after two bad delivery experiences we switched to Wilo." Grundfoss and Wilo are two leading manufacturers of pumps. Three mediating variables can be recognized. First manufacturer M4 states that the technical complexity of a

product influences buying behavior. For high-tech components engineers tend to choose more relational, and for low-tech components more transactional. M4, a manufacturer of pipe systems, states: "A pipe is a pipe, so engineers often choose the cheapest option". The second mediating variable is engineer company size. Smaller engineers tend to choose more relational, while larger companies buy more transactional. M2 states: “Larger engineers have larger calculation processes and choose way more rational. Smaller engineers don’t even have the technical capability to work with other manufacturers. Most engineers will often work with one manufacturer because of conservative reasons". The third mediating variable is the importance of a component. W2 explains that components that are vital to the system are chosen more relational, while less important components are chosen more transactional. Barrier 14 has been found to causally relate to barrier 9. Manufacturer choice is often historically determined.

14.2 Engineers generally choose a wholesaler based on relational arguments.

Two out of three wholesalers confirm barrier 14 in the context of wholesaler choice. 5 other stakeholders deny relational procurement in the context wholesaler choice. Four stakeholders mention that engineers choose between a small selection (2 or 3) wholesalers they have built up a relationship. This can be regarded as a combination of relational and transactional buying behavior. The choice to limit the selection to 2 or 3 wholesalers implies relational buying. The choice between those preferred vendor is often made based on transactional arguments. For example, E1 states: “The E1 group has some buying arrangements and preferred vendors”. M2 states: “99% of engineers have 2 or 3 preferred wholesalers and he doesn’t even look at others”. Two mediating variables can be recognized. Three stakeholders mention that the size of the order influences decision-making. For small orders engineers choose more relational, and for larger orders start to compare prices and choose more transactional. For example, W3 states: “There is a difference between projects, and regular orders. Most of the engineers work together with multiple wholesalers to mix the best portfolio. For larger projects, engineers make separate deals by requesting offers from different wholesalers". Also, the size of the engineering company influences decision-making. Smaller engineers often order at their standard wholesale partner. Larger engineers tend to choose more transactional. Barrier 14 has also been found to causally relate to barrier 9. Supplier choice is often historically determined.

Since the relationship between barrier 14 and adoption intention of stakeholders is not measured, barrier 14 will not be considered as a barrier in the conclusion of this research. The relationships of barrier 14 are given in Figure 24.

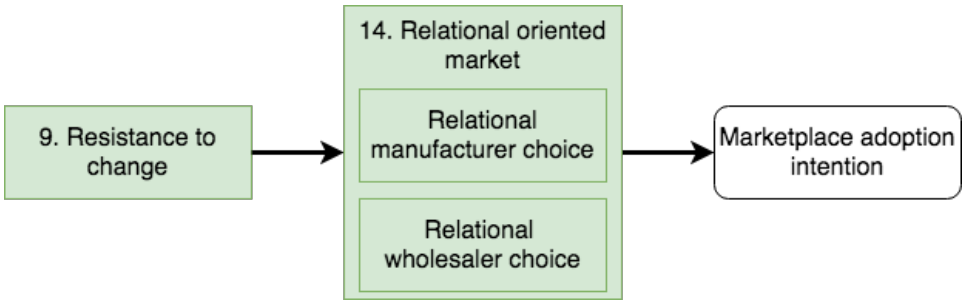

Figure 24 Causal diagram barrier 14

15. Consultancy services wholesale

Barrier 15 is confirmed by 3 out of 5 manufacturers, 1 out of 4 engineers, and 3 out of 3 wholesalers. For example, M2 states: “Wholesale advises engineers to mix and match different components and manufacturers to build a system”. Wholesale names consultancy as a core added value of wholesale. For example, W2 explains: “A wholesaler advises on the composition of components to increase the lifecycle of a complete system"; "If engineers ask for advice from a

manufacturer they will only receive technical knowledge from one specific component". The relationship between barrier 15 and the marketplace adoption intention is not measured. Since consultancy services are internal business processes of manufacturers, barrier 15 can be related to barrier 4. Since wholesale provides logistic services, the logistic processes of manufacturers are underdeveloped. These relationships are given in Figure 25.

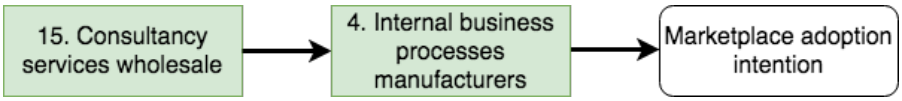

Figure 25 Causal diagram barrier 15

Table 19 gives an overview of the stakeholder interview results.

Table 19 Stakeholder interviews results

Barrier	Description	Confirmation Round 1	Confirmation Round 2	Confirmation Round 3	Confirmed affected stakeholders (E, W, M)	Related barriers
1	Fragmented industry structure	+	0	++	E, W, M	2, 3, 12
2	Information transparency	+	++	++	E, W	1, 11
3	Lack of interoperability	+	0	++	E, W, M	1, 6
4	Internal business processes	+	++	++	E	5, 6, 9, 11
5	Human resources	+	0	+	E	4
6	Technological investment costs	0	0	+	E, M	3, 4
7	Lack of legal framework	0	0	+	E	
8	Lack of technology trust	0	+	+	-	
9	Resistance to change	+	+	++	E, M	4, 13, 15, 16, 18
10	Traditional construction delivery method	n.a.	0	++	W, M	2, 4
11	Negotiation culture	n.a.	++	++	W	3
12	Lack of awareness	n.a.	0	+	E, M	4
13	Logistic services wholesale	n.a.	++	++	M	
14	Relational oriented market	n.a.	n.a.	++	W, M	
15	Consultancy services wholesale	n.a.	n.a.	+	M	4
16	Commercial services wholesale	n.a.	n.a.	n.a.	M	4
17	Technical limitations	n.a.	n.a.	n.a.	E, W, M	4, 15
18	Financial services wholesale	n.a.	n.a.	n.a.	M	4

7.3 Conclusion

The stakeholder interviews elicited three new barriers and confirmed different aspects of previously defined barriers.

The analysis of the results concluded upon the degree of confirmation, identified causalities, relationships, and distinguished different aspects of barriers. This chapter will use the results of the stakeholder interviews to redefine barriers and restructure the list of barriers. The result is a final list of confirmed barriers with explanations of how these barriers originate, and how they obstruct adoption. The results are visually presented in a conceptual model.

1. Lack of interorganizational cooperation

Since the interviews did not measure the relationship between a fragmented industry and stakeholder adoption intention, the role of the fragmented industry structure is not confirmed. The role of interorganizational cooperation is confirmed and according to literature this barrier might be caused by the fragmented industry structure. Barrier 1 decreases the adoption intention because it slows down the adoption of BIM and obstructs the adoption of standards (barrier 3).

2. Vertical information transparency

The data confirmed the obstructing role of information transparency only in the context of vertical price transparency for wholesalers, and vertical BIM model transparency for engineers. Therefore, vertical information transparency reflects in two aspects. First vertical price transparency of a BIM-based e-marketplace obstructs adoption by wholesalers. Currently vertical price transparency is low. An explanation for this low price-transparency is the negotiation culture. Another explanation provided by literature is the fragmented structure of the supply chain. Wholesalers fear that an increase of vertical price transparency will reduce margins. Secondly, vertical BIM model transparency obstructs adoption of BIM-based e-marketplaces by engineers. When BIM models become transparent to contractors or end clients, engineers fear margin erosion. The current lack of vertical BIM model transparency can be caused by the fragmented supply chain which relates to a fragmented industry structure.

3. Lack of interoperability

The lack of interoperability forms a barrier for the adoption of BIM, and thus a barrier for the adoption of a BIM-based e-marketplace. First vertical interoperability reflects in a low availability of BIM content, and the lack of standards in BIM content. Second horizontal interoperability reflects in the incompatibility of BIM software. The lack of interoperability is caused by the high perceived investment costs of developing content (barrier 6), and the lack of interorganizational cooperation (barrier 1).

4. Underdeveloped internal business processes

The results show that the internal business processes of engineers are not ready for procurement on a BIM-based e-marketplace. This reflects in the use of traditional procurement channels, incompleteness of BIM models, manual calculation processes, and the traditional design-calculation-procurement role distribution. Barrier 4 obstructs adoption because of perceived high costs to innovate their business processes. Causes for incompatible internal business processes of engineers can be: the lack of skilled human resources (barrier 5), high perceived technological investment costs (barrier 6), resistance to change (barrier 7), a lack of BIM software functionality (barrier 10) and a negotiation culture.

The results suggest that technically, the internal business processes of manufacturers are sufficient to participate on a BIM-based e-marketplace. Manufacturers develop BIM content, deliver on the building site, and have experience with direct engineer-manufacturer transactions. But due to the added value of wholesale, business processes of manufacturers cannot compete (barrier 11).

5. Engineers lack skilled BIM designers

Engineering companies lack skilled BIM designers. Therefore, they are not able to adapt business processes to BIM (barrier 4), and this reduces their BIM-based e-marketplace adoption intention. The lack of skilled human resources can

be caused by a shortage of BIM designers on the job market.

6. Technological investment costs

High perceived technological investment costs obstruct manufacturers and engineers to adopt BIM business processes (barrier 4). This reduces BIM adoption and BIM-based e-marketplace adoption intention. Technological investments are developing BIM content, and develop complete BIM models. A lack of interoperability (barrier 3) relates these two aspects.

7. Resistance to change

Resistance to change is a cultural aspect that in particular affects the marketplace adoption intention of engineers. Resistance to change obstructs the adoption of BIM business processes (barrier 4) and therefore also the adoption of a BIM-based e-marketplace. Manufacturers are less obstructed by resistance to change but barrier 7 might reduce the adoption intention because of the added value of wholesale (barrier 11). Barrier 7 is considered an exogenous cultural characteristic of the industry.

8. Traditional construction delivery method

The traditional construction delivery method, were the scope of work separates the design and procurement phases, reduces decision-making power of the engineer. Data collection methods did not succeed in measuring the effect of the scope of work on the adoption intention. The scope of work might decrease the adoption intention for manufacturers and wholesalers. Barrier 8 is considered exogenous.

9. Lack of awareness

Market stakeholders lack awareness of the functionality and added value of a BIM-based e-marketplace. Three aspects of barrier 9 are confirmed to obstruct adoption. First manufacturers are not aware of the value and functionality of BIM or e-marketplaces. This also deters manufacturers from developing BIM content (barrier 3). Second engineers are not aware of the functionality of BIM. Engineers often view BIM as a modelling tool. Third contractors and clients are not aware of the functionality and added value of BIM. Literature relates the lack of awareness to the fragmented structure of the construction industry.

10. Lack of BIM software functionality

The lack of BIM software functionality deters engineers from adopting BIM processes (barrier 4), and therefore obstructs the adoption of a BIM-based e-marketplace. Besides, the results suggest that BIM software functionality could decrease the consultancy added value of wholesale and thus decrease the role of barrier 11. Barrier 10 is considered exogenous.

11. Perceived added value of wholesale

The added value of wholesale in the building services industry, obstructs the adoption of a marketplace by manufacturers. The added value of wholesale reflects in four aspects: logistic services, financial services, consultancy services and commercial services. Since the related internal business processes of manufacturers (barrier 4) are not able to compete, manufacturers are obstructed to conduct direct transactions with engineers on a BIM-based e-marketplace. Barrier 11 is considered exogenous.

Table 20 gives the final list of barriers including the analysis results. The barriers are categorized in three types based on the TOE framework descried in subsection 4.2.2. The TOE framework distinguishes technological barriers, organizational barriers and environmental barriers.

Table 20 Final list of barriers for adoption of an open BIM-based e-marketplace

Barrier	Description	Affected stakeholders	Degree of confirmation	Related barriers	TOE category
1	Lack of interorganizational cooperation	E, W, M	++	3	Environmental
2	Vertical information transparency				Environmental
	Vertical price transparency	W	++		
	Vertical BIM model transparency	E	++		
3	Lack of interoperability	E, W, M	++	1, 6	Technological
4	Underdeveloped internal business processes				Organizational
	Engineers use traditional procurement channels	E	++	7	
	Engineers don't develop complete BIM models		++	6	
	Engineers use manual calculation processes		++	7	
	Engineers maintain traditional role distribution		++	5, 7	
5	Engineers lack skilled BIM designers	E	+	4	Technological
6	High perceived technological investment costs				Technological
	High costs of developing BIM content	M	+	3	
	High costs of developing complete BIM models	E	+	4	
7	Resistance to change	E	++	4	Organizational
		M	+	11	
8	Traditional construction delivery method	M	++		Environment
		W	++		
9	Lack of awareness				Organizational
	Suppliers are not aware of the commercial opportunity of BIM.	M W	+	3	
	Engineers are not aware of the functionality of BIM and a BIM-based e-marketplace	E	+		
	There exists a lack of BIM awareness among contractors.	Contractor	+		
10	Lack of BIM software functionality	E	+	4, 11	Technological
11	Perceived added value of wholesale				Organizational
	Wholesale provides logistic added value	M	++	4	
	Wholesale provides consultancy to engineer		+	4	
	Wholesale generates turnover for manufacturers		++	4	
	Wholesale provides financial services to support the engineer		+	4	

By combining the above described barriers and relationships, a final conceptual model is developed and visualized in Figure 26. Coloring is used to distinguish the concepts and relationships confirmed in this research (green), and the concepts and relationships that were mentioned by previous literature (blue) or developed using logical reasoning but not measured in this research (black).

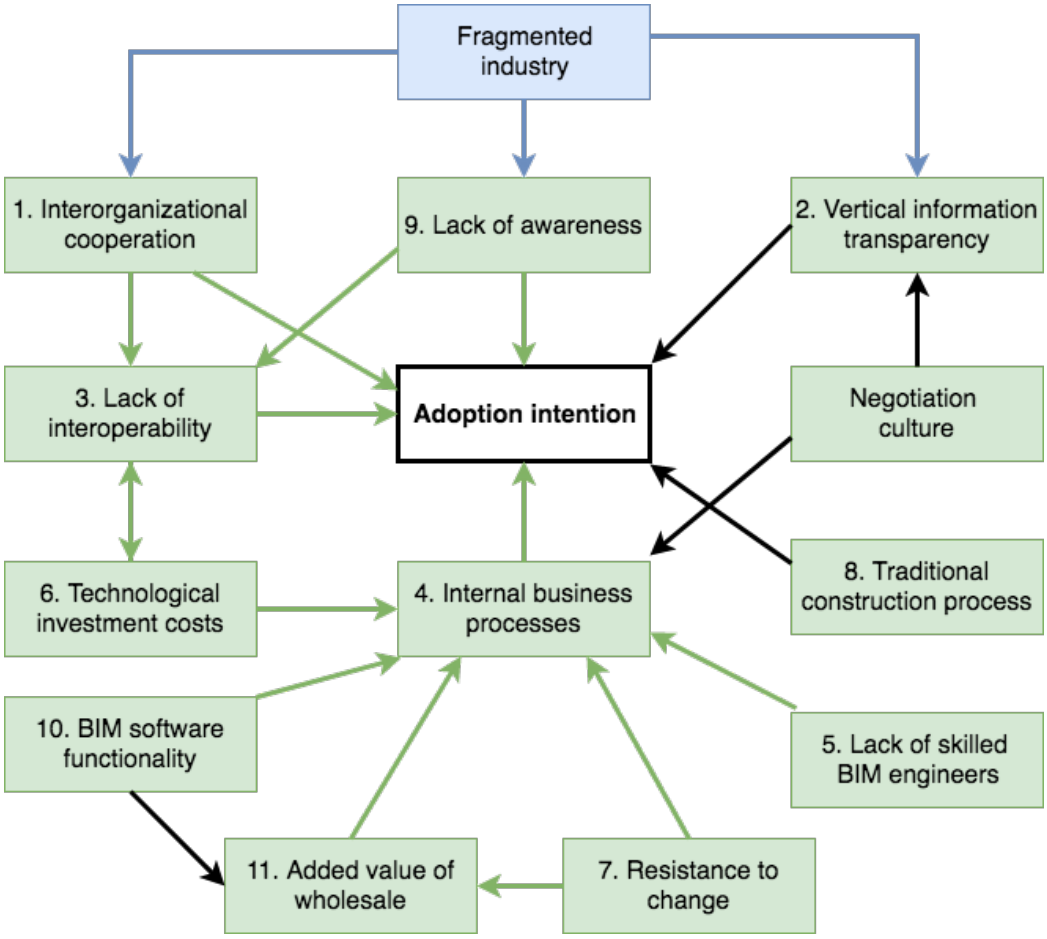

Figure 26 Final conceptual model

8 DISCUSSION AND CONCLUSION

The previous three chapters described the data collection phase of this research. Three data collection rounds collected and interpreted data to answer the research question. This chapter aims to discuss the main findings, discuss the limitations and make recommendations for research and practice.

This chapter is structured as follows. First section 8.1 will conclude upon the main findings of this research and answer the research question. Section 8.2 will discuss the results and null results in relation to prior literature. Section 8.3 will summarize the theoretical contribution of this research. Section 8.4 discusses the limitations of the research design. Section 8.5 evaluates the generalizability of the results. Section 8.6 makes recommendations for further research. And finally, section 8.7 makes recommendations for practice.

8.1 Main Findings

This research project was initiated by the notion of a discrepancy between literature and the current market situation in the construction industry. Although prior literature emphasized the added value of e-marketplace platforms, the construction industry still falls behind on e-marketplace adoption. Since academic literature does not provide a sufficient explanation for this discrepancy, a knowledge gap could be defined. To fill this knowledge gap within the defined scope, this research aimed to explain how European building services manufacturers, wholesalers and engineers are obstructed to adopt BIM-based e-marketplaces. The following research question and sub-questions were defined:

How are European building services manufacturers, wholesalers and engineers obstructed to adopt BIM-based e-marketplace platforms?

1. *What are the barriers that obstruct European building services manufacturers, wholesalers and engineers to adopt a BIM-based e-marketplace?*
2. *Why do these barriers exist?*
3. *How do these barriers obstruct the adoption of BIM-based e-marketplaces by European building services manufacturers, wholesalers and engineers?*

This research answered the research question by eliciting and confirming 11 technical, organizational and environmental adoption barriers. Technological barriers are: a lack of interoperability, technological investment costs and a lack of BIM software functionality. Organizational barriers are: underdeveloped internal business processes of engineers, a lack of skilled BIM designers, resistance to change, and a lack of consensus and awareness of the functionality of a BIM-based e-marketplace**.** Environmental barriers are: a lack of interorganizational cooperation, vertical information transparency, the traditional construction delivery method, and the added value of wholesale. Besides, the findings explain to a certain extent, why these barriers exist, and how they obstruct adoption. The following section will discuss the results of this research in relation to prior literature.

8.2 Discussion

Section 7.3 gives the results of this research that answer the research question. This section will discuss and interpret these findings in relation to the theoretical framework and related work described in chapter 4.

