Pathways for next adopters to adopt industrialised timber construction in Dutch practice: a contractors perspective

Master Thesis | P5
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“Timber construction: a cure for many crises”

- TU Delft, Delta Journalistic platform (September 2022)

Foreword

In front of you lies the graduation thesis that focuses on pathways for the adoption of industrialised timber construction in Dutch practice, especially from the viewpoint of next adopters. In the report, emphasis is laid on general contractors and their process towards the decision to adopt the innovation of building in industrialised timber constructions. The aim of the research is to come up with pathways that describe and explain this adoption process. The research design has been written in the context of graduating from the master track Management in the Built Environment at Delft University of Technology.

My inspiration for researching this topic comes from a personal interest in timber constructions and reading the book ‘Tomorrow's Timber: Towards the Next Building Revolution’ by Pablo van der Lugt and Atto Harsta. Moreover, I also followed the course Leadership and Strategic Management at the CME track at TU Delft, which discusses processes of change. This combination led to a curiosity towards the current trend in the Dutch construction industry related to industrialised timber constructions and how general contractors would cope with this innovation. Thereby, next to my studies, I am also working at a general contractor and therefore especially interested in this viewpoint.

Jimi van Leeuwen

Utrecht, April 20th 2023

Abstract

Recently, there has been growing concerns about CO_2-emissions, labour dynamics and demand volumes in the Dutch construction industry and industrialised timber constructions have the potential to help solve parts of these challenges. However, relatively little is known about how to identify pathways to adopt industrialised timber construction in practice, especially from the viewpoint of next adopters. Therefore, this study addresses the question of what are pathways for next adopters to adopt industrialised timber construction in Dutch practice? To find an answer to this question a combination of literature review and interviews will be used. The interviews will be of exploratory nature and conducted within firms that are planning on adopting industrialised timber construction in the near future or are in the middle of this process. The goal of this research is to develop pathways for next adopters to adopt industrialised timber construction in Dutch practice. Besides just the final thesis report itself, deliverables contain amongst others a coherent literature review on the used constructs, an interview protocol, the results of analysing the data and the outcomes of the verification by the interviewees and the focus group.

From the data analysis in this research, 8 aggregate dimensions can be identified that prove to be critical in the process of adopting industrialised timber construction. These dimensions are (1) identifying next adopters, (2) context of adopting, (3) role of network/partners in the adoption process, (4) learning processes, (5) challenges when adopting, (6) risk management, (7) critical success factors and finally, (8) advantages when adopting. Also, most striking findings from the interviews are pointed out. Thereby, much of the analysed data corresponds with findings from previous studies. For each of the case studies, their pathway of adopting is described using the above 8 dimensions. These pathways also have a relation to time and are based upon 5 stages in the innovation adoption process which are defined in previous studies and theories. These stages are: attitude, persuasion, decision, implementation and confirmation.

Between the different case studies, differences and similarities are described. As a result, 3 different pathways are identified and presented in this research. The three pathways differ per aggregate dimension, but also in timeframe and emphasis per stage.

The three different stories of the cases in this study show that the adoption process can not always be framed in the same linear steps that have been found in literature. Therefore, this research introduces the ‘Cycle of innovation adoption in industrialised timber construction’ model. In this model, the typical steps in the innovation adoption process are recognized, but they are placed in a circle and supplemented with the 8 aggregate dimensions found in the data analysis. These 8 dimensions show the different phases in which organisations can ‘jump on’ or ‘jump off’ the innovation adoption process.

Keywords: Industrialised Timber Construction - Pathways - Innovation Adoption - Next adopters - General contractors

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1. Introduction

1.1 Background information

To meet national climate goals set by the government (49% less CO_2 emissions in 2030 and 95% less CO_2 emissions in 2050, both compared to 1990), the construction sector must change drastically compared to the way it is currently building (Ministerie van Economische Zaken en Klimaat, 2020). Globally, in 2018 building construction and operations accounted for the largest share of both final energy use and energy-related CO_2 emissions. The buildings and construction sector should be a primary target for greenhouse gas emissions mitigation efforts, as it accounted for 36% of final energy use and 39% of energy- and process-related emissions in 2018. From these 39% of emissions, 11% is related to the portion of the overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Using timber instead of steel or concrete has the potential to decrease the amount of CO_2-emissions drastically (Global Alliance for Buildings and Construction, 2019).