8.2.1 Discussion of Results

The results indicate a lack of interorganizational cooperation as a barrier for the adoption of BIM-based e-marketplaces by engineers, manufacturers and wholesalers. Related work by e.g. Walasek and Barszcz (2017) and Zou and Seo (2005) also mentioned the lack of interorganizational cooperation. These studies approach interorganizational cooperation from a technical perspective that reflects in a lack of interorganizational communication channels. However, the results of this research also indicate a cultural aspect of cooperation. This implies that organizations, regardless of the technical possibilities, are not willing to cooperate. This cultural aspect of interorganizational cooperation mainly causes a lack of cooperation between sub-contractors and contractors during a building projects, and the willingness of companies to comply to industry standards.
Alternative explanations for this discrepancy might be found in cultural differences between markets and countries. The participants of the stakeholder interviews were mainly focused on the Dutch market. Other European countries and markets might feature a stronger cooperation culture that does not form a barrier for the adoption of BIM.
Related work from e.g. Wang et al. (2007) and Walasek and Barszcz (2017) relate interorganizational cooperation to the fragmented structure of the construction industry. This research did not measure the relationship between interorganizational cooperation and the fragmented industry structure. Therefore, interorganizational cooperation cannot be related to the DOI framework as suggested in section 4.4. Because of time limitations, this research failed to explain the lack of interorganizational cooperation. Further research should consider studying the cultural aspect of interorganizational cooperation in more detail, to explain why construction organizations are not willing to cooperate.

The second barrier identified by this study is vertical information transparency of a BIM-based e-marketplace. Wholesalers are obstructed by vertical price transparency, and engineers are obstructed by vertical transparency of BIM models. The results complement the findings of Nakayama (2000), who studied the role of information transparency in the supply chain. Nakayama (2000) only mentioned a loss of bargaining power for wholesalers in a transparent supply chain, but the results of this research shows that this also holds for other supply chain intermediaries, like in this case engineers. Furthermore the results contrast with the study of Zhu (2002), who argues that all suppliers fear data exposure, pricing pressure, and margin erosion on a transparent marketplace. This research indicates that only intermediaries perceive these disadvantages. This discrepancy might be explained by the sample of this research. Zhu (2002) emphasized that information transparency particularly affects high-cost firms, and the cost structures of the sampled suppliers is unknown.
Since the results show that information transparency forms a major barrier, it is remarkable that related work does not address this barrier. This might be explained by characteristics of the Dutch construction supply chain compared with other countries. The participating stakeholders of this research were mainly focused on the Dutch market. Maybe supply chains in other countries or industries are more transparent and the transparency of an BIM-based e-marketplace is less disruptive. Further research addressing the barrier of information transparency should first consider studying the current level of vertical transparency in different markets and countries.
Prior studies of Nawi et al. (2014) argue that transparency is low because of the fragmented industry structure. As mentioned earlier this research failed to measure the role of transparency. The results of this research suggest that the negotiation culture of the building services industry decreases vertical price transparency. The results do not provide enough evidence for this relationship and therefore we suggest further research should take this aspect into account.

Furthermore, this research identified the lack of interoperability as a barrier for the adoption of BIM-based e-marketplaces. The first aspect, horizontal incompatibility of BIM software, aligns with related work by Walasek and Barszcz (2017). But related work did not mention a lack of vertical interoperability of BIM content. The results show that not only standardization of file types is important, but also availability of BIM content and consistency in graphical details

and information parameters. We recommend further research on interoperability, to study the vertical interoperability issues of BIM in more detail.
Other related studies like Rankin et al. (2006), Bhutto et al. (2005) and Wang et al. (2007) also mentioned that a lack of standards in the representation of information that is not related to BIM. The results of this research deny this, and stakeholders mention a high level of standardization due to standards and classifications. This discrepancy can be explained by the age of previously mentioned studies. Classifications like ETIM were adopted in the years after those studies were published. This research did not focus on the role of standardization of non-BIM data, but further research should conclude if this aspect is definitely resolved.
The results confirm both horizontal and vertical interoperability issues, and as explained by Choi and Whinston (2000), interoperability is critical in enabling network externalities on a platform. Based on the results we can conclude that a BIM-based e-marketplace platform faces a chicken-egg problem in the availability of interoperable BIM software and content. Suppliers will only develop BIM content, when engineers use interoperable BIM software. And the other way around, engineers will only adopt BIM software, when interoperable BIM content is available.
The results identify the lack of interorganizational cooperation, the lack of awareness among manufacturers, and high perceived technological investment costs as causes for the lack of interoperability. Both the lack of awareness and high perceived costs of developing BIM content align with findings from i.a. Walasek and Barszcz (2017). Related work did not mention the causal relationship of interorganizational cooperation on interoperability. Further research on the cultural aspect of interorganizational cooperation should also consider studying the adoption of standards.

The fourth barrier indicated by this research is incompatibility of internal business processes of engineers and manufacturers. This barrier mainly reflects in incompatible internal business processes of engineers. Related work already mentioned this barrier from a technological perspective in the context of e-commerce and BIM adoption (Isikdag et al., 2011; Rankin et al., 2006; Walasek & Barszcz, 2017). The incompatibility of engineering business processes aligns with this technological perspective. These related studies also identify resistance to change and a lack of skilled BIM designers as causes for incompatible business processes. In addition, the results of this research also suggest that the negotiation culture of the construction industry obstructs engineers from adopting BIM procurement technologies. We suggest that further research should study the role of negotiation in e-procurement adoption in more detail.
Section 4.4 defined the incompatibility of internal business processes based on the TOE framework. The results primarily align with organizational aspect of the TOE framework. Engineers face difficulties in organizational change.
The results also mention a relationship between the added value of wholesale, and the readiness of internal business processes of manufacturers. This relationship will be in discussed together with the discussion of barrier 11.

The next confirmed barrier shows that some engineering companies lack skilled BIM designers and are therefore not able to adapt business processes to BIM. This result aligns with related work by Walasek and Barszcz (2017) and Chien et al. (2014). Similar to the results, these related studies also mention the shortage of BIM designers on the job market. Besides BIM skills, Rankin et al. (2006) and Isikdag et al. (2011) also mentioned a lack of non-BIM technological capabilities among employees. The results only focus on skills related to BIM and no stakeholder mentioned other technical capabilities. This discrepancy can be explained by the sampling method used for the stakeholder interviews (section 7.1.1). The sample contained mainly innovative companies that generally employ more skilled employees. That also explains the low degree of confirmation of barrier 5 (Table 20). Further research addressing the problem of skilled employees, should consider selecting a sample that represents the average engineering company.
Section 4.4 defined the lack of technologically skilled human resources based on the TOE framework. The results align with the technological aspect of the TOE framework.

Furthermore, this research recognized a minor role of perceived technological investment costs when participating on a

BIM-based e-marketplace. This barrier reflects in the costs of developing BIM content by manufacturers, and developing complete BIM-models by engineers. Ghaffarianhoseini et al. (2017) and Chien et al. (2014) already recognized this barrier but did not study it in more detail. In contrast to the results, related work e.g. Rankin et al. (2006) and Bhutto et al. (2005) also mentioned the costs of investing in technological systems. This discrepancy can be explained by the sampling method that selected stakeholders with extensive BIM experience. These companies already invested in technical systems to support BIM. This might also explain the low confirmation of barrier 6 (Table 20). Further research might first map out the perceived technological investment in more detail using a sample that represents the average construction company.
The results show that engineers perceive high costs of developing complete BIM models. This barrier is not mentioned by related work, but the results show that it obstructs engineers from innovating internal business processes (barrier 4). Since the costs of developing complete BIM models are high, engineers still partly procure manually. Further research related to BIM adoption should study this barrier in more detail.
This barrier was defined as a hypothesis based on the TOE framework. When internal technologies do not align with technological innovations, adoption will be hindered. The results align with the technological aspect of the TOE framework.

The seventh barrier identified by this research is resistance to change. This cultural aspect aligns with related literature from Zou and Seo (2005) and Isikdag et al. (2011), who emphasize the lack of innovative culture that obstruct the adoption of e-commerce. The results show that especially engineers are widely known to resist change. One might expect that due to the sampling method, which selected relatively innovative companies, resistance to change plays a minor role. But even the most innovative companies of the industry, show signs of conservativism. This makes the results even stronger. The results did not explain how resistance to change originated, but further research should consider studying the causes of this highly relevant cultural characteristic.
When reflecting this result on the DOI framework by Rogers (1962), a large portion of construction companies can be referred to as late majority and laggards. The social system of the construction industry is not receptive to new innovations.

The eighth barrier that results from this research, suggest that the traditional construction delivery method inhibits the adoption of a BIM-based e-marketplace. The reason for this is the separation of the design and procurement phases that reduce decision-making power of the engineer. Related work did not mention the obstruction role of the tradition construction delivery method. Other prior literature did address the separation of design and construction of the DBB method (Nawi et al., 2014), but only studied this in relation to productivity.
This research did not succeed to conclude upon the relationship between the traditional construction delivery method and the adoption intention of market stakeholders. The results confirm that the scope of work affect decision power of the engineer and we expect this will affect the adoption intention of suppliers. Since especially industry experts explicitly emphasized this barrier, further research should consider studying the role of the scope of work in more detail. The fact that related work did not address this seemingly relevant barrier might be explained by the geographical orientation of the sample. The role of the scope of work could be less obstructing in other countries and markets. We suggest that studies on the role of the scope of work, address the construction delivery methods used in different countries.

The results of this research mention a lack of awareness of the functionality and added value of a BIM-based e-marketplace. We found this affects adoption intention of manufacturers and engineers. Related work did address the lack of awareness of the functionality of BIM (Chien et al., 2014; Walasek & Barszcz, 2017). These studies align with the lack of BIM awareness among engineers that this research confirms.
Related work did not recognize the lack of awareness of the commercial functionality of an e-marketplace for suppliers.

Literature is clear about the advantages of participating on an e-marketplace (Alarcón et al., 2009), but the results show that manufacturers are not aware of this opportunity.
In addition to related work, the results suggest a lack of BIM awareness among contractors. Engineers often don't work with BIM because contractors or clients request traditional construction methods. This lack of BIM awareness among contractors is remarkable since the productivity advantages of BIM, are in particular expected to benefit the client. (Ghaffarianhoseini et al., 2017). Also the adoption of BIM-based e-marketplaces and the corresponding supply chain integration, mainly benefits the client (R.J. et al., 2001). The fact that related work did not mention this lack of awareness among contractors and clients, might be biased by the sampling method that mainly selected local oriented Dutch engineers. Furthermore, the results do not provide extensive evidence for this barrier. The interviews did not specifically test awareness among contractors and clients.
Section 4.4 argued that the lack of awareness might be caused by the fragmented industry structure. This would align with the DOI framework that explains how the flow of information through a social system affects awareness. This research did not succeed in confirming the relationship between the fragmented structure and lack of awareness. We suggest that further research should pay attention to the causes for this lack of awareness and especially focus on the fragmented industry structure.

This research identified the lack of BIM software functionality that withholds engineers from adopting BIM business processes and withholds manufacturers from conducting direct transactions with engineers on an e-marketplace.
Related work did not mention this as a barrier for the adoption of BIM. According to engineers, additional functionality on error detection and component suggestion, could help engineers to adopt BIM processes. An alternative explanation for this discrepancy can be found in the sampling method used for the stakeholder interviews. The sample mainly contains small sized engineers that focus on the Dutch market. Possibly larger engineering firms in other markets do use these extended software functionalities. Further research on BIM adoption should consider studying the available functionalities of BIM software in more detail.
Related work also did not mention the role of software functionality on the added value of wholesale. Further research should consider studying the opportunities of software functionality on disrupting the position of wholesale.

The last result of this research is the obstructing role of wholesale on e-marketplace adoption by manufacturers. Manufacturers are not able to compete with the logistic, financial, commercial and consultancy services of wholesalers. Related work did not address the obstructing role of wholesale on the adoption of e-marketplaces. This is remarkable since the results of this research identify the role of wholesale as one of the main barriers for adoption of e-marketplaces. Nakayama (2000) and Zhu (2002) did argue that information transparency can be disadvantageous for wholesale. But no prior academia studied the strategies wholesale apply to obstruct the adoption of these e-marketplaces.
One alternative explanation for this discrepancy might be that the position of wholesale is less dominant in other countries or markets. The participants of this research mainly operated in the Dutch building services industry were wholesale protects a dominant position. Since the results of this research explicitly confirm the obstructing role of wholesale in the adoption of e-marketplaces, we strongly suggest further research on the adoption of e-marketplaces to study the defensive strategies of wholesale in more detail. These studies should consider mapping the role of wholesale in different countries and markets.

8.2.2 Discussion of Null Results

The results of this research describe 11 barriers for the adoption of a BIM-marketplace. This subsection will discuss the barriers mentioned by related work, that are not present in the results.

Hypothesis 1, defined in section 4.4 mentioned the role of a fragmented industry. This hypothesis is based on studies from Wang et al. (2007), Walasek and Barszcz (2017) and Nawi et al. (2014). These studies argue that the fragmented industry structure inhibits interorganizational cooperation, decreases awareness, and reduces vertical transparency. These consequences are expected to obstruct the adoption of BIM-based e-marketplaces. Although the results confirm these three consequences of fragmentation, this research failed to measure the actual role of fragmentation. The data collection method chosen for this research was not able to address the complex and comprehensive concept of fragmentation.

Related studies from i.a. Zhu and Kraemer (2005), Rankin et al. (2006) and Isikdag et al. (2011) emphasize the lack of a legal framework that obstructs the adoption of BIM and e-commerce in the construction industry. Section 4.4 used this related work to define hypothesis 7. The results of this research do not confirm this barrier. An explanation for this discrepancy could be a lack of legal expertise of the interviewees. Since most of the interview participants are not concerned with legal affairs in their daily work, the legal implications received little attention during the interviews. Further research should also consider inviting legal experts representing the stakeholders, to conclude upon the legal barriers.

The theoretical study by Ratnasingam et al. (2002), and related work by Rankin et al. (2006) , Isikdag et al. (2011) and Ghaffarianhoseini et al. (2017) emphasize the role of technology trust. Section 4.4 used this related work to define hypothesis 7. The results of this research do not mention technology trust as a barrier for adoption. This can be explained by the sampling method, that selected mostly innovative early adopting companies. These participating companies have extensive experience with BIM and e-procurement. These experiences are expected to positively influence their technology trust. Further research on the role of technology trust should use a sample that represents the average company in terms of innovativeness.

8.3 Contribution to Research

Based on the discussion of the results, this section summarizes the theoretical contribution of this research. We emphasize the results of this inductive research are still hypothetical and should be confirmed by more rigor deductive research before they can complement the knowledge landscape.

- This research shows that the construction industry culture is characterized by a lack of interorganizational cooperation. This cultural aspect forms a barrier for the adoption of BIM. Related work only addressed this lack of cooperation from a technical, knowledge sharing, perspective.
- The results of this research show that vertical price transparency is a major barrier for the adoption of e-marketplaces by wholesale. Related literature did not mention the obstructing role of vertical price transparency on the adoption of e-marketplaces in the construction industry.
- The results show that vertical information and price transparency is a barrier for the adoption of BIM-based e-marketplaces by engineers. When sharing BIM models in a price transparent supply chain, engineers fear margin erosion. Related literature on the adoption of BIM or e-marketplaces did not mention this as a barrier. The results complements prior research by Nakayama (2000), who only identified a loss of bargaining power for wholesalers on a transparent supply chain. This research shows that also other intermediaries, like engineers, can experience margin erosion due to vertical information transparency.
- In addition to related work, this research shows that both horizontal and vertical interoperability is critical to the adoption of BIM. Preliminary literature only focused on horizontal interoperability and the standardization of file types. Vertical interoperability in the context of BIM reflects in: availability of BIM content, and consistency in

graphical details and information parameters of BIM content.

- In contrast to related work, this research denies the lack of standards in commercial information representation. Due to recently adopted standards and classifications, e.g. EAN and ETIM, standardization of commercial information representation improved.
- Related work did not mention the causal relationship of interorganizational cooperation and interoperability. The results of this research show that organizations are not willing to comply to standards. This implies a lack of interorganizational cooperation from a cultural perspective.
- The results show that engineers perceive high costs of developing complete BIM models. Due to these costs, engineers develop incomplete BIM models and are not able to automate procurement processes. Related work did not mention this as a barrier for the adoption of BIM and e-commerce.
- This research identified the lack of awareness of the commercial opportunities of an e-marketplace by manufacturers. Related work did not mention this barrier for the adoption of e-marketplaces in the construction industry.
- The results identify the lack BIM software functionality as a barrier for adoption of BIM processes by engineers. Related work did not mention the enabling role of specific BIM software functionalities on the adoption of BIM.
- This research emphasizes the obstructing role of wholesale on the adoption of e-marketplaces. Wholesale companies developed extensive logistic, financial, commercial and consultancy services, to inhibit direct manufacturer-engineer transactions. Related work did not mention the services of wholesale as a barrier for adoption of e-marketplaces.

The following notions need further inductive research to formulate a theoretical contribution.

- The results suggest that a negotiation culture of the building services industry might decrease vertical price transparency. Related literature did not discuss the role of a negotiation culture or the role of vertical price transparency in the adoption of BIM or e-marketplaces.
- The results of this research suggest that a negotiation culture in the construction industry, might obstructs engineers from adopting BIM procurement technologies. Related literature did not discuss the role of a negotiation culture on the adoption of BIM.
- This research suggests an obstructing role of the traditional Design-Bid-Build construction delivery method on the adoption of BIM-based e-marketplaces. The scope of work affects decision power of the engineer and this might affect the adoption intention of suppliers. Related literature only mentioned the influence of the traditional construction delivery method on productivity.
- Related work did not mention the lack of BIM-awareness among contractors and clients. The results suggest an important role for contractors and clients on the adoption of BIM.

8.4 Limitations

Section 8.2 discussed the results of this research and identified multiple discrepancies with related work. Some of these discrepancies were nuanced by potential limitations of this research. This section will evaluate these limitations in more detail and discuss how they might bias the results. First the limitations of the sampling methods are discussed. Than the limitations of the chosen data collection methods are evaluated.

8.4.1 Sampling method

The first limitation that follows from the discussion is the sampling method for the stakeholder interviews. Sampling

should randomly select from the defined sample unit. The sample unit was defined as: innovative European building services manufacturers, wholesalers and engineers'. In practice, the sampling procedure mainly selected companies that were located in the Netherlands. In addition, during the interviews many of the participants showed a regional focus. This sampling bias can affect the results because of cultural or structural differences between European countries. Cultural differences in cooperation culture might affect barrier 1. Differences in supply chain structurers between countries might affect barrier 2. Adoption of national standards in other countries might affect barrier 3. Differences in BIM adoption among engineers might affect barrier 4. Differences in labor markets and education might affect the supply of BIM designers and affect barrier 5. Cultural differences in attitude towards innovation might affect barrier 7. International differences in construction delivery methods and a different role of the scope of work might affect barrier 8. International differences in BIM awareness might affect the barrier 9. Differences in used software functionalities might affect barrier 10. Wholesale might have a different competitive position in other countries which will affect barrier 11. Further research should be careful with applying the results of this research in other markets. We recommend further research first studies the cultural and structural differences between construction markets.