With the score for the Environmental Performance of Buildings (MPG-score), the environmental impact of a building is reduced to a single numerical value. The lower the MPG-score, the smaller the environmental impact. The currently allowed MPG-score is a maximum of 0.8. The government wants to tighten the requirement to a limit value of 0.5 by 2030 at the latest. However, the government would like to accelerate and it is advised to set the MPG standard to a maximum of 0.5 by 2025. This would have a major impact on the materials that can be used in newly built projects in coming years and will only speed up the need for building in timber (Rijksdienst voor Ondernemend Nederland, 2017). Increasing the amount of timber used in (residential) buildings, has great potential to reduce CO_2-related emissions and increase the accompanying carbon storage. This will help achieve an advantageous MPG-score.

At the same time, Minister of Housing Hugo de Jonge recently announced the ambition to build an additional 900.000 homes in the coming 8 years to resolve the major housing shortage in the Netherlands (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2022). To build these homes, enough specialised employees in the construction sector are necessary to be able to meet these ambitious goals. This is another challenge, since the current construction capacity of the construction industry is too low and it is not easy to get that capacity quickly to get to a higher level. This is primarily due to the shortage on the labour market; currently 23 percent of vacancies in the construction sector cannot be filled. In the period 2022-2025, more than 60,000 new workers will be needed in the construction industry (Economisch Instituut voor de Bouw, 2021).

In a report by Bertram et al. (2019) from McKinsey and Company, seven factors were identified that determine the attractiveness of a market for industrialised housing. In figure xx below, these factors are shown. The report concludes that both labour shortages and the mismatch between supply and demand (shortage on the supply side) stand out as the most decisive. Taking the figures from the paragraph above into account, it can be concluded that

the Dutch housing market would have the potential to drive adoption of industrialised construction principles.

Figure 01: 7 factors that determine the attractiveness of a market for industrialised construction (Bertram et al., 2019)

As stated by Bertram et al. (2019): "A limited supply of skilled labour, which in turn drives up wages and costs, often sets the stage for modular construction solutions. …shifting to offsite manufacturing work is cheaper—and it may even attract new people into the workforce who do not wish to move from one construction site to another following projects."

1.2 Problem definition and research questions

Recently there has been growing concerns about CO_2-emissions, labour dynamics and demand volumes in the Dutch construction industry and industrialised timber construction has the potential to help solve parts of these challenges. However, relatively little is known about how to identify pathways to adopt industrialised timber construction in practice, especially from the viewpoint of next adopters as identified earlier. For example, as proposed by Gosselin et al. (2018), further research could aim to identify pathways to establish and improve collaboration relationships. Thereby, to create a more focussed and in-depth research, research could focus on a specific actor rather than a mix of actors in its sample. Few studies have tried to identify pathways for general contractors to adopt industrialised timber construction in practice. Therefore, this study addresses the question of what are pathways for next adopters to adopt industrialised timber construction in Dutch practice?

To be able to answer the research question, sub-questions are introduced. Each sub-question is meant to answer a part of the research question. After answering all sub-questions separately, a substantiated answer can be formulated to answer the research question. Below the four sub-questions are listed.

Sub-questions:

1. What are the characteristics of next adopters in industrialised timber construction?

2. How can adoption pathways be analysed?

3. What are factors, drivers and barriers for next adopters to adopt industrialised timber construction and how can the barriers be overcome?

4. What are typologies of pathways that can be used to put adoption of industrialised timber construction in practice?

1.3 Societal and scientific relevance

This research will mainly focus and contribute to the literature related to adopting industrialised timber construction in practice by main contractors. This will be relevant because of the current trend in the Dutch construction industry related to industrialised timber construction, incentivised by tightening national climate regulation, acute housing shortage and growing challenges in the construction industry when it comes to CO_2-emissions and labour dynamics.

1.4 Structure of the report

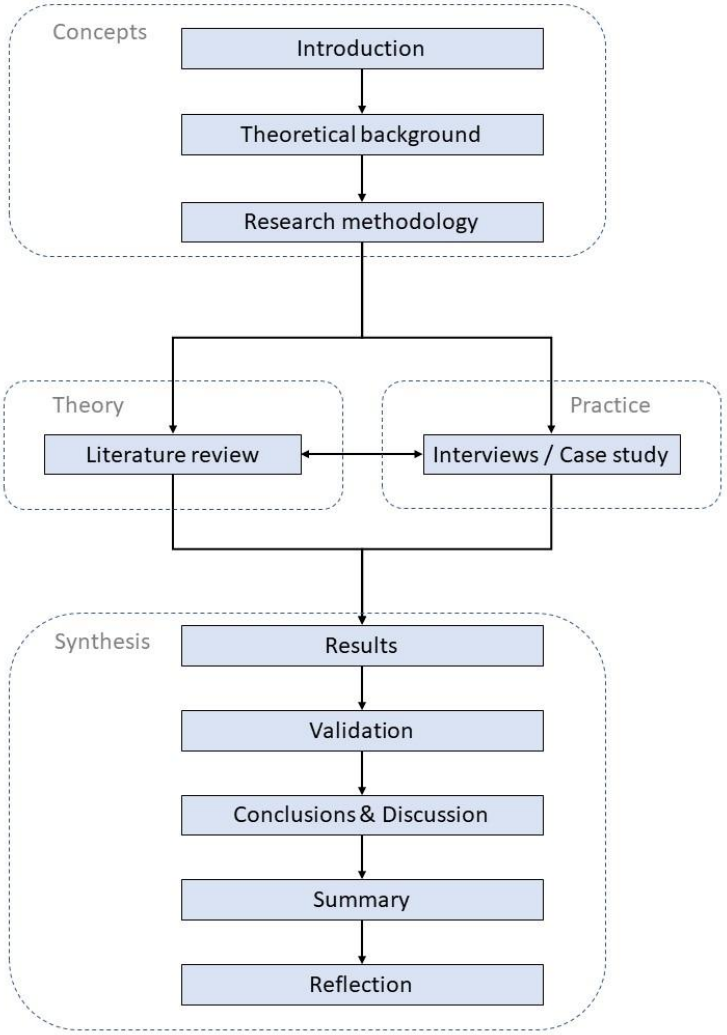


Figure 02: Research design

“Mass timber will disrupt the building industry...”

- Pablo van der Lugt, Keynote “Mass Timber: Towards the next building revolution” (March 2021)

2. Theoretical background

2.1 Introduction

As well as digitization, industrialised construction is promising when it comes to the potential to disrupt the construction industry and related fields after years of relative slow change. In this process, all actors should evaluate the trend and potential impact that it could have on their related field to make sure they make the right strategic choices and can benefit instead of risking to be left behind (Bertram et al. 2019).

2.2 Timber structure adoption in construction

Gosselin et al. (2016) have identified the existence of barriers preventing timber as a structural material for multifamily buildings and have divided these into six categories: code implementation, technology transfers, costs, material durability and other technical aspects, culture of the industry and material availability. In a follow-up research, Gosselin et al. (2018), states that the fifth barrier, 'culture of the industry', has an impact on innovation adoption and that "the relationships between stakeholders of structural timber building supply chains, stakeholders' respective knowledge and their experience gained through time and projects" is minimally included. As a result, their research aimed at identifying and characterising the relationships developed between stakeholders in the supply chain for structural timber building projects. Another aim was to identify what enablers for the use of timber as a structural material were.

To be able to research the interrelationships between stakeholders in supply chain structures for timber buildings, the paper first defines the construction supply chain. It appeared that already many studies have been conducted on the factors influencing the construction supply chain, looking at better supply chain integration, strategic partnerships and collaborative agreements between supply chain actors (Holti et al., 2000.; Akintoye et al., 2000.; Briscoe & Dainty., 2005; Rimmers., 2009). Few studies had aimed at describing the relationships that are developed within the supply chain itself (Gosselin et al., 2018).

When looking at the most traditional and commonly used project delivery system in the world, the design-bid-build system (Kantola et al., 2016), the figure below by Behera et al. (2015) shows what the phases in a typical construction project are.