The second limitation of the stakeholder sampling method relates to the choice of the sample unit. The sample only contained innovative companies which decreases representativeness and will bias the results. The role of barrier 5 might be larger than measured because less innovative companies are expected to employ lower-skilled employees. Innovativeness of companies might influence their perception of technological investment costs and affect barrier 6. The cultural factor of resistance to change might be more dominant among late adopting companies which would affect barrier 7. The awareness among less innovative organizations will affect the results of barrier 9. And finally, the role of technology trust will be larger in first adopters.
On the other hand, barriers that obstruct innovative companies will probably also obstruct less innovative companies. Further research should be aware that the results do not provide a complete overview of the adoption barriers, but only the most important barriers that hold for the most innovative companies in the market.

The third limitation follows from the interviewees that were sampled to represent the market stakeholder. Since the interviews covered a broad range of business processes, interviewees were chosen based on their knowledge of both technical and commercial activities of the company. But in some cases, the interviewees did not fully represent the stakeholders. An example of a bias that results from the interviewee choice is the barrier related to legal practices described in subsection 8.2.1. In this case the results were biased because the interviewees lack knowledge of legal affairs and will therefore not mention this as a barrier. Other interviews were significantly biased by the personal beliefs of interviewees. Barrier 1, the lack of interorganizational cooperation, is mainly based on the personal vision of one interviewee. This personal opinion might significantly deviate from the common opinion within that company. Barrier 7 is partly confirmed by an interviewee that seemed to be very skeptical towards the adoption of BIM. This interviewee might not represent the attitude of his employer.

The fourth limitation follows from the sampling methods used for the industry expert interviews and focus group. These industry experts were chosen to represent the unit of analysis. A bias can be recognized since the industry experts all have a local focus on the Dutch market and the unit of analysis is a European market stakeholder. This limitation has a similar bias comparted to the stakeholder sampling method.

8.4.2 Data collection method

The first data collection method limitations results from the focus group method, used in the second data collection round. Bhattacherjee (2012) mentions two important limitation of the focus group. First the focus group may be

dominated by a dominant personality. This was definitely the case since P3 spoke during more than half of the focus group time. The evaluation questionnaires also show that the input from participants was unevenly distributed. This limitation reduces the effectiveness of the focus group.
The second limitation might occur when participants are reluctant to voice their opinions in front of their peers or superiors. But since: the evaluation questionnaires show that all participants felt free to speak, the focus group did not contain employee/superior relationships, and the researcher cannot recognize any sensitive topics, we assume this limitation can be neglected.
Besides the limitations mentioned by Bhattacherjee (2012), the agenda of the focus group limits the results. As mentioned in subsection 6.1.2, the focus group contained much topics out of the scope of this research. Although some relevant statements were made during the platform design discussions, the agenda definitely limits the effectiveness of the focus group. We also noticed that little discussion took place during the focus group. Participants generally agreed on the topics.

The second data collection method related limitation is the structure and timing of the semi-structured stakeholder interviews. Despite the availability of an interview protocol, the interviews were less structured than intended. This lack of structure particularly affects the thoroughness and transparency of the barrier testing parts because it is not possible to directly compare questions and answers. Besides due to the lack of structure, interviewees often strongly steered the conversation to topics that were important from their point of view. Therefore, the interviews ran out of time without testing all the barriers. A topic that received little attention due to this bias is legal framework. Further research should test the barriers identified in this research in a more structured and rigor manner.

The next limitation is determined by the role of the researcher during the stakeholder interviews. There are two characteristics of the researcher that could bias the answers of stakeholders. First the researcher operates as an intern at Stabiplan. This can bias the answers because Stabiplan is a strategic partner of the participants. Potential biases can affect the results in barrier 3, 6 and 10. Stabiplan has an active role in the development of BIM content (barrier 3), the costs of BIM content (barrier 6), and the BIM software functionality (barrier 10). Stakeholders also realize that Stabiplan is in the position to develop a BIM-based e-marketplace. Some participants even felt violated or threatened because of the concept of a BIM-based e-marketplace. One engineer responded stated: “If you develop this, our role value will be reduced to an installer”.
Second the academic reputation of the researcher can bias the answers. Participants often mentioned to perceive a conflict between the scientific perspective and the practical perspective. This perceived conflict can make participants more skeptical towards questions from the researcher. E.g. one participant stated: “I think an open platform is never going to work, but I understand that people from the university think otherwise?”. This reaction is clearly biased by a skeptical attitude towards university and the researcher.

The last limitation we want to outline relates to the interview protocols for the stakeholder interviews. Section 7.1.2 proposed a method to test the adoption barriers in three different protocols. Some of the decisions that were made during the development of these protocols directly affect the results. For example, the hypothesis related to legal issues, technology trust and consultancy services of wholesale received little attention because of these choices. Also, the questions that were asked did not always accurately measure the underlying barrier. For example, question 7 of the manufacturer protocol given in appendix C.2, aims to measure ‘transparency’. But the question does not ask a specific kind of transparency (horizontal/vertical price/information etc.). Besides the explanation of the question refers to relational oriented market instead of transparency.
Evidently it is not feasible to reflect upon every question of the protocols. Therefore, we must emphasize that the results of this research need to be verified in further, more rigor, research.

8.5 Generalizability

This section will discuss the generalizability of the results. First the generalizability within the defined scope is discussed. The geographical generalizability is limited. The sample contains ten participants from the Netherlands, one from Belgium and one from Ireland. The participants from the Netherlands were found to be very nationally oriented. An example of this local orientation appeared in the interview with the general director of the Dutch division of M2. On the question “What BIM standards do German clients use?”, he answered: “I don’t know, I only look at the Netherlands”. Among the sample only one participant with an international focus was interviewed. Because of ambiguity of terminology, a part of this interview could not be analyzed. This local focus confirms that the results are not easily generalizable outside the Netherlands. Further research should be cautious in applying results

The scope section of 1.3, limits the focus of this research based on five aspects. The research question was scoped to only addresses BIM-based e-marketplaces for the European building services industry. The results are partially generalizable outside the scope of this research.
The findings are developed in the context of the building services industry. As explained in the scope definition of this research the building services industry is expected to be an early adopter of e-marketplaces in the construction industry because products and services are more standardized. But other industries within construction also devote to standardization. Prefabrication forms an opportunity for e-commerce implementations. A BIM-based e-marketplace can also play a role in the procurement of prefabricated buildings.
The findings were developed in the context of BIM-based e-marketplaces but are also partially applicable to general e-marketplaces. The findings that relate vertical information transparency to the adoption of wholesale (barrier 1) also apply on general e-marketplaces. Barrier 7, resistance to change is also expected to obstruct adoption of general e-marketplaces. Barrier 8, that explains how decision power of the buyers is reduced by the construction delivery method also affects general e-marketplace adoption. The lack of awareness among suppliers of the commercial opportunity of an e-marketplace (barrier 9), also holds for general e-marketplaces. Finally, logistic, financial, commercial and consultancy services will also obstruct manufacturer adoption on a non-BIM e-marketplace (Barrier 11).

8.6 Recommendations for Further Research

The contribution of this research can be regarded as a research agenda on the topic of e-marketplaces and BIM adoption in the construction industry. As shown in the discussion section, this research unearthed a broad range of new unexplored topics that are relevant in the adoption of e-marketplaces and BIM. Section 8.1 already made multiple recommendations for further research. But initially this research was not intended as a research agenda was motivated by a practical problem. Section 1.1 described how e-marketplaces can disrupt the inefficient construction supply chain. This section will discuss the contributions of this research in the context of this problem.

This inductive research project stands at the beginning of a chain of research projects. First the hypothetic barriers developed in this research can be further completed in a more rigor theory building research project. Second the results can be tested in hypothesis-testing research to answer the research question of this research: “What are the barriers for adoption of a BIM-based e-marketplace by stakeholders of the building services industry?”. The next step in theory building research could be a project that aims to develop design-requirements that minimize the influence of adoption barriers on the adoption intention of stakeholders. Hypotheses-testing research, for example an experiment could test these design requirements by measuring the adoption intention for different BIM-based e-marketplace designs. Based on these confirmed design requirements, design research can build theory on ‘How to design a BIM-based e-marketplace to maximize the adoption intention’.

Furthermore, the results can also be used in theory building and hypothesis testing research on b2b marketplace adoption in the building services and construction industry, or the role of BIM in the adoption of b2b marketplaces for the building services and construction industry.

8.7 Recommendations for Practice

Although the findings of this research need to be tested by more rigor hypothesis testing research, business actors can substantially benefit from the insights. This section will first make recommendations for entrepreneurs like Stabiplan that aspire to develop and launch an e-marketplace or BIM-based e-marketplace. Besides that, recommendations for the construction industry stakeholders are made.

Entrepreneurs that aspire to develop a BIM-based e-marketplace or non-BIM e-marketplace, can use the results of this thesis in platform design. First, based on the results related to transparency, we recommend entrepreneurs to clear define information disclosure rules. These rules might limit information transparency and lower adoption barriers for wholesalers and engineers. Entrepreneurs might consider the BIM-based e-marketplace design given in Figure 7. This implementation limits vertical information transparency for wholesalers and engineers. During the stakeholder interview sessions, both wholesalers and engineers preferred this second design example.

Second entrepreneurs should consider adapting the e-marketplace to existing business processes of engineers like ERP. Many engineers still manually calculate and order a BOM. Partially due to the conservative culture, they perceive high costs in changing these business processes and corresponding role distribution.

As mentioned in the discussion, a BIM-based e-marketplace faces a chicken-egg problem in the availability of interoperable BIM content and BIM software. Researchers like Tiwana (2014), argue that subsidizing could help solving the chicken egg problem. We suggest that entrepreneurs should consider subsidizing manufacturers in the development of interoperable BIM content. With interoperable BIM content available, engineers will experience less costs in adapting their internal business processes.

A BIM-based e-marketplace might add more value in the context of a design-and-build construction delivery method. The traditional Design-Bid-Build construction delivery method limits the freedom of choice of the BIM designer.
Engineers often depend on the consultancy services of wholesale with regards to the combination of components in a system. Entrepreneurs should consider adding functionalities to BIM software that suggests certain components based on technical specifications or warn BIM designers for compatibility errors. This added functionality will reduce the consultancy added value of wholesale and stimulate manufacturers to conduct direct engineer transactions.

This research shows that the added value of wholesale forms a major barrier for the entrance of manufacturers on an e-marketplace. Entrepreneurs should consider inviting third party service providers on a marketplace to compete with wholesale services. An example of third party services that is strongly emerging is logistics (Ekeskär & Rudberg, 2015). Companies like DHL are heavily investing to compete with wholesale logistics.

The problem of interoperability is widely recognized as a barrier for the adoption of BIM and e-commerce in the construction industry. The adoption of Industry Foundation Classes (IFC) and ETIM classifications have been first steps to European interoperability. The results of this research particularly identify the lack interorganizational cooperation that hinders the adoption of common standards. Organizations in the construction industry should aim for a European

standard to accelerate the BIM adoption. Governmental efforts or initiatives from non-profit organizations should be embraced.

The results of this research recognized a strong market pull effect in the adoption of BIM. Actors primarily look at the demands of their customer one step further in the supply chain. Manufacturers are devoted to developing BIM content, when their customers use it to design BIM models. And engineers only design BIM models when the scope of work prescribes the BIM construction method. This denotes the critical role of the client in the adoption of BIM. And because initiatives like a BIM-based e-marketplace increase supply chain efficiency, clients can perceive significant benefits from BIM. Clients, which includes governments, should consider stimulating the BIM construction method in projects.

The results of this research identify the position of wholesale as a barrier for adoption of e-marketplaces by manufacturers. The added value of wholesale services obstructs marketplace adoption by manufacturers. As argued by academia like Zhu (2002) and Parker et al. (2016), manufacturers can significantly benefit from participating on e-marketplaces. Manufacturers should consider looking into outsourcing services to compete the added value of wholesale.

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APPENDICES

A Industry Expert Interviews

A.1 Preparation Document

To prepare the participants of the industry expert interviews for the topic, an introduction is distributed some days before the interview. Since all participants of the focus group at Stabiplan are Dutch, the introduction is written in Dutch. The preparation document is given in Figure 27.

A.2 Interview Protocol

Example interview questions

Construction culture
How do actors in the construction industry do business?
What is the role of trust in the process of an order? Is a good name enough?
What is the role of negotiation in the construction culture?
How innovative is the construction/MEP sector? How much resistance to change? Do you have examples of innovations that succeeded?

E-commerce
What do you expect of the development of construction e-commerce?
What art the incentives for engineers/manufacturers/wholesale to participate on an open e-commerce platform?
What art the barriers for engineers/manufacturers/wholesale to participate on an open e-commerce platform?
Why does the building services industry fall behind on e-commerce compared to b2c markets?
Why do online marketplaces connected to wholesalers do work, and why hesitate manufacturers to create their own supply chain?
Have you heard other actors (manufacturers or engineers) about the idea of an e-commerce platform connected to BIM software?

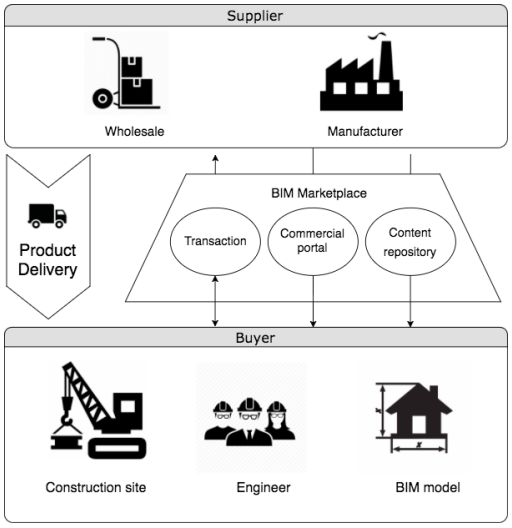
Supply chain
What are the intermediaries in the construction supply chain?
What is the added value of wholesale in the supply chain? Why are they so large and powerful?
Which manufacturers would be interested in cooperation to setup an e-commerce platform?
Should we collaborate with wholesale or fight them?

Platform
What do you expect from the MEPcontent platform in the future?
How can we make the platform grow and attract manufacturers and users?
In the end multisided platforms often have the winner-takes-it-all result, do you think this will happen for the MEPcontent, BIMstore, BIMobject platforms?

Data collection
Do you know interesting external parties (engineers/manufacturers/wholesalers) to interview?

BIM Marketplace

Dit document geeft een beknopte introductie van het concept 'BIM Marketplace'. Een BIM Marketplace is een samenvoeging van een online marktplaats en een content platform zoals MEPcontent.eu. Het idee volgt uit de adoptie van de BIM-werkwijze in de bouwsector, en de opkomst van de digitale economie in b2c sectoren. Figuur 1 geeft de BIM Marketplace op een zo conceptueel mogelijke manier weer in de markt context. Aanbieders, dat kunnen groothandels of fabrikanten zijn, komen in contact met installateurs via het platform. Zowel productpresentatie, BIM content uitwisseling en de transactie vinden allemaal plaats op het platform. Alleen de product levering verloopt vervolgens buitenom de marktplaats.



Figuur 1 BIM Marketplace, contextueel schema

De belangrijkste eigenschap van een marktplaats, zoals de BIM Marketplace, is dat er meerdere aanbieders, en meerdere afnemers samenkomen. Deze 'meerzijdigheid' impliceert meteen de belangrijkste eigenschap van een marktplaats, namelijk netwerk effecten. Zonder voldoende leveranciers is het voor een installateur niet interessant om deel te nemen aan de marktplaats. En zonder veel installateurs is het voor een leverancier niet interessant om zijn producten aan te bieden. De platform eigenaar loopt daarom in de beginfase altijd tegen het kip/ei probleem aan. De functionaliteiten van BIM Marketplace zijn te verdelen in drie categorieën. Als eerste biedt een 'commercial portal' leveranciers de mogelijkheid om marketing content bij de installateur aan te bieden. Als tweede bevat een 'content repository' alle CAD en BIM content die bij producten op het platform horen. En als laatste biedt een 'transaction portal' de mogelijkheid om transactie gerelateerd contact tussen leverancier en afnemer mogelijk te maken.
Uiteraard zijn er nog vele aanvullende functionaliteiten aan het platform toe te voegen die ook eventueel door derden gefaciliteerd kunnen worden. Voorbeelden van aanvullende functionaliteiten zijn: data-analyse, BIM content ontwikkeling, betalingssystemen, logistieke dienstverlening, contracten opstellen en de uitwisseling van BIM en CAD modellen.

Figure 27 Industry expert interview introduction

A.3 Coded Transcripts

The transcripts from the industry expert interviews are coded using a color coding method. The codes correspond to the 13 hypothetical and emergent barriers. Table 21 gives an overview of the codes and corresponding colors.

Table 21 Color code table, industry expert interview

Code	Barrier	Type	Color code
1	Fragmented structure	Hypothetical	Grey
2	Information transparency	Hypothetical	Green
3	Interoperability	Hypothetical	Red
4	Internal business processes	Hypothetical	Red
5	Human resources	Hypothetical	Brown
6	Technological investment costs	Hypothetical	Pink
7	Lack of legal framework	Hypothetical	Purple
8	Lack of technology trust	Hypothetical	Grey
9	Resistance to change	Hypothetical	Yellow
10	Traditional construction delivery method	Emergent	Blue
11	Negotiation culture	Emergent	Green
12	Lack of awareness	Emergent	Blue
13	Logistic services wholesale	Emergent	Turquoise

P1 (20-04-2017, 30 min)
The culture of the construction industry is traditional and there is a high resistance to change. Price negotiation is an important aspect of the business in the construction industry. Some buyers use standard price agreements with wholesalers, some buyers negotiate an individual price for every project. This also depends on the project size. Interviews with buyers at large companies can clarify the process in more detail. Sales department of Stabiplan could give contact details of large buyers.
P1 recognizes the low adoption of e-commerce processes in the construction industry. He first notices that Stabiplan is specialized in the building services (MEP = Mechanical Electrical and Plumbing) industry. This building services industry can potentially benefit a lot from e-commerce because it involves standardized products and solutions. The traditional construction industry working with raw materials has possibly less benefit from online business. The reason why the MEP industry is less engaged in e-commerce than other industry is besides resistance to change the role of intermediates like wholesalers. P1 thinks they block development of e-commerce platforms because they fear that their added value will shrink. According to P1 these phenomena could be an interesting subject of the study.
Wholesale will not be very enthusiastic about a BIM-based e-marketplace because they cannot control supply. A single wholesaler can commit to an e-commerce platform but will probably not collaborate with other wholesale companies on the platform. How to deal with this situation?
In the current MEP industry there are three large players: engineers, manufacturers and wholesale companies. In what way will these roles change due to a two-sided platform? What is the added value of wholesale? Currently logistics and warranty are important responsibilities of wholesale. Can the manufacturer take all these responsibilities? What aspects of the role of wholesale are covered by the platform? Can data analytics generate customer knowledge like wholesale companies do in the current model?
Research topics that could be relevant according to P1: what determines the speed of growth of an e-commerce platform in an industry like the construction industry? Culture? Or power play of stakeholders?
P1 is also not sure about the added value of a two-sided platform of the manufacturer. P1 advise to apply for the 'Shopping tomorrow' platform where also some B2B experts are discussing the possibilities of e-commerce.