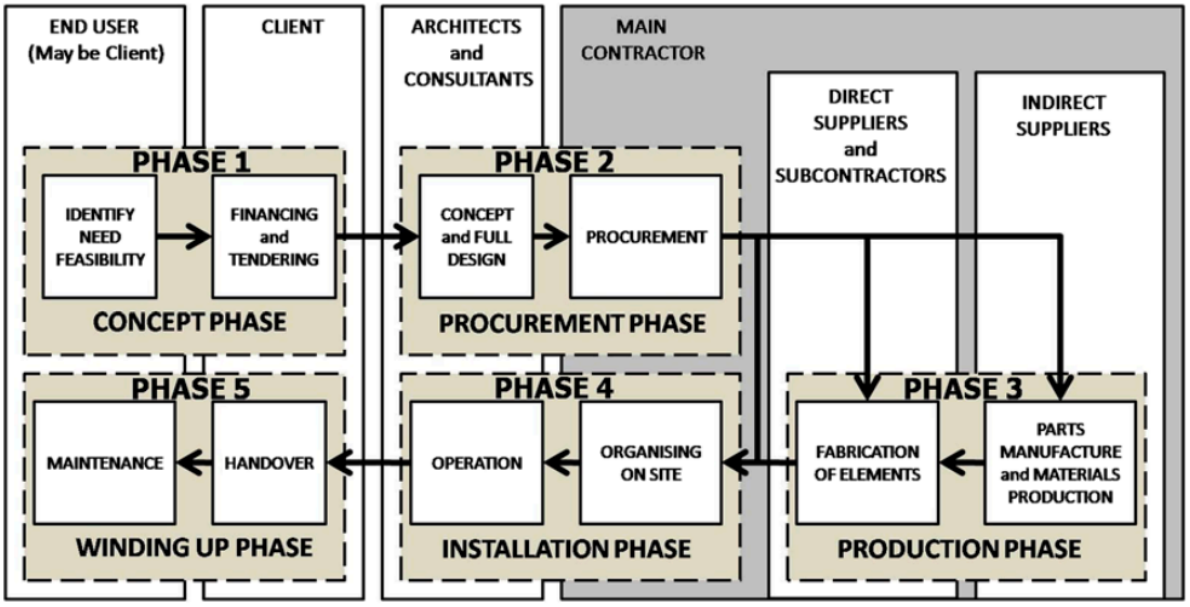


Figure 03: Phases in a typical construction project (Behera et al., 2016; reprinted with permission: Taylor and Francis).

Thereafter, the authors try to define a typical structural timber building supply chain, Gosselin et al. (2018) makes use of the figures and list of stakeholders from Behera et al. (2016) and proposes the following representation of a typical structural timber building supply chain, illustrated in figure 04 below. As can be seen in figure 04, a typical structural timber building supply chain can integrate either six or five stakeholders depending on the construction mode. Typically, a real estate developer needs an Architect to design the building and an engineer to draw and calculate the structure. Another contract is given to the general contractor who hires different sub-contractors integrating a builder. Lastly, a final contract is given to a structural timber element supplier to produce the timber elements needed for the structure (left path). In fact, from the main contractor, the project will either go left (path with 6 main stakeholders) or right (path with 5 main stakeholders) because in some projects the general contractor hires a supplier that also offers building services.

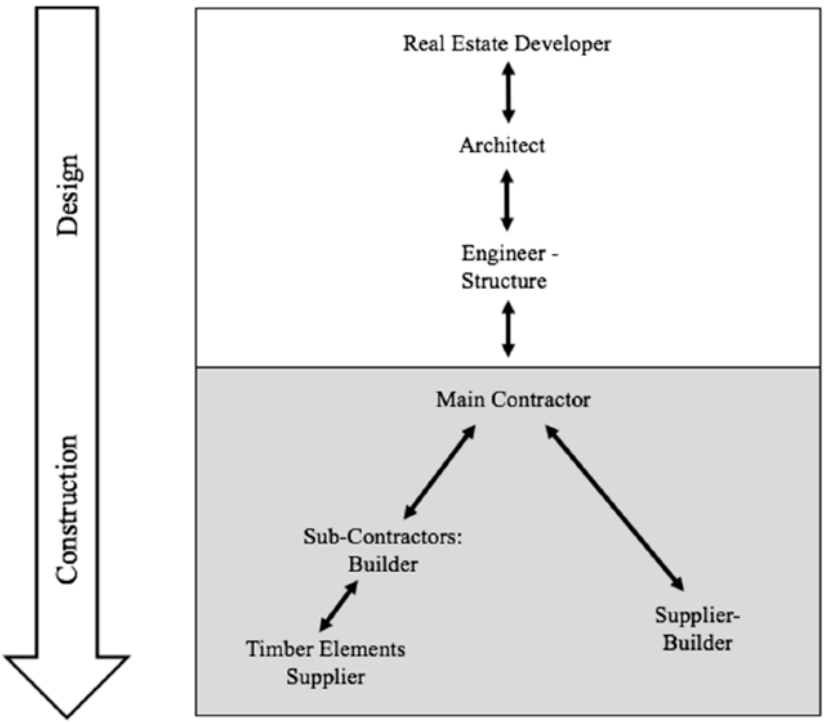


Figure 04: Typical structural timber building supply chain (Gosselin et al., 2018)

By the means of interviews, participant observation and secondary data, the researchers then try to answer the question of what are the relationships involved in structural timber building supply chains? And what would facilitate greater use of timber as structural material? In a sample of Architects, structural engineers, builders, timber element suppliers, supplier-builders, timber board suppliers and timber building technology developers across Switzerland, Germany, Austria, England, Sweden, Italy, Australia, Norway and Scotland, answers were found to these two main questions.

The observed relationships were divided into three levels of interaction: (1) 'contractual', (2) 'timber building project' and (3) 'development of the structural timber building industry'. Levels 1 and 2 are well defined because their nature is respectively legal and based on projects. However, level 3 relationships aim towards better timber structural material adoption and utilisation because they imply knowledge transfers and strengthening of expertise. The results furthermore show the cultural transition that is needed in the timber building industry: Thinking about a value network rather than a linear chain and favouring collaboration between members of the network rather than simple transactional relationships. Also, the results showed that contract procurement modes where stakeholders from both phases, design and construction, work closely together from the beginning to the end of the project better suit the timber building industry. Finally, in the timber building projects studied, the use of prefabricated (industrialised) elements and modules facilitated project erection and realisation.

These systems can be seen as facilitators to the growth of the structural timber building industry since they limit the numbers of stakeholder relationships involved in the construction

process and bring collaboration within the same organisation. The researchers conclude that further research could aim to identify pathways to establish and improve these collaboration relationships (Gosselin et al., 2018).

2.3 The use of prefabrication

Cox et al. (2011) conducted questionnaires and interviews to define hindrances and stimulants related to the level of the use of prefabrication in the UK. The research sample consisted of eleven experienced (average of 17 years) professionals operating in the UK construction industry. The research listed decreased construction times and increased quality as the main advantages and poor education within the industry regarding prefabricated practices, the archaic nature of the industry lacking trust, reluctance to embrace new and innovative techniques, and the absence of a proven holistic and encompassing evaluation technique to provide accurate and reliable comparisons between differing methods as main obstacles to prefabricated systems in the construction industry (Cox et al., 2011).

The study by Cox et al. (2011) also identified two key factors related to stimulating a more efficient use of prefabrication within the construction industry. What remained prevalent in the realisation of prefabrication as an efficient and effective construction method was an increase and improvement in the current knowledge levels through an increased availability of accurate and founded comparison data, and the development and provision for an accurate and industry-wide accepted evaluation technique regarding the selection of construction method. However, it is also acknowledged that with any new and innovative phenomenon there will always exist the issue of ‘who jumps first’. Eventually one party has to be willing to openly share information and encourage others to adopt a similar mutually agreeable exchange.