P2 (20-04-2017, 30 min)
P2 believes that the MEP industry will transform to an e-commerce industry but that the investment has to be small for manufacturers. Currently there are three parties involved in the design of a model: the designer, the calculator and a buyer. Most of the time these are separate roles. This implies that the designer is not in full control when he places components in a model. The client, calculator and buyer are also influencing the model choices. P2 thinks this is changing and these roles are merging. This means the engineer has more influence in component choices. P2 believes that negotiation is important for large projects and that wholesalers use individual price agreements or quantity discount for smaller projects. Manufacturer does not see the value of customer data and an e-commerce platform. This must be completely clear and the investment costs should be low before manufacturers are willing to cooperate.

P3 (26-04-2017, 30 min)

P3 is a senior sales engineer and has been with the company more than 25 years. He has a lot of experience in the construction and building services industry and communicates with manufacturers every day.
According to P3 the construction and building services is still a conservative market with some exceptions. Most engineers only use brands and components they feel familiar and comfortable with and their choices are based on trust and habit. All tough engineers have a strong connection with specific brands they don't have a significant relation with wholesale. They choose a supplier based on price and delivery time. Also, engineers don't expect much consultancy from a wholesale company. With technical questions, they will go to the manufacturer.
This tradition is changing slowly due to the changing role of the engineer. The designer-, calculator- and buyer role slowly merge together and this trend rationalizes decision-making. Engineers get more freedom to choose between different components and brands. Decision-making is therefore more and more based on technical data and prices instead of gut feeling and habit. The decision power of engineers is still limited by the details in a scope of work. A scope of work is constructed by the client and an advisor. Most of the details are generic but also contain suggestions for brands. These suggestions are often based on conservative or emotional arguments and cannot be avoided by the engineer easily.
Price agreements in the construction business are often based on a combination of a fixed individual discount and a variable discount based on purchase volume per year. Price agreements for individual projects happen regularly but only for larger projects or special orders. Wholesale companies that provide engineers with discount are often so powerful that they can shift discounts to the manufacturers.
The major part of the supply chain in construction and building services is mediated by wholesale. Some manufacturers supply directly to the engineer but those are mostly custom-made solutions with corresponding service. According to P3 wholesale intermediates are a pain to manufacturer but cannot yet be avoided because of two reasons. First wholesale can keep stock and corresponding risk. Second wholesale companies have a lot of experience in construction logistics. Especially the logistic activities cannot be easily transferred to the manufacturer or outsourced to a third party. Logistics and especially delivery requires a lot of knowledge about the industry and ideally a relationship with sender and receiver. There are multiple examples of failing collaboration between manufacturers and logistics companies and manufacturers.
There are two incentives for manufacturers to avoid wholesale. First a financial incentive because wholesale companies squeeze profit margins of manufacturers. The second reason is that wholesale blocks the flow of customer data. Manufacturers are often not able to know their customer and their preferences because the buyer only communicates with wholesale.
Customer data mined in a BIM content or e-commerce platform like MEPcontent could potentially be valuable to manufacturers. Some manufacturers don't know how to use customer data or are worried by privacy issues. Others want to know how and by whom their components are used to maximize value for the engineer. Engineers are often not completely sure which component to choose and customer data could help manufacturers to advise engineers.
P3 thinks that e-commerce will play a role in the building services industry but always a supporting role. Engineers are willing to order components online but only for repeating business or simple orders. Emotional connection with a brand and people will always be important. Trust and added value for engineers should be larger because they are sceptic about the use of customer data. According to P3 MEPcontent is not large enough to commercialize data. With a larger installed base the value of customer data increases.

P4 and P5 (25-04-2017, 25min)
P4 believes that culture in the MEP industry can change quickly due to the BIM adoption. He recognized innovative trends in the past years and he believes BIM will put new people in charge that can force a cultural change. This also correlates with the larger role of the engineer in the construction process. Roles of designer, buyer and calculator merge together and the engineer behind the model has a higher influence on the component choices.
According to P4 and P5 the logistic process of wholesale is extremely efficient and fast. This is something difficult to achieve for manufacturers and it will be a barrier. Another barrier is the transformation from wholesale intermediation and direct supply. A parallel supply chain can be a lot of administrative work for manufacturers of small inexpensive components. Early adopters of an e-commerce platform could be niche manufacturers with expensive components and low production volume.
P4 and P5 are not very familiar with the construction supply chain.
What steps should the MEPcontent platform make to gain a larger installed base? MEPcontent should focus more on international available but locally adapted BIM content. The platform should involve data analytics to increase the added value for manufacturers and engineers. In the current datamining techniques of Stabiplan it is nog possible yet to extract project information. This is very valuable tot the manufacturer. Apps could significantly increase data extraction because the project is monitored from the beginning.
The costs for manufacturers are not a problem. According to P4 and P5 a free platform would have a negative low-quality image. This would hinder the entrance of manufacturers.
What can be first steps in the transformation to an e-commerce platform? Engineers should be familiar with ordering components online. This can be initiated with a collaboration with the wholesalers by making a single-sided platform. Make applications that include direct orders at wholesalers. This will change the culture slowly and make it more easy to setup a two-sided platform.

P6 (06-06-2017 60min)
P6 has been within the company from the very beginning and is devoted to sales. Because of his role in the company P6 knows the engineer, the culture and supply chain very well. According to P6 there are multiple barriers for manufacturers to participate on an open e-commerce platform. First the logistics and commercial operations are hard to organize by manufacturers. Logistics processes of wholesale companies are very efficient, fast and complete. Especially for manufacturers with smaller and cheaper solutions, these processes will become very complex. Second manufacturers cannot afford to maintain stocks and achieve low delivery times. These low delivery times achieved by wholesale are especially relevant to compensate for mistakes and corrections in the project design. With the development of better BIM models these mistakes and corrections are less frequent and manufacturers may be able to adopt a build-to-order strategy. Also BIM software developers, like Autodesk, are not ready to organize commercial and logistics processes.
Barriers for engineers to participate on an open e-commerce platform are the result of cultural aspects. P6 confirms the building services industry is a conservative market. Processes are hard to change and jobs of for example calculators and buyers are protected. Cultural change may be possible when innovative pioneers form an examples. Engineers are often emotionally connected to a wholesale supplier. The complexity and uniqueness of the product hinders the adoption of e-commerce compared to b2c markets. Another barrier is that engineering companies expect that knowledge and skills of BIM is concentrated to a few engineers. These skilled people are very rare on the job market.
A barrier in the building process is regulation of open tender bidding. For the construction of every large public or private building, open tender bidding determines the engineer that gets the job. A notary collects bids from engineers and often selects the cheapest offer. This decreases transparency in quality and puts significant pressure on prices. P6 emphasize the price sensitive character of the building service industry. Decisions are often made based on prices and that puts pressure on wages and earnings. P6 thinks this price oriented culture hinders innovation.
Incentives for manufacturers to participate on an open platform could be: financial, customer data collection and controlled marketing and sales Some manufacturers could use customer data to anticipate for demand but most are not prepared. There is a chicken/egg problem in the utilization of customer data. Manufacturers can avoid the advantage of stocks from wholesale by leveraging customer data using anticipated production, but until manufacturers don't directly supply to engineers this customer data is not available.
Many small executive manufacturers feel the need to control their own marketing campaigns and sell directly to the customer.
The BIM ideas describe one centralized flow and stock of data around a project. This implies one common platform for the whole Architectural Engineering and Construction industry. According to P6 a single platform would be a utopia because of two reasons Actors in the building services and construction industry don't easily share data and models because of the conservative exchange culture. Collecting data and building models costs time and money so they don't easily share this with other stakeholders. The second reason is that developing one standard for data exchange is hard if not impossible. IFC has most potential to become the BIM standard but still there exist a lot of sub standards for niche markets and in different countries. CONSTRUCTION industry still has a local focus and often looks at BIM as a marketing tool.

P7 (07-06-2017)
P7 has been with Stabiplan for about 10 years and has a longer career in wholesale companies in the building services industry. P7 also believes the building service industry is a conservative industry. Engineering companies often have a short term focus that hinders the adoption of BIM and e-commerce.
The procurement process starts when a client calls for an advisor to develop a scope of work. A scope of work often gives suggestions about component brand choices, but these suggestions are often ignored. To determine the engineer that gets the job, clients will utilize his relationships with engineers (1), organize selective tender bidding (2) or open tender bidding (3). Public buildings often use open tender bidding to sell the job to an engineer. Agreements about the aspects of tenders that determine the winner are set up front. This can be price, delivery times, quality etc.. Public tender biddings are becoming less popular because the transparent online tender biddings attract more and more engineers. This puts significant pressure on prices.
According to P7 engineers are emotionally connected to wholesale companies but because of the transparent market this connection gets slowly weaker. Engineers are motivated by cost and delivery time reduction but will only change their processes if necessary. The relationship of an engineer with component brands is often stronger and more historically embedded than the relationship with suppliers.
Wholesale companies apply successful defensive strategies in this transparent market. They adopt consulting activities and try to provide as much service as possible to achieve a lock-in effect. Delivery times get shorter and wholesalers adopt a larger assortment. P7 believes that conventional intermediaries will experience a margin squeeze and will disappear within five years if they don't develop these supporting service activities.
Negotiation and discount is very important. Suppliers apply discounts based on quantity and relationship but in some cases engineers bypass the normal discount structures using tender bids. They invite a selection of suppliers to a tender bidding and the cheapest option gets the deal. This happens only with standardized low-tech solutions like piping.

B Focus group

B.1 Preparation Documents

To invite participant to the focus group, an invitation is sent two weeks up front. This invitation is given in Figure 28. To prepare the participants of the focus group for the topic, a preparation document is distributed one week before the focus group. Since all participants of the focus group at Stabiplan are Dutch, the preparation is written in Dutch. The preparation document is given in Figure 29.
To collect data from the personal context of the participants, their opinion on the value of a BIM-based e-marketplace, and their opinion on design of a BIM-based e-marketplace, a questionnaire in Dutch is distributed among the participants. This questionnaire is given in Figure 30, Figure 31 and Figure 32. The questionnaire consists of questions on a ratio scale, likert scale and open scale.
Table 22 gives the results of the questionnaire. The answers on a likert scale are given as a number from 1= 'totally agree' to 5='totally disagree'.

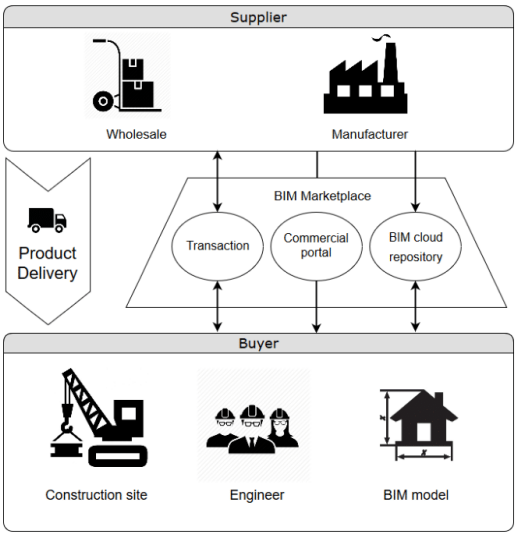
Invitation

Beste collega
Zoals u heeft gemerkt ben ik de afgelopen tijd bezig geweest met mijn afstudeeronderzoek binnen Stabiplan. In mijn project onderzoek ik alle business aspecten van een BIM Marketplace in de installatietechnische sector. Een BIM Marketplace is een BIM content platform met e-commerce functionaliteit. Leveranciers en installateurs komen hier samen om BIM content uit te wisselen en transacties af te handelen. Het concept van een BIM Marketplace is veelbelovend maar loopt in de praktijk tegen allerlei barrières aan. De afgelopen tijd ben ik bezig geweest om deze problemen in kaart te brengen en heb een aantal tools die zouden kunnen helpen om de problemen te tackelen.
Graag zou ik je uitnodigen om in een workshop na te denken over de toekomst van ons MEP content platform. De workshop zal een open brainstorm structuur hebben en ongeveer 120 minuten in beslag nemen. De belangrijkste aspecten van de BIM Marketplace komen aan bod zodat we samen tot een eerste ontwerp komen. In het vervolg van mijn onderzoek zal ik de resultaten van de workshop toetsen bij fabrikanten, groothandels en installateurs.

Figure 28 Focus group invitation

Beste collega,

Goed dat je deelneemt aan de BIM Marketplace workshop komende vrijdag. Ter voorbereiding op de sessie wil ik het concept alvast uitleggen. Ik wil je vragen de beschrijving door te nemen en vervolgens de korte vragenlijst in te vullen.
Allereerst een beknopte introductie van het concept 'BIM Marketplace'. Een BIM Marketplace is een samenvoeging van een online marktplaats en een content platform zoals MEPcontent.eu. Het idee volgt uit de adoptie van de BIM werkwijze in de bouwsector, en de opkomst van de digitale economie in b2c sectoren. Figuur 1 geeft de BIM Marketplace op een zo generiek mogelijke manier weer in de markt context. Aanbieders, dat kunnen groothandels of fabrikanten zijn, komen in contact met installateurs via het platform. Productpresentatie, BIM content uitwisseling, BIM model uitwisseling en transacties vinden allemaal op het platform plaats. Alleen de product levering verloopt vervolgens buitenom de marktplaats. Er zijn meerdere mogelijkheden om dit concept in de praktijk uit te werken.



Figuur 1 BIM Marketplace, contextueel schema

De belangrijkste eigenschap van een marktplaats, zoals de BIM Marketplace, is dat er meerdere aanbieders, en meerdere afnemers samenkomen. Deze 'meerzijdigheid' impliceert meteen de belangrijkste eigenschap van een marktplaats, namelijk netwerkeffecten. Zonder voldoende leveranciers is het voor een installateur niet interessant om deel te nemen aan de marktplaats. En zonder veel installateurs is het voor een leverancier niet interessant om zijn producten aan te bieden. De platform eigenaar loopt daarom in de beginfase altijd tegen het kip-ei probleem aan. De functionaliteiten van BIM Marketplace zijn te verdelen in drie categorieën. Als eerste bied een 'commercial portal' leveranciers de mogelijkheid om marketing content bij de installateur aan te bieden. Als tweede bevat een 'content repository' alle CAD en BIM content die bij producten op het platform horen. Als laatste biedt een 'transaction portal' de mogelijkheid om transactie gerelateerd contact tussen leverancier en afnemer mogelijk te maken.
Uiteraard zijn er nog vele aanvullende functionaliteiten aan het platform toe te voegen die ook eventueel door derden gefaciliteerd kunnen worden. Voorbeelden van aanvullende functionaliteiten zijn: data analyse, BIM content ontwikkeling, betalingssystemen, logistieke dienstverlening, contracten opstellen en de uitwisseling van BIM en CAD modellen.

Figure 29 Focus group preparation document

Vragenlijst

De volgende vragen zijn bedoelt ter voorbereiding voor de workshop 'BIM Marketplace' op 22 september 2017.

1. Persoonlijk

   a. Hoe lang bent u werkzaam in de bouwsector?

…… jaar

   b. Hoe lang bent u werkzaam in de installatietechnische sector?

…… jaar

   c. In hoeverre beschouwt u uzelf als een sector expert binnen Stabiplan?

Zeker	Enigszins	Neutraal	Niet echt	Totaal niet

   d. In hoeverre beschouwt u uzelf als een innovatieve denker binnen Stabiplan?

Zeker	Enigszins	Neutraal	Niet echt	Totaal niet

   e. In hoeverre kent u de cultuur en werkwijze van installateurs?

Zeer goed	Goed	Neutraal	Niet goed	Totaal niet

   f. In hoeverre kent u de cultuur en werkwijze van technische groothandels?

Zeer goed	Goed	Neutraal	Niet goed	Totaal niet

   g. In hoeverre kent u de cultuur en werkwijze van installatietechnische fabrikanten?

Zeer goed	Goed	Neutraal	Niet goed	Totaal niet

2. BIM Marketplace
   In hoeverre komen de volgende stellingen overeen met uw opinie?

   a. Het concept van een BIM Marketplace is veelbelovend.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

   b. Stabiplan heeft de marktpositie en kennis om een BIM Marketplace te ontwikkelen.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

   c. Een BIM Marketplace kan waardevol zijn voor installateurs.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

   d. Een BIM Marketplace kan waardevol zijn voor installatietechnische fabrikanten.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

   e. Een BIM Marketplace kan waardevol zijn voor installatietechnische groothandels.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

   f. Een BIM Marketplace kan waardevol zijn voor de platform eigenaar, in dit geval Stabiplan.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

3. Platform ontwerp

Figure 30 Focus group preparation questionnaire I

Het ontwerp van een BIM Marketplace als commercieel platform behelst een aantal kritieke afwegingen. Hieronder staan een aantal afwegingen waarover u uw mening kunt geven. Deze afwegingen zullen een belangrijke rol spelen in de workshop. De vragen bedekken slechts een klein deel van de afwegingen die in de workshop behandelt worden. De bedoeling is dat u al nagedacht heeft over de meest cruciale ontwerpkeuzes.

a. Een BIM Marketplace moet vanaf het begin zo open mogelijk zijn voor aanbieders. Fabrikanten en groothandels mogen altijd producten aanbieden, wijzigen of verwijderen. Hierdoor is de drempel voor leveranciers laag en ontstaat er een grote variëteit aan producten.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

b. Een BIM Marketplace moet aanvankelijk samenwerken met één groothandel per product categorie, zodat groothandels minder concurrentie op het platform ervaren. Voorbeeld: Voor elektrotechnische producten werkt het platform samen met Sonepar, maar sanitair producten worden geleverd door Wasco.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

c. Een BIM Marketplace moet aanvankelijk samenwerken met één groothandel per regio per product categorie, zodat groothandels minder concurrentie op het platform ervaren. Voorbeeld: In de categorie sanitair werkt het platform in Nederland samen met Wasco, maar in Duitsland met Reuter.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

d. Door een BIM Marketplace open te stellen voor logistieke dienstverleners, kunnen fabrikanten makkelijker deelnemen aan het platform en de logistieke kosten beperken. In de praktijk kiest een installateur na de bestelling een logistieke dienstverlener die de verzending vervolgens afhandelt. Meerdere externe logistieke dienstverleners kunnen hun diensten aanbieden op het platform.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

e. Een BIM Marketplace moet ruimte bieden voor externe BIM content ontwikkelaars. In de praktijk werkt dit als volgt: een leverancier upload productdata naar het platform en kan vervolgens een content ontwikkelaar kiezen. Deze derde partij ontwikkeld vervolgens BIM content en publiceert het op de marktplaats.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

f. Een leverancier mag zelf bepalen welk type content, welk bestandstype en welk detailniveau hij hanteert. Dit verlaagt de instapkosten voor leveranciers om aan de marktplaats deel te nemen.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

g. Een leverancier mag zelf bepalen welk type en kwaliteit marketing materiaal hij hanteert. Dit verlaagt de instapkosten voor leveranciers om deel te nemen aan het platform. Het platform stelt dus geen eisen aan de kwaliteit van productafbeeldingen en productomschrijvingen.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

h. De platformeigenaar van een BIM Marketplace moet er streng op toezien dat fabrikanten hun content en productspecificaties regelmatig updaten.

Figure 31 Focus group preparation questionnaire II

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

i. De platformeigenaar van een BIM Marketplace moet de publicatie van producten streng controleren zodat de marktplaats altijd kwalitatief hoogwaardige producten bevat.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

j. Op een BIM Marketplace moeten zowel de fabrikant, als de installateur aan de platform eigenaar betalen.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

k. Aanbieders moeten de platform eigenaar een vast percentage van de behaalde omzet betalen.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

4. Workshop
   a. Hoe nuttig vindt u de workshop/focus-group methode en waarom? Denk ook terug aan de workshop van Arent van 't Spijker over "Data is het nieuwe olie".

   b. Heeft u nog opmerkingen of tips voor de invulling van de workshop komende vrijdag?

Figure 32 Focus group preparation questionnaire III

Table 22 Focus group preparation questionnaire results

Question	Scale	Participant P5	P2	P8	P3	P9
1a	Ratio	25	23	1	30	1
1b	Ratio	25	23	1	30	1
1c	Likert	2	2	2	1	3
1d	Likert	2	3	1	2	1
1e	Likert	2	2	3	2	4
1f	Likert	3	3	4	3	4
1g	Likert	3	3	2	1	4
2a	Likert	1	2	2	3	4
2b	Likert	2	3	2	3	4
2c	Likert	1	2	1	2	2
2d	Likert	1	3	1	2	2
2e	Likert	3	2	1	3	4
2f	Likert	1	2	1	2	2
3a	Likert	2	1	2	2	2
3b	Likert	4	5	3	4	4
3c	Likert	4	5	3	4	4
3d	Likert	2	2	1	4	2
3e	Likert	4	4	2	3	2
3f	Likert	4	4	4	4	2
3g	Likert	2	2	2	2	2
3h	Likert	2	4	1	2	3
3i	Likert	2	4	3	3	3
3j	Likert	1	1	3	3	4
3k	Likert	3	1	1	4	2

4a	Open	Goed om met een groepje richting/ideeën te bespreken. Met elkaar kom je verder
		Heel nuttig. Met elkaar probeer je de stappen te zetten. Met elkaar vorm je een mening. Soms krijg je heel andere inzichten door inbreng van een ander
		Zolang workshop daadwerkelijk interactief is en zaken worden uitgewerkt is het nuttig. Moet geen eenrichtingsverkeer zijn
4b	Open	Zorg voor voldoende interactiemogelijkheden en bewaak de tijd per spreker zodat iedereen voldoende aan bod kan komen. Anders worden de 'stillen' overschaduwd.

B.2 Introduction Presentation

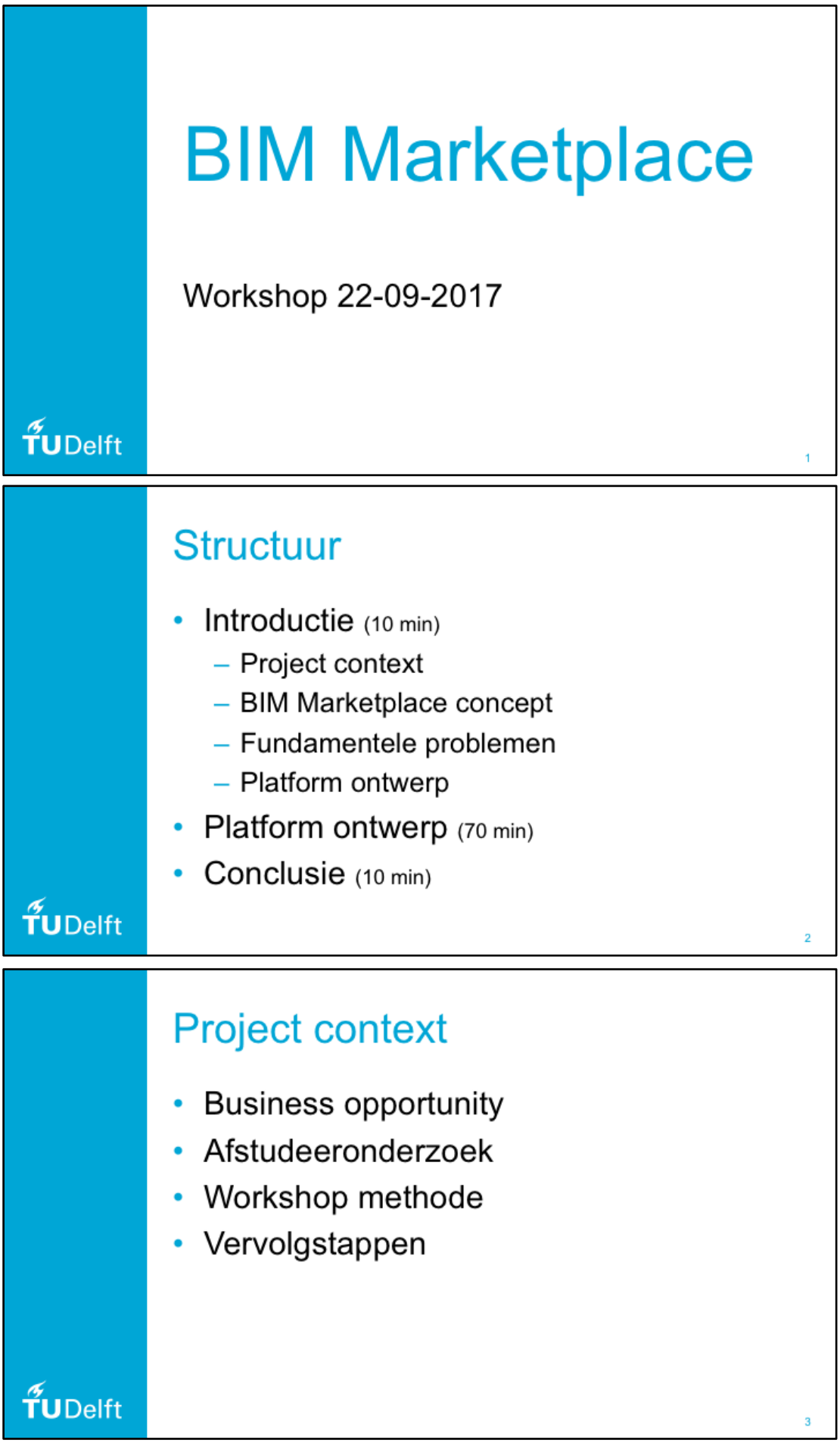


Figure 33 Focus group introduction presentation I

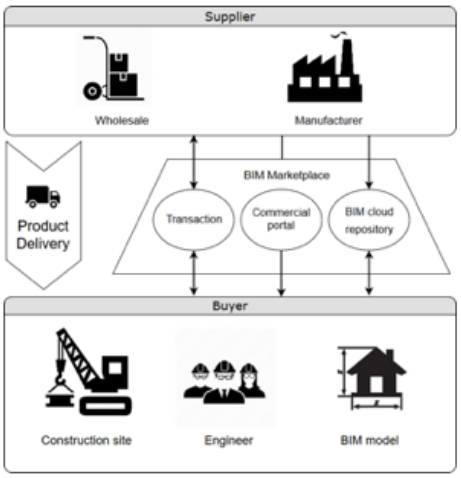
BIM Marketplace

- What's new?
  - Two-sided platform
  - Transparrantie
  - Data opportunity
- Content platform + E-commerce
- Markt context
- Functional model

TUDelft

4

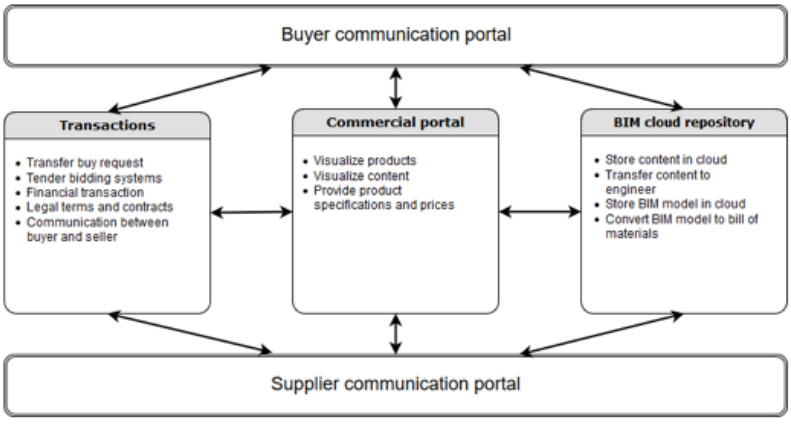
Markt context



TUDelft

5

Functional model



TUDelft

6

Figure 34 Focus group introduction presentation II

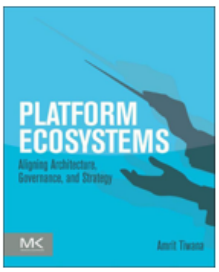
Platform adoptie

- Rol van het bestek
- Aanbesteding
- Conservatisme
- Onderhandelingscultuur
- Gefragmenteerde sector
- Business processen niet aangepast
- Werknemers en rolverdeling
- Hoge investering
- Gebrek aan wetgeving
- Gebrek aan vertrouwen in veiligheid
- Gebrek aan data standaarden
- Gebrek aan kennis van de voordelen
- Transparantie weerhoud groothandels
- Beperkte kennis van data
- Fabrikanten moeten hoge logistieke kosten

TU Delft

Platform ontwerp

- Generiek naar specifiek(er)
- Design parameters
  - Modularity
  - Control
  - Pricing
  - Complementary services
- Structuur van de workshop



TU Delft

Adoption barriers (section 2.7)	Platform design parameters (section 3.4)				
	Modularity	Decision right authority	Control	Pricing	Complementary services
(1) Scope statement					
(2) Tender bidding process					
(3) Resistance to change					
(4) Negotiation culture					
(5) Fragmented nature of the industry					
(6) Internal business process not ready					
(7) Human resources and role distribution					
(8) High technological investments					
(9) Lack of legal structures					
(10) Lack of trust in security					
(11) Lack of data standards					
(12) Lack of awareness of BIM functionality					
(13) Wholesale companies fear transparency					
(14) Low awareness of customer data value					
(15) Manufacturers experience high logistic costs					

TU Delft

Figure 35 Focus group introduction presentation III

B.3 Evaluation Questionnaire

To evaluate the focus group, an evaluation questionnaire is distributed. The questionnaire is given in Figure 36 and Figure 37. Since the participants of the focus group are Dutch, the questionnaire is written in Dutch. The results of the evaluation questionnaire are given in Table 23.

Table 23 Focus group evaluation results

		Participant			
Question	Scale	P5	P8	P3	P9
1	Likert	2	2	2	2
2	Likert	1	2	2	1
3	Likert	2	2	2	1
4a	Number	1	2	2	1
4b	Open	Dat is de basis, geeft een globaal plaatje hoe een marketplace zou moeten werken	Heeft de meeste strategische impact op de organisatie. Overige onderdelen gaan meer over de invulling	Openheid en Revit standaarden raken elkaar bij dit onderwerp. Goede verdieping	Je moet vooraf goed de belangen van de diverse stakeholders bepalen en kiezen hoe je hierop inspeeld.
5a	Number	3	5	3	5
5b	Open	Heeft minst consequenties voor structuur/strategie	Hangt er grotendeels vanaf hoe de BIM-based e-marketplace wordt gerealiseerd en is daardoor ook erg abstract en afhankelijk van de ontwikkeling.	Was het meest triviaal. De EMCS als leidraad	Moet je vooral bespreken met de gebruikers dus kan in een later stadium
6	Likert	2	1	2	2
7	Likert	1	2	3	2
8	Likert	3	3	2	3
9	Likert	2	1	2	2
10	Ordinal	9	9	7	8
11	Open	Goed om met elkaar te brainstormen hoe een idee te vormen naar een levensbatbaar concept	Kennis intensief, mensen met visie die het concept konden onderbouwen en toetsen met praktijkervaring of met ervaring vanuit ander branches.	Open ruimte voor invulling	Heldere stellingen die leiden tot goede discussie en daarna tot gezamelijke visie
12	Open	Ivm beperkte tijd verschillende scenario's wat concreter voorbereiden/uitwerken	Meer input ter voorbereiding om een scherper beeld te hebben van de BIM-based e-marketplace en de kansen en bedreidingen voor het realiseren ervan	Vooraf meer info. Duidelijke tijdlijn stellen en vasthouden. Laatste onderwerpen kregen nu onvoldoende tijd.	Tijd per punt bleek meer nodig

Beste collega,

Dank dat u heeft deelgenomen aan de 'BIM Marketplace' workshop! Om de betrouwbaarheid van de resultaten vast te stellen verneem ik graag hoe u de workshop heeft ervaren. Ik wil u daarom vragen de volgende korte vragenlijst in te vullen. Alvast bedankt!

Evalueer de volgende stellingen:

1. De workshop voldeed aan mijn verwachtingen.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

2. Het niveau van de workshop was voldoende.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

3. De voorbereiding voor de workshop was voldoende.

Volledig mee eens	Mee eens	Neutraal	Mee oneens	Volledig mee oneens

Hieronder vind u een overzicht van de vijf onderdelen waaruit de workshop was opgebouwd.

I	*"Generiek naar specifiek(er)"* In dit onderdeel hebben we de verschillende praktische uitwerkingen van een BIM Marketplace uitgedacht. We hebben een cloud BIM model besproken maar ook een uitwerking met fabrikant specifieke apps.
II	*"Modularity"* In deel II hebben we nagedacht over de openheid van het platform t.o.v. gebruikers en producten. Moeten we samenwerken met meerdere één groothandel of met meerdere fabrikanten? Willen we een ebay achtig model of juist een model met fabrikant specifieke PLIPS?
III	*"Control"* In deel III hebben we nagedacht over de regels die we toepassen op het platform en in hoeverre de kwaliteit van producten of content weerspiegelt op de reputatie van het platform.
IV	*"Pricing"* In deel IV hebben we nagedacht over de mogelijkheden om gebruikers te subsidiëren. Voorbeelden van subsidie zijn content ontwikkelen, helpen met marketing of cursussen aanbieden.
V	*"Complementary services"* In deel V hebben we nagedacht over de mogelijkheden voor aanvullende dienstverlening op het platform. Aanvullende dienstverleningen zijn o.a. betalingssystemen, logistieke dienstverlening en consultancy.

4. Welk onderdeel van de workshop heeft u als **meest** nuttig ervaren? Geef een korte toelichting

Onderdeel: ……..
Toelichting:

5. Welke onderdelen van de workshop heeft u als **minst** nuttig ervaren? Geef een korte toelichting

Onderdeel: ……..
Toelichting:

Figure 36 Focus group evaluation questionnaire I

6. Hoe nuttig vond u de workshop voor u zelf?

Zeer nuttig	Redelijk nuttig	Neutraal	Beetje nuttig	Tijdverspilling

7. Hoe efficiënt was de workshop naar uw ervaring?

Zeer efficiënt	Redelijk efficiënt	Neutraal	Inefficiënt	Redelijk inefficiënt

8. Heeft iedere deelnemer een gelijke bijdrage geleverd aan het proces?

Zeer gelijk	Gelijk	Neutraal	Ongelijk	Zeer ongelijk

9. Heeft u het gevoel gehad dat u voldoende kans kreeg om uw mening en bijdrage te leveren?

Zeer gelijk	Gelijk	Neutraal	Ongelijk	Zeer ongelijk

10. Hoe zou u de workshop waarderen op een schaal van 1 tot 10?

11. Wat vond u positief aan de BIM Marketplace workshop?

12. Wat zijn verbeterpunten voor de BIM Marketplace workshop?

2

Figure 37 Focus group evaluation questionnaire II

B.4 Coding Process

The focus group transcripts were coded using Atlas.ti. Figure 38 shows a screenshot of the coding process in Atlas.ti. The middle screen shows the focus group transcripts and right to it the codes that are attached. Figure 39 show a screenshots of coding manager. The code manager shows all 17 codes that were used in the process. Among these 17 codes, code 15, 16 and 17 are labeled as ‘emergent codes’. These codes were not predefined but emerged during the process.

After coding the quotations are exported to excel for further analysis. Figure 40 shows a screenshot of the excel file. The first column shows the code that is attached to the quote in the second column. The third column indicates if the quotation confirms the barrier, and the fourth column shows some further analyzing statements.

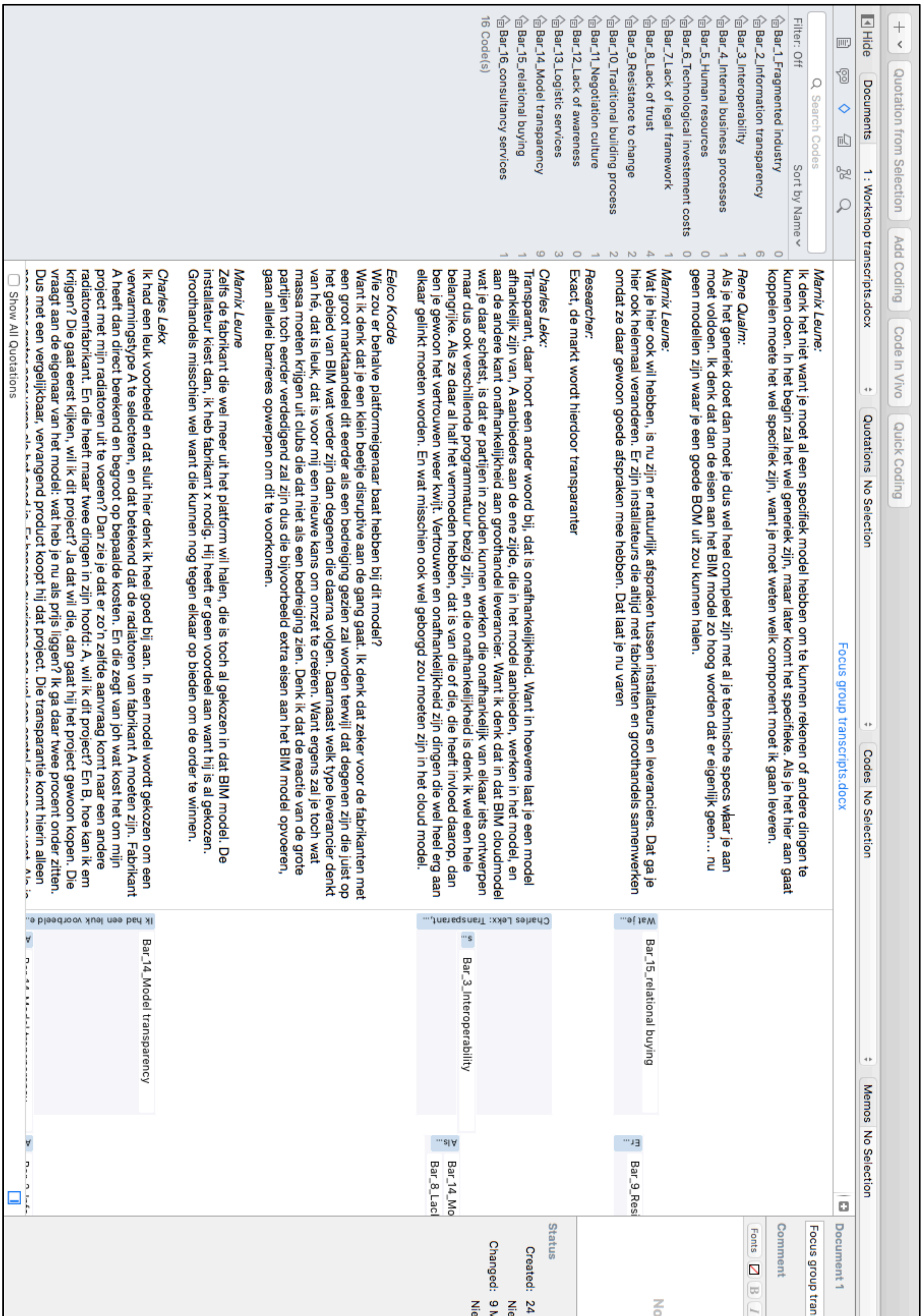
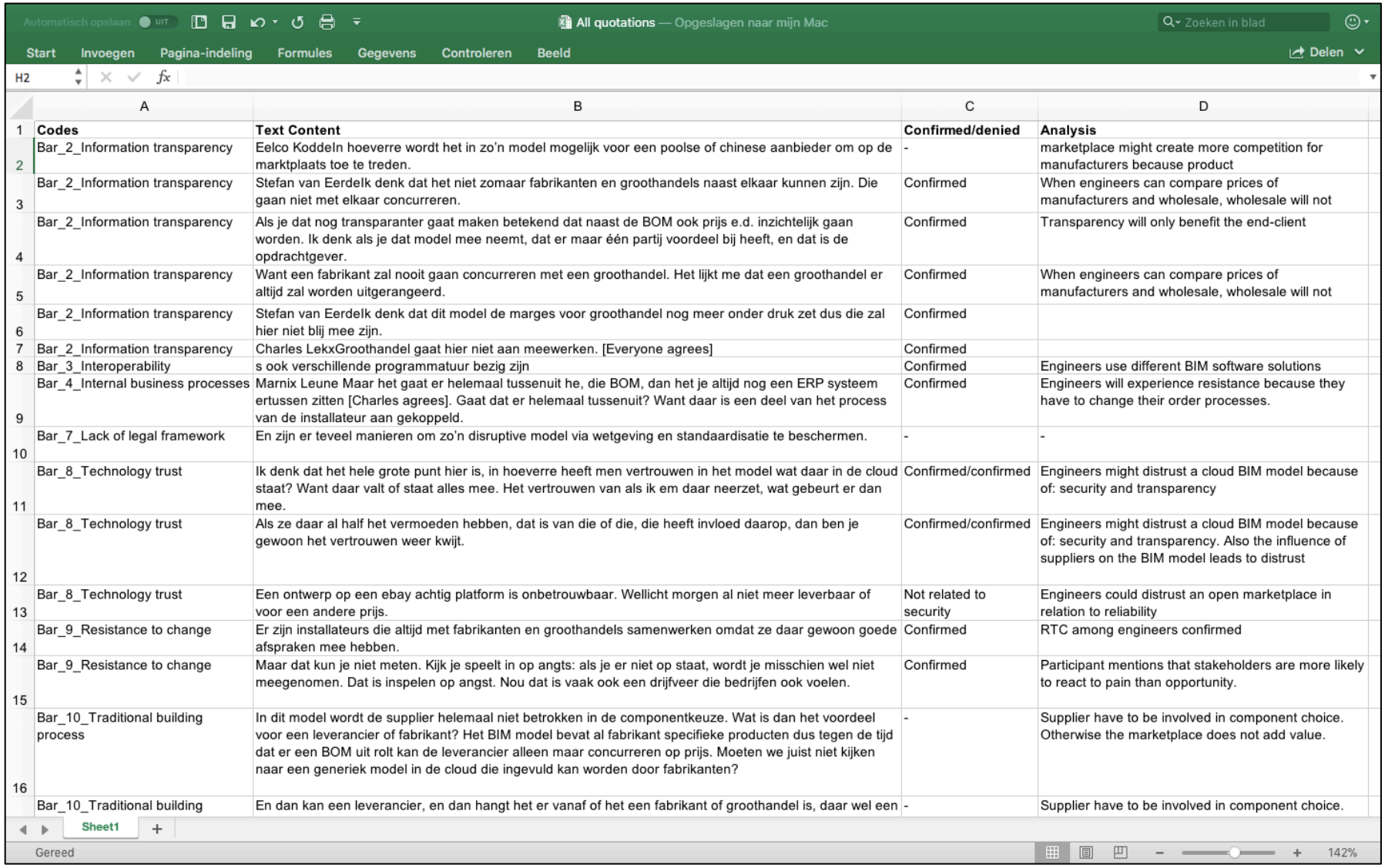


Figure 38 Focus group coding process I

Figure 39 Focus group coding process II



	A	B	C	D
1	**Codes**	**Text Content**	**Confirmed/denied**	**Analysis**
2	Bar_2_Information transparency	Eelco KoddeIn hoeverre wordt het in zo'n model mogelijk voor een poolse of chinese aanbieder om op de marktplaats toe te treden.	-	marketplace might create more competition for manufacturers because product
3	Bar_2_Information transparency	Stefan van EerdeIk denk dat het niet zomaar fabrikanten en groothandels naast elkaar kunnen zijn. Die gaan niet met elkaar concurreren.	Confirmed	When engineers can compare prices of manufacturers and wholesale, wholesale will not
4	Bar_2_Information transparency	Als je dat nog transparanter gaat maken betekend dat naast de BOM ook prijs e.d. inzichtelijk gaan worden. Ik denk als je dat model mee neemt, dat er maar één partij voordeel bij heeft, en dat is de opdrachtgever.	Confirmed	Transparency will only benefit the end-client
5	Bar_2_Information transparency	Want een fabrikant zal nooit gaan concurreren met een groothandel. Het lijkt me dat een groothandel er altijd zal worden uitgerangeerd.	Confirmed	When engineers can compare prices of manufacturers and wholesale, wholesale will not
6	Bar_2_Information transparency	Stefan van EerdeIk denk dat dit model de marges voor groothandel nog meer onder druk zet dus die zal hier niet blij mee zijn.	Confirmed	
7	Bar_2_Information transparency	Charles LekxGroothandel gaat hier niet aan meewerken. [Everyone agrees]	Confirmed	
8	Bar_3_Interoperability	s ook verschillende programmatuur bezig zijn	Confirmed	Engineers use different BIM software solutions
9	Bar_4_Internal business processes	Marnix Leune Maar het gaat er helemaal tussenuit he, die BOM, dan het je altijd nog een ERP systeem ertussen zitten [Charles agrees]. Gaat dat er helemaal tussenuit? Want daar is een deel van het process van de installateur aan gekoppeld.	Confirmed	Engineers will experience resistance because they have to change their order processes.
10	Bar_7_Lack of legal framework	En zijn er teveel manieren om zo'n disruptive model via wetgeving en standaardisatie te beschermen.	-	-
11	Bar_8_Technology trust	Ik denk dat het hele grote punt hier is, in hoeverre heeft men vertrouwen in het model wat daar in de cloud staat? Want daar valt of staat alles mee. Het vertrouwen van als ik em daar neerzet, wat gebeurt er dan mee.	Confirmed/confirmed	Engineers might distrust a cloud BIM model because of: security and transparency
12	Bar_8_Technology trust	Als ze daar al half het vermoeden hebben, dat is van die of die, die heeft invloed daarop, dan ben je gewoon het vertrouwen weer kwijt.	Confirmed/confirmed	Engineers might distrust a cloud BIM model because of: security and transparency. Also the influence of suppliers on the BIM model leads to distrust
13	Bar_8_Technology trust	Een ontwerp op een ebay achtig platform is onbetrouwbaar. Wellicht morgen al niet meer leverbaar of voor een andere prijs.	Not related to security	Engineers could distrust an open marketplace in relation to reliability
14	Bar_9_Resistance to change	Er zijn installateurs die altijd met fabrikanten en groothandels samenwerken omdat ze daar gewoon goede afspraken mee hebben.	Confirmed	RTC among engineers confirmed
15	Bar_9_Resistance to change	Maar dat kun je niet meten. Kijk je speelt in op angts: als je er niet op staat, wordt je misschien wel niet meegenomen. Dat is inspelen op angst. Nou dat is vaak ook een drijfveer die bedrijfen ook voelen.	Confirmed	Participant mentions that stakeholders are more likely to react to pain than opportunity.
16	Bar_10_Traditional building process	In dit model wordt de supplier helemaal niet betrokken in de componentkeuze. Wat is dan het voordeel voor een leverancier of fabrikant? Het BIM model bevat al fabrikant specifieke producten dus tegen de tijd dat er een BOM uit rolt kan de leverancier alleen maar concurreren op prijs. Moeten we juist niet kijken naar een generiek model in de cloud die ingevuld kan worden door fabrikanten?	-	Supplier have to be involved in component choice. Otherwise the marketplace does not add value.
	Bar_10_Traditional building	En dan kan een leverancier, en dan hangt het er vanaf of het een fabrikant of groothandel is, daar wel een	-	Supplier have to be involved in component choice.

Figure 40 Focus group coding process III

C Stakeholder Interviews

C.1 Invitation and Preparation

The participants were invited using the invitation mail shown in Figure 41. To prepare the participants for the interview, a preparation document was send one week before the session. Manufacturers, engineers and wholesale all received a different preparation document with a different perspective. Figure 42 and Figure 43 show the preparation document for manufacturers.

Dear mr/mrs [name],

My name is Niels Koeman, master student at Delft University of Technology. As a graduate intern at MEPcontent, I'm conducting a research project on the future of e-commerce in the building services industry. I have been looking into the possibilities of an e-commerce platform to connect engineers, manufacturers and wholesale through a BIM model. This involves interesting subjects such as: customer data, cloud based modelling and anticipated production. To test this proposition, I'm looking for industry experts with knowledge on BIM. Because you represent [stakeholder company name] and are familiar with the BIM workflow, you could be very helpful for my research. I would like to invite you to think about the next step of BIM. If you're interested I will contact you to make an appointment.
Hope to hear from you.

Kind regards,

NIELS KOEMAN INTERN
STABIPLAN +31 172 65 02 65 WWW.STABIPLAN.NL DISCLAIMER

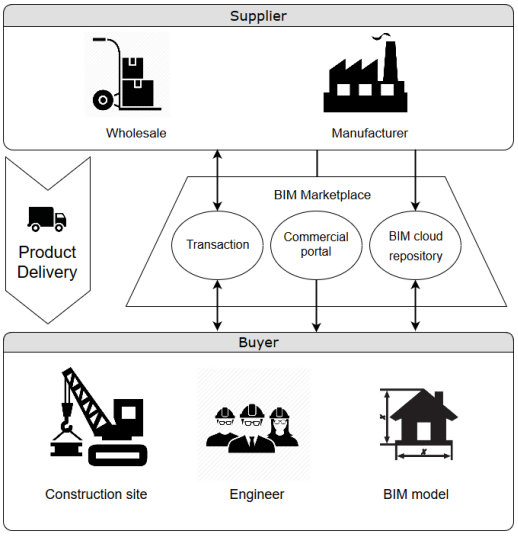
Figure 41 Stakeholder interview invitation

BIM MARKETPLACE INTRODUCTION

The adoption of Building Information Modeling is currently one of the most important trends in the construction industry. The concept of BIM is based on the integration of information management and communication between stakeholders. According to many experts, BIM will also reflect on the integration of commercial processes. Strategy consultant Roland Berger writes in one of their studies: "When BIM really takes off as a platform, it could do to the construction industry what the Amazon platform has done to retail."[1] Here they refer to the impact of BIM on transparency in the market. Open platforms that mediate multiple suppliers and multiple buyers could significantly change the role distribution and added value of stakeholders. Engineers will profit from transparency because prices and products become more easy to compare. Manufacturers will get closer to the engineer and wholesale risks losing added value in the supply chain.[1]

My research project tries to identify the viability of an open e-commerce platform called a 'BIM Marketplace'. I use theoretical design concepts and practical input from industry experts to maximize the added value of a platform for the building service industry.

First I will briefly introduce the concept of a BIM Marketplace. A BIM Marketplace is a merger between a regular online marketplace, and a BIM content platform like MEPcontent.com. Figure 1 gives a very generic contextual model of the BIM Marketplace. On a regular online marketplace like Ebay, suppliers and buyers exchange products or services. Suppliers present their products on the marketplace, buyers issue a purchase and the marketplace arranges a financial transaction. On a BIM Marketplace the suppliers, that can be manufacturers or wholesale, also present products to the buyers, that are engineers. To present a product a supplier uses marketing content, like pictures and text, but also BIM content. An engineer issues a purchase when he imports BIM content in his model and finalizes the model. After that, a transaction is arranged and the product scan be delivered. Note that this concept is very generic and the implementation can take many different forms.



[1] "Turning point for the construction industry", by Roland Berger, link: www.rolandberger.com/nl/Publications/pub_disruptive_impact_of_building_information_modelling_switzerland.html

TU Delft Stabiplan

Figure 42 Stakeholder interview preparation document I

In real life, a BIM Marketplace faces many challenges. In the initial phase of my research I mapped out the fundamental problems of the BIM Marketplace. I will use the interview to test these problems and get more insight in the nature of those problems. I also developed an initial design that I would like to discuss. To prepare I will explain one of the possible practical implementations of a BIM Marketplace. Figure 2 gives a general model.

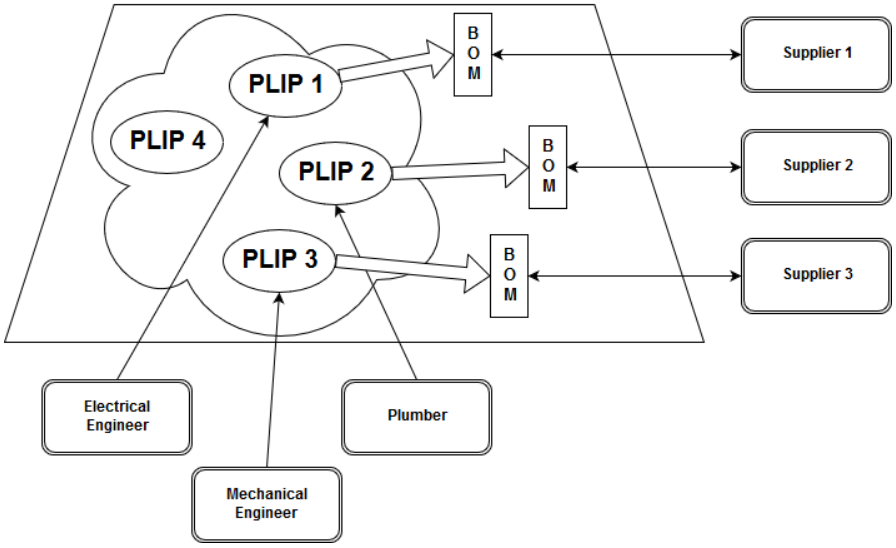


Figure 2 Cloud Based Product Line Marketplace

The marketplace (square in figure 2) contains multiple independent applications called Product Line Placers (PLiP). A PLiP is an application to design a specific system in the cloud and is based on BIM software like Autodesk Revit. A PLiP only supports components of one specific manufacturer or wholesale supplier and often contains special functionalities to support engineers in design. When an engineer enters the marketplace he chooses a supplier PLiP and designs a system of components from that manufacturer. When the design is finished, the marketplace generates a bill of materials. Using individual of staff discounts the price is calculated and a financial transaction is arranged. After the transaction is completed, the supplier delivers the components.

Examples of questions that can be discussed during the interview are:

A BIM Marketplace can extract customer data in a very early stage of a building project. What customer data could be of interest to you? Do you have the human resources to utilize customer data?

A BIM Marketplace allows for direct transactions between engineer and manufacturer, without intermediation of wholesale. Could this be beneficial for your supply chain?

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Figure 43 Stakeholder interview preparation document II

C.2 Interview Protocol

The 12 participants were interviewed using an interview protocol. As explained in section 2.3, the interviews have a semi-structured interview. That means the interview is structured with a list of questions, but the researcher can deviate from the standard protocol when he feels needed. Also, the order of questions can change due to input from the interviewee. There exist three different interview guides for manufacturers, engineers and wholesale with three different perspectives. Figure 44, Figure 45 and Figure 46 give the interview protocol for manufacturers.

Manufacturer Interview Protocol

Style:	Semi-structured
Description:	The questions in this guide form an open framework for the interview sessions. The interviewer can deviate from this guide when it seems necessary to capture the whole picture.
Time duration:	60 min
Target audience:	Managers at building services manufacturers

Introduction

Project introduction

Goals:

- Introduce myself
- Explain the incentive for the research project

BIM Marketplace (optional)

In some cases the BIM Marketplace can be revealed in the introduction. This depends on the strategic value of the idea. Revealing the idea right away can be useful to attract the attention of the interviewee.

Goals:

- Explain the concept of a BIM marketplace
- Introduce the different practical implementations.

Test adoption barriers

Goals:

- Test the relevant adoption barriers of section 2.7.
- Focus on the relationship between the manufacturer and wholesaler
- Focus on the possibilities of direct transactions with the engineer

Internal business processes

When participating on a BIM Marketplace, manufacturers need to change their supply chain. Instead of mediation by wholesale, the manufacturer needs to do direct transactions with the engineer.

Goals:

- Identify the distribution channels that are used by the manufacturer.
- Identify how strong partnerships between wholesale and manufacturer are and what is necessary to change them.

1. What distribution channels do you use to sell your products?
2. How do partnerships with wholesale companies develop and how do they change?

Human resources

When participating on a BIM Marketplace, manufacturers need to change their sales and marketing activities because they need to sell directly to the engineer. This is expected to cause problems in the available human resources.

Goals:

- Identify if manufacturer has salespersons that can sell directly to the engineer

3. How do you influence sales to the engineer? Do you perform sales activities to wholesale only or also to the engineer?

Figure 44 Stakeholder interview protocol - manufacturers I

Technological investment costs

Manufactures are expected to experience high technological investment costs because they have to develop BIM content for all their products.
Goals:

- Identify how high the technological investment costs will be

4. For what products do you possess BIM content and for what not? What influences that decision?

Interoperability

The lack of data standards is expected to be a problem when manufacturers want to share BIM content with their customers.
Goals:

- Identify which data representation standards clients of this manufacturer uses

5. What BIM/CAD programs do your customers use and what content data standards do you distribute?

Logistics services wholesale

Manufacturers are expected to experience high costs when setting up logistic processes to deliver directly to the engineer instead of bulk to wholesale.
Goals:

- Identify how high the perceived logistic costs would be when a manufacturer participates on a BIM Marketplace.

6. Would you be able to deliver products to the engineer or building site? What investments are necessary to make that possible?

Platform design

Modularity

The workshop resulted in an initial platform design with high system modularity and low user modularity. This implies an open marketplace with multiple suppliers side by side, and system configurator structure were engineers can order systems instead of individual products.

Goals

- Identify the transparency of the market to test if a marketplace with high user-modularity and therefore high transparency could be viable.
- Test a highly monolithic marketplace with regards to products (PLIP solution)

7. How transparent is your market with regards to manufacturers and how do you adapt marketing and sales activities to that market?
    - Transparent: engineers choose a brand by comparing prices and specs of different brands.
    - Non-transparent: engineers choose a brand based on feeling or habit. They are loyal to their brand

8. Do you often sell individual products of complete systems?
    - Individual products: systems are mixed and matched using different manufactures?
    - Complete systems: do you advise in the design of these systems and do you have configurators to help with design?

9. Propose the product line marketplace solution. What is your feedback?

10. Propose the open BIM marketplace. What is your feedback?

Figure 45 Stakeholder interview protocol - manufacturers II

Control

The workshop did not give any results on control measures against engineers. Interviews could result in the opinion of manufacturers.

Goals:

- Test what kind of gatekeeping measures are relevant for manufacturers
- Test if process control measures are relevant on a BIM marketplace.

11. Do you ever apply reasons or terms that withhold engineers from buying your products?
12. How often do you update/upgrade products? Do you think it's necessary to update content as well? Does this cost you much time?

Pricing

The workshop resulted in a positive opinion on subsidizing manufacturers. This can be done by developing BIM content or marketing content.

Goals:

- Identify the influence of subsidizing?
- Identify what pricing strategy would be appropriate on the manufacturer side

13. Before entering a BIM Marketplace, the manufacturer should provide BIM content and marketing content. Would this be a barrier to participate on a platform and why?

Complementary services

During the workshop, complementary services are discussed. Interviews can identify the added value of complementary services for manufacturers.

Goals:

- Identify which complementary services could be useful for manufacturers

14. We could invite third parties to develop BIM content. Would that help you?
15. We could invite third parties to develop marketing content. Would that help you?
16. We could invite third parties to offer logistic services. Would that help you and would that work for this industry?

Stakeholder Value Analysis

From section 1.1.2 of the report, it becomes clear that participation on a BIM Marketplace is expected to generate value for stakeholders. The participation on a BIM marketplace could potentially generate value for stakeholders. This section aims to measure the added short and long term value for manufacturers and identifies the incentives to participate on the marketplace.

Wholesale

Goal:

- Map out the incentives for manufacturer to bypass wholesalers in the supply chain.
- Map out the barriers for delivering directly to the engineer.

17. Could it be advantageous for you to sell and deliver directly to the engineer, without intermediation of wholesale? What barriers need to be overcome to make this possible?

Awareness

Goals:

- Identify the value of customer data for manufacturers

18. What customer and project data would be commercially interesting for you? How would you utilize this data?

Figure 46 Stakeholder interview protocol – manufacturers III

C.3 Coding Round I

Figure 47 shows a screenshot from the coded transcripts in Atlas.ti. The left column shows all the twelve transcripts and the middle screen shows the transcript of the interview with Rexel The Netherlands. On the right side of the transcript the codes are visible that are attached to the quotations. The right column gives the selected quotation, the attached codes and a comment from the researcher.
Figure 48 also shows a screenshot from the coding process but now the left column shows all the 29 codes that were used. The figure shows the transcript of the E1 interview and on the right side all the coded quotations are visible.
Figure 49 shows a screenshot from the code manager of Atlas.ti. The middle screen shows all the codes including short descriptions. Emergent codes are codes that were created during the coding process and the other codes are pre-set. The right column shows the selected code, in this case the emergent code ‘relational market’ and its detailed description.

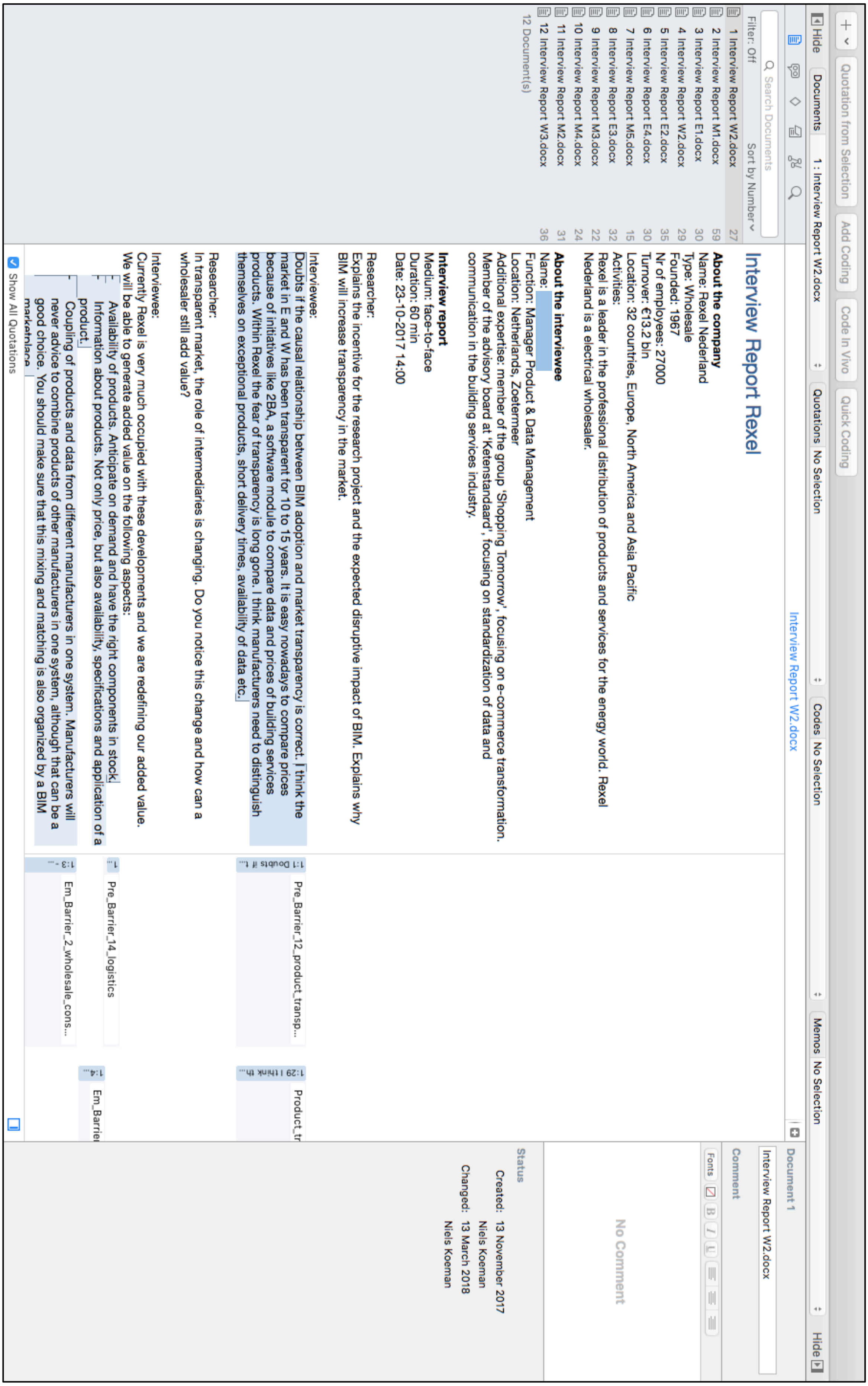


Figure 47 Stakeholder interview, first coding round I

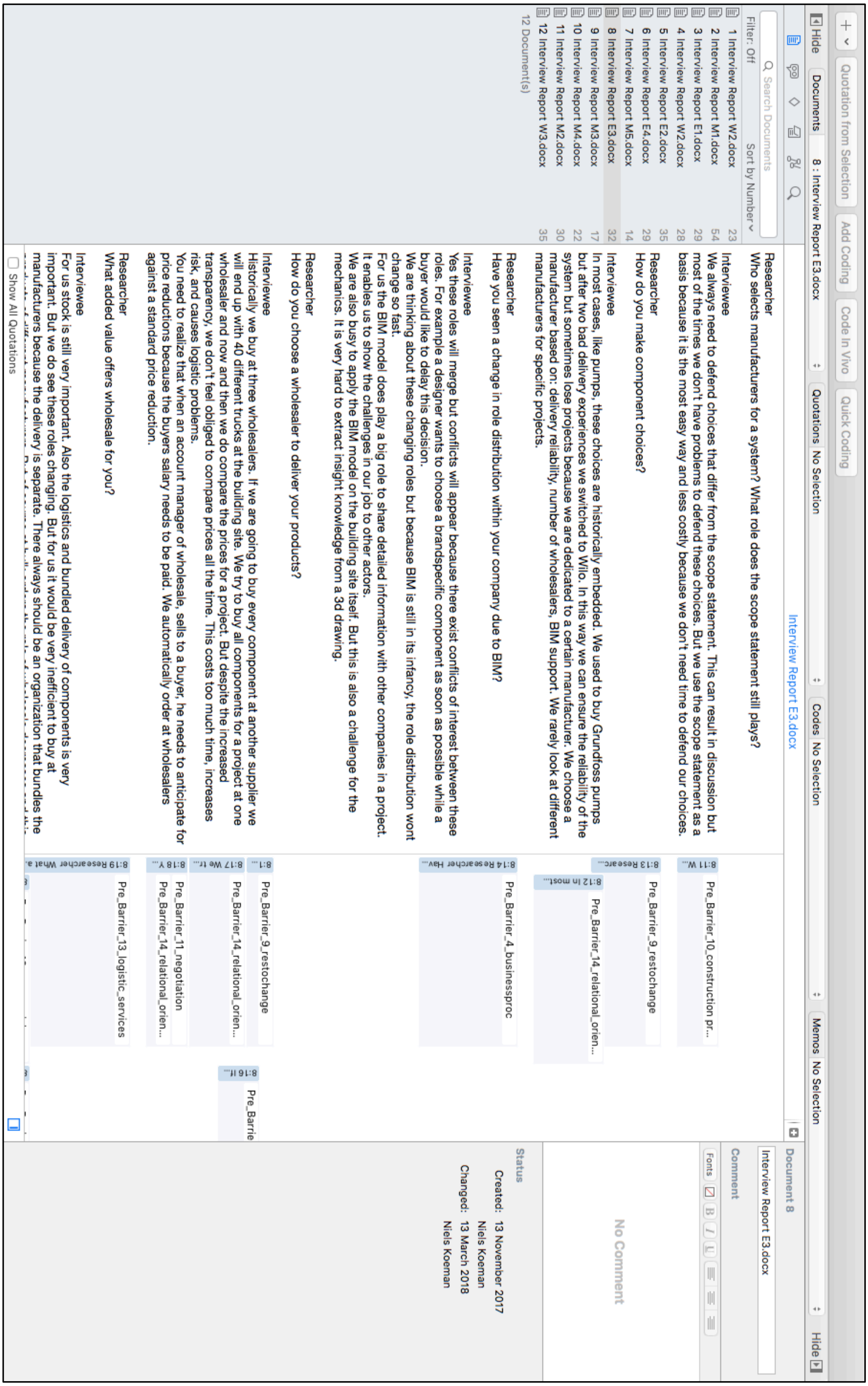
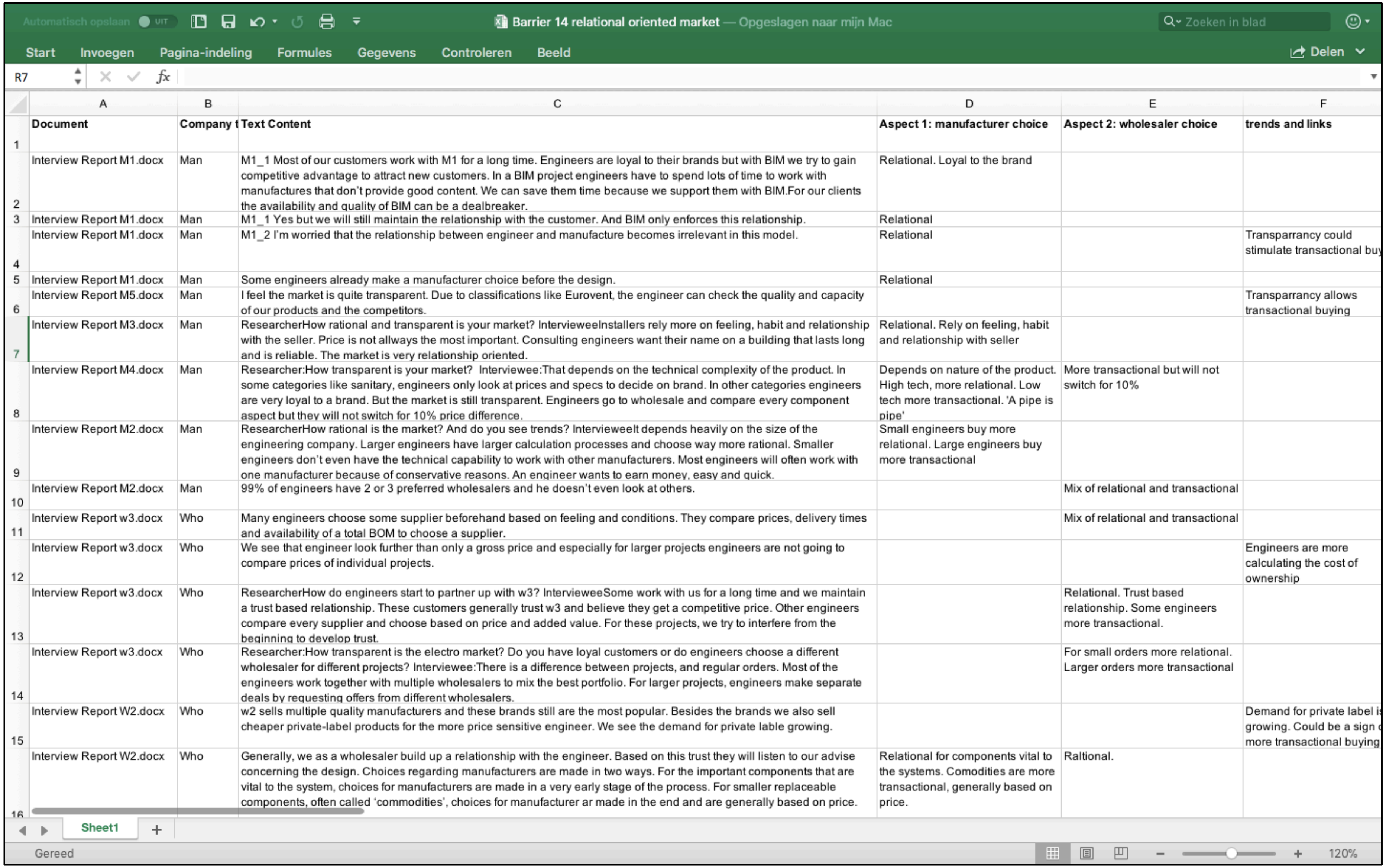


Figure 48 Stakeholder interview, first coding round II

Figure 49 Stakeholder interview, first coding round III

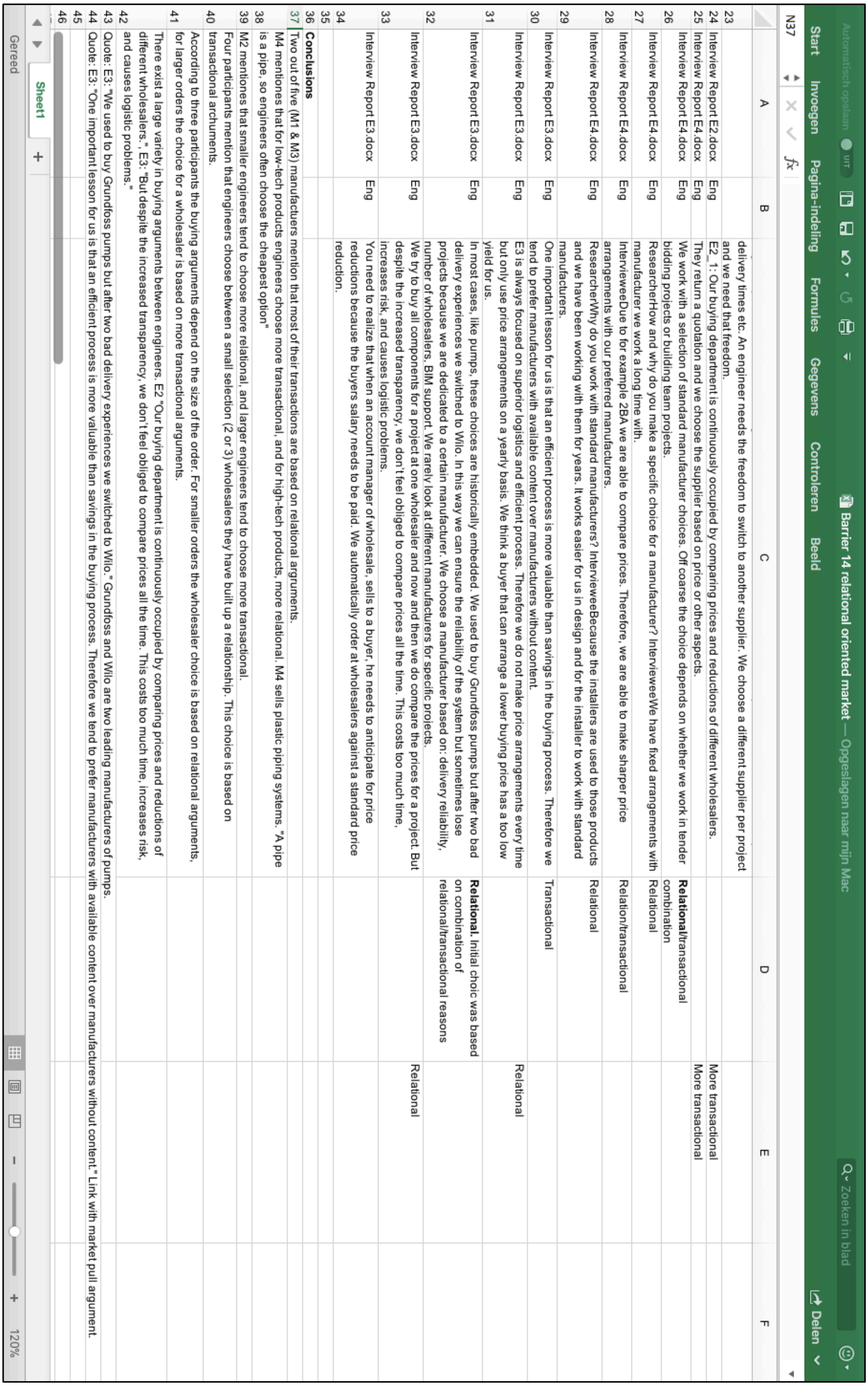
C.4 Coding Round II

Figure 50 shows an example of the 2nd coding round in Excel. This excel sheet shows all the codes that relate to barrier 14 'Relational oriented market'. The 1st, 2nd and 3rd columns show the name of the company, company type and the quote. Columns 4 and 5 contain the two aspects of barrier 14 that were identified. The 6th column contains trends or relationships with other barriers. Figure 51 shows the bottom of the excel sheet and how every component is used to draw conclusions from the data. Figure 52 and Figure 53 show the same process for barrier 4. Barrier 4 is a more complex code with more different aspects.



Document	Company t	Text Content	Aspect 1: manufacturer choice	Aspect 2: wholesaler choice	trends and links
Interview Report M1.docx	Man	M1_1 Most of our customers work with M1 for a long time. Engineers are loyal to their brands but with BIM we try to gain competitive advantage to attract new customers. In a BIM project engineers have to spend lots of time to work with manufactures that don't provide good content. We can save them time because we support them with BIM.For our clients the availability and quality of BIM can be a dealbreaker.	Relational. Loyal to the brand		
Interview Report M1.docx	Man	M1_1 Yes but we will still maintain the relationship with the customer. And BIM only enforces this relationship.	Relational		
Interview Report M1.docx	Man	M1_2 I'm worried that the relationship between engineer and manufacture becomes irrelevant in this model.	Relational		Transparrancy could stimulate transactional buy
Interview Report M1.docx	Man	Some engineers already make a manufacturer choice before the design.	Relational		
Interview Report M5.docx	Man	I feel the market is quite transparent. Due to classifications like Eurovent, the engineer can check the quality and capacity of our products and the competitors.			Transparrancy allows transactional buying
Interview Report M3.docx	Man	ResearcherHow rational and transparent is your market? IntervieweeInstallers rely more on feeling, habit and relationship with the seller. Price is not allways the most important. Consulting engineers want their name on a building that lasts long and is reliable. The market is very relationship oriented.	Relational. Rely on feeling, habit and relationship with seller		
Interview Report M4.docx	Man	Researcher:How transparent is your market? Interviewee:That depends on the technical complexity of the product. In some categories like sanitary, engineers only look at prices and specs to decide on brand. In other categories engineers are very loyal to a brand. But the market is still transparent. Engineers go to wholesale and compare every component aspect but they will not switch for 10% price difference.	Depends on nature of the product. High tech, more relational. Low tech more transactional. 'A pipe is pipe'	More transactional but will not switch for 10%	
Interview Report M2.docx	Man	ResearcherHow rational is the market? And do you see trends? IntervieweeIt depends heavily on the size of the engineering company. Larger engineers have larger calculation processes and choose way more rational. Smaller engineers don't even have the technical capability to work with other manufacturers. Most engineers will often work with one manufacturer because of conservative reasons. An engineer wants to earn money, easy and quick.	Small engineers buy more relational. Large engineers buy more transactional		
Interview Report M2.docx	Man	99% of engineers have 2 or 3 preferred wholesalers and he doesn't even look at others.		Mix of relational and transactional	
Interview Report w3.docx	Who	Many engineers choose some supplier beforehand based on feeling and conditions. They compare prices, delivery times and availability of a total BOM to choose a supplier.		Mix of relational and transactional	
Interview Report w3.docx	Who	We see that engineer look further than only a gross price and especially for larger projects engineers are not going to compare prices of individual projects.			Engineers are more calculating the cost of ownership
Interview Report w3.docx	Who	ResearcherHow do engineers start to partner up with w3? IntervieweeSome work with us for a long time and we maintain a trust based relationship. These customers generally trust w3 and believe they get a competitive price. Other engineers compare every supplier and choose based on price and added value. For these projects, we try to interfere from the beginning to develop trust.		Relational. Trust based relationship. Some engineers more transactional.	
Interview Report w3.docx	Who	Researcher:How transparent is the electro market? Do you have loyal customers or do engineers choose a different wholesaler for different projects? Interviewee:There is a difference between projects, and regular orders. Most of the engineers work together with multiple wholesalers to mix the best portfolio. For larger projects, engineers make separate deals by requesting offers from different wholesalers.		For small orders more relational. Larger orders more transactional	
Interview Report W2.docx	Who	w2 sells multiple quality manufacturers and these brands still are the most popular. Besides the brands we also sell cheaper private-label products for the more price sensitive engineer. We see the demand for private lable growing.			Demand for private label i growing. Could be a sign more transactional buying
Interview Report W2.docx	Who	Generally, we as a wholesaler build up a relationship with the engineer. Based on this trust they will listen to our advise concerning the design. Choices regarding manufacturers are made in two ways. For the important components that are vital to the system, choices for manufacturers are made in a very early stage of the process. For smaller replaceable components, often called 'commodities', choices for manufacturer ar made in the end and are generally based on price.	Relational for components vital to the systems. Comodities are more transactional, generally based on price.	Raltional.	

Figure 50 Stakeholder interview, second coding round I

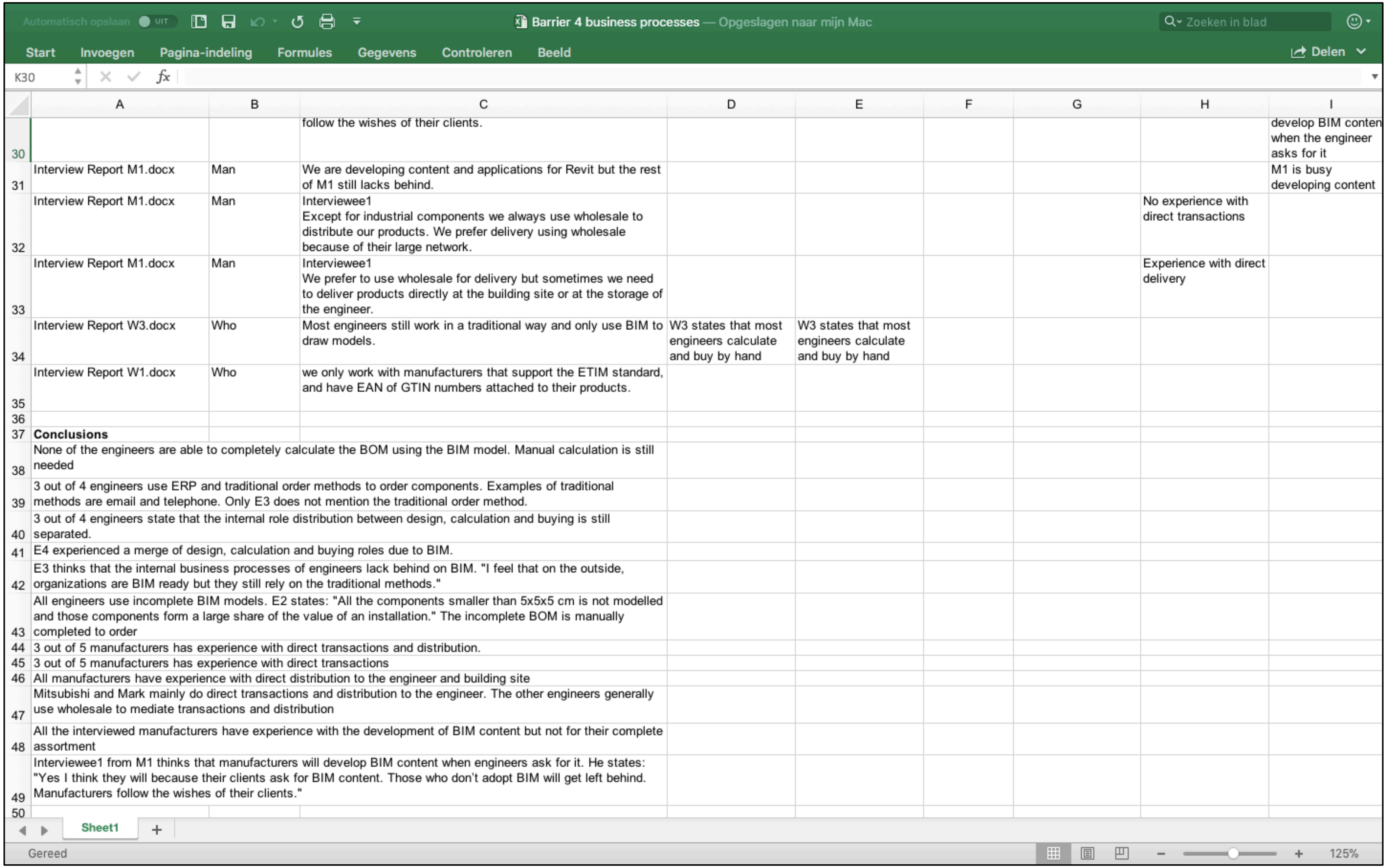


	A	B	C	D	E	F
23			delivery times etc. An engineer needs the freedom to switch to another supplier. We choose a different supplier per project and we need that freedom.			
24	Interview Report E2.docx	Eng	E2_1: Our buying department is continuously occupied by comparing prices and reductions of different wholesalers.		More transactional	
25	Interview Report E4.docx	Eng	They return a quotation and we choose the supplier based on price or other aspects.		More transactional	
26	Interview Report E4.docx	Eng	We work with a selection of standard manufacturer choices. Off coarse the choice depends on whether we work in tender bidding projects or building team projects.	**Relational**/transactional combination		
27	Interview Report E4.docx	Eng	ResearcherHow and why do you make a specific choice for a manufacturer? IntervieweeWe have fixed arrangements with manufacturer we work a long time with.	Relational		
28	Interview Report E4.docx	Eng	IntervieweeDue to for example 2BA we are able to compare prices. Therefore, we are able to make sharper price arrangements with our preferred manufacturers.	Relation/transactional		
29	Interview Report E4.docx	Eng	ResearcherWhy do you work with standard manufacturers? IntervieweeBecause the installers are used to those products and we have been working with them for years. It works easier for us in design and for the installer to work with standard manufacturers.	Relational		
30	Interview Report E3.docx	Eng	One important lesson for us is that an efficient process is more valuable than savings in the buying process. Therefore we tend to prefer manufacturers with available content over manufacturers without content.	Transactional		
31	Interview Report E3.docx	Eng	E3 is always focused on superior logistics and efficient process. Therefore we do not make price arrangements every time but only use price arrangements on a yearly basis. We think a buyer that can arrange a lower buying price has a too low yield for us.		Relational	
32	Interview Report E3.docx	Eng	In most cases, like pumps, these choices are historically embedded. We used to buy Grundfoss pumps but after two bad delivery experiences we switched to Wilo. In this way we can ensure the reliability of the system but sometimes lose projects because we are dedicated to a certain manufacturer. We choose a manufacturer based on: delivery reliability, number of wholesalers, BIM support. We rarely look at different manufacturers for specific projects.	**Relational.** Initial choic was based on combination of relational/transactional reasons		
33	Interview Report E3.docx	Eng	We try to buy all components for a project at one wholesaler and now and then we do compare the prices for a project. But despite the increased transparency, we don't feel obliged to compare prices all the time. This costs too much time, increases risk, and causes logistic problems.		Relational	
34	Interview Report E3.docx	Eng	You need to realize that when an account manager of wholesale, sells to a buyer, he needs to anticipate for price reductions because the buyers salary needs to be paid. We automatically order at wholesalers against a standard price reduction.			
35						
36	**Conclusions**					
37	Two out of five (M1 & M3) manufactuers mention that most of their transactions are based on relational argruments.					
38	M4 mentiones that for low-tech products engineers choose more transactional, and for high-tech products, more relational. M4 sells plastic piping systems. "A pipe is a pipe, so engineers often choose the cheapest option"					
39	M2 mentiones that smaller engineers tend to choose more relational, and larger engineers tend to choose more transactional.					
40	Four participants mention that engineers choose between a small selection (2 or 3) wholesalers they have built up a relationship. This choice is based on transactional archuments.					
41	According to three participants the buying arguments depend on the size of the order. For smaller orders the wholesaler choice is based on relational arguments, for larger orders the choice for a wholesaler is based on more transactional arguments.					
42	There exist a large variety in buying arguments between engineers. E2 "Our buying department is continuously occupied by comparing prices and reductions of different wholesalers.", E3: "But despite the increased transparency, we don't feel obliged to compare prices all the time. This costs too much time, increases risk, and causes logistic problems."					
43	Quote: E3: "We used to buy Grundfoss pumps but after two bad delivery experiences we switched to Wilo." Grundfoss and Wilo are two leading manufacturers of pumps.					
44	Quote: E3: "One important lesson for us is that an efficient process is more valuable than savings in the buying process. Therefore we tend to prefer manufacturers with available content over manufacturers without content." Link with market pull argument.					
45						
46						

Figure 51 Stakeholder interview, second coding round II

Document	Company type	Text Content	Aspect 1: calculation processes	Aspect 2: buying processes	Aspect 3: internal roles	Aspect 4: model completenes	Aspect 5: direct transaction/ distribution	Aspect 6: bim content
Interview Report E1.docx	Eng	ResearcherDo you also calculate using BIM software? IntervieweeNo we calculate the BOM the traditional way. In housing construction, commercial calculation is used.	By hand without the BIM model	-	-	-	-	-
Interview Report E1.docx	Eng	ResearcherWhat channels do you use to order components? IntervieweeOff coarse ERP but also the traditional telephone is used and we visit wholesale themselves.	-	ERP but also telephone/email.	-	-	-	-
Interview Report E1.docx	Eng	ResearcherDo you notice the merge of design, calculation and buying roles? IntervieweeNo these roles are still separated. Because we use E1 standard systems, the component choice is already determined by the standard design (conceptual building). And if not it will be determined by the scope statement.	-	-	Separated	-	-	-
Interview Report E1.docx	Eng	ResearcherHow complete are the BIM models used by E1 engineers? IntervieweeEspecially in prefab the models as very complete. Nearly all the components are modelled. Currently we calculate up front but in the future we would like to use the calculations from the BIM model as a price calculation for the tender biddings.	-	-	-	Not complete. Prefab is allmost complete	-	-
Interview Report E1.docx	Eng	A problem with buying directly from a BIM model, is the overlap in processes. A buying process is followed up by a financial transaction and a logistic process.	-	-	-	-	-	-
Interview Report E2.docx	Eng	The problem with the BIM Marketplace is that a BIM Model is not complete and will not result in a complete BOM. All the components smaller than 5x5x5 cm is not modelled and those components form a large share of the value of an installation.	-	-	-	Not complete. Every component smaller than 5x5x5 is not modelled.	-	-
Interview Report E2.docx	Eng	No only the design phase is done using BIM. Because the model is not complete, calculation and buying should be done by hand.	By hand	By hand	Separated	-	-	-
Interview Report E2.docx	Eng	Calculation is done by hand and the results are entered in ERP software. Prices in ERP are updated by wholesale.	By hand	ERP	-	-	-	-
Interview Report E2.docx	Eng	Interviewee2: Our internal processes are organized using four departments:Buying department – Focused at long term contractsOrder department – Order components at suppliers Technical planning – Calculation and develops a complete BOMDesign department – Develops a BIM model	-	-	Separated in different departments	-	-	-
Interview Report E2.docx	Eng	Interviewee2: Let's say that currently we model 80% of components wich costs us 100 man hours. To model that extra 20%, we need an extra 100 man hours.				Confirmed. Relation to costs		
Interview Report E2.docx	Eng	Interviewee2: The technical planner already made a basic design and the scope statement also gives signs for specific component choices. The choices that the BIM designer faces in the design are consulted with the technical planner. In most cases the	-	-	Separated	-	-	-

Figure 52 Stakeholder interview, second coding round III



Barrier 4 business processes — Opgeslagen naar mijn Mac

	A	B	C	D	E	F	G	H	I
30			follow the wishes of their clients.						develop BIM conten when the engineer asks for it
31	Interview Report M1.docx	Man	We are developing content and applications for Revit but the rest of M1 still lacks behind.						M1 is busy developing content
32	Interview Report M1.docx	Man	Interviewee1 Except for industrial components we always use wholesale to distribute our products. We prefer delivery using wholesale because of their large network.					No experience with direct transactions	
33	Interview Report M1.docx	Man	Interviewee1 We prefer to use wholesale for delivery but sometimes we need to deliver products directly at the building site or at the storage of the engineer.					Experience with direct delivery	
34	Interview Report W3.docx	Who	Most engineers still work in a traditional way and only use BIM to draw models.	W3 states that most engineers calculate and buy by hand	W3 states that most engineers calculate and buy by hand				
35	Interview Report W1.docx	Who	we only work with manufacturers that support the ETIM standard, and have EAN of GTIN numbers attached to their products.						
36									
37	**Conclusions**								
38	None of the engineers are able to completely calculate the BOM using the BIM model. Manual calculation is still needed								
39	3 out of 4 engineers use ERP and traditional order methods to order components. Examples of traditional methods are email and telephone. Only E3 does not mention the traditional order method.								
40	3 out of 4 engineers state that the internal role distribution between design, calculation and buying is still separated.								
41	E4 experienced a merge of design, calculation and buying roles due to BIM.								
42	E3 thinks that the internal business processes of engineers lack behind on BIM. "I feel that on the outside, organizations are BIM ready but they still rely on the traditional methods."								
43	All engineers use incomplete BIM models. E2 states: "All the components smaller than 5x5x5 cm is not modelled and those components form a large share of the value of an installation." The incomplete BOM is manually completed to order								
44	3 out of 5 manufacturers has experience with direct transactions and distribution.								
45	3 out of 5 manufacturers has experience with direct transactions								
46	All manufacturers have experience with direct distribution to the engineer and building site								
47	Mitsubishi and Mark mainly do direct transactions and distribution to the engineer. The other engineers generally use wholesale to mediate transactions and distribution								
48	All the interviewed manufacturers have experience with the development of BIM content but not for their complete assortment								
49	Interviewee1 from M1 thinks that manufacturers will develop BIM content when engineers ask for it. He states: "Yes I think they will because their clients ask for BIM content. Those who don't adopt BIM will get left behind. Manufacturers follow the wishes of their clients."								
50									

Figure 53 Stakeholder interview, second coding round IV