2.4 Culture of the industry

The findings by Cox et al. (2011), correspond with one of the elements seen as a facilitator to the increase of timber use as a structural material by Gosselin et al. (2019). In this later study it is stated that a cultural mindset switch is needed if timber used as a structural material is to become more popular. Akintoye et al. (2000), showed that partnership/collaboration agreements between contractors, suppliers and clients are more common but they also referred to workplace culture as a barrier to partnerships/collaboration in the implementation of supply chain management. In line with these thoughts, the construction industry culture is limiting partnerships and collaboration within the timber construction value creation chain. It is recognised that many legal aspects cannot easily be changed, but the behaviour of the supply chain’s actors can be modified (Akintoye et al., 2000). Morgan (1997), explains in his book ‘Images of Organisation’ that organisations have their own cultural contexts with their own system of knowledge, ideology, values, laws and day-to-day ritual. Concluding: (1) the industry should shift from a linear construction supply chain towards a value network and (2) one should think in collaboration partnerships instead of simple relation transactions.

By reviewing the above recent studies, it is identified that most have elaborated on principles of adopting industrialised timber construction, especially from the viewpoint of first-adopters, focussing on collaboration between actors and the 'shift in cultural mindset' that is needed in both the industry and within organisations itself. Furthermore, it is shown that barriers exist which prevent the massive use of timber as a structural material in construction. Moreover, besides the complication of designing, contracting and building these structures, the complexity of their value chain relationships encompassing architects, engineers, builders and suppliers brings great challenges. Also, mainly a mix of actors in the construction industry is used as a sample to find answers to the questions raised.

In the paragraphs below, literature is reviewed to specify and name the group that would follow after these first-adopters in adopting industrialised timber constructions. To focus this research, the perspective of main contractors will be emphasised. Due to the central position of the main contractor in the typical structural timber building supply chain by Gosselin et al. (2018) and its coordinating and managing tasks (Winch, 2010), this actor is expected to be highly affected by the adoption of industrialised timber construction and therefore an interesting actor to research.

2.5 The Technology Adoption Life Cycle

In his book 'Crossing the Chasm', Geoffrey A. Moore (1991) discusses a model for understanding the acceptance of new products: The Technology Adoption Life Cycle. The model aims to describe the progression in the types of consumers it attracts throughout its useful life when a new technology penetrates the market (Moore, 1991). By the means of a standard deviation, Rogers (1983) showed that a normal adopter distribution can be divided into five categories: (1) innovators, (2) early adopters, (3) early majority, (4) later majority, and (5) laggards. In the curve on the figure below, the normal frequency distribution can be seen to be divided into five adopter categories (Rogers, 1983). Moore (1991) used the same standard deviation to explain its technology adoption life cycle.

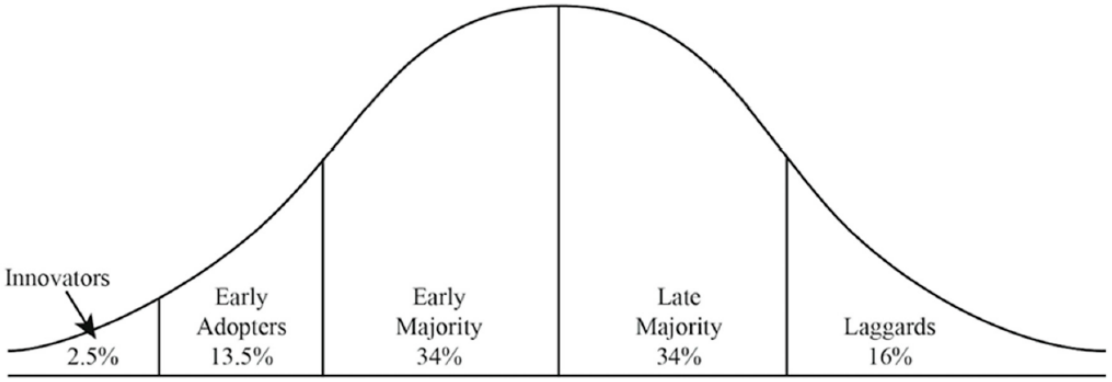


Figure 05: Adopter categorization on the basis of innovativeness (Rogers, 1983)

"The criterion for adopter categorization is innovativeness: the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system" (Rogers, 1983). In past studies, multiple categorization systems and titles for adopters can be identified. In the research by Rogers, the most used 'standard' set of adopter categories has been used. It should be noted that the five categories are

conceptualizations based on observations of reality and designed to make comparisons possible. Below, some dominant attributes of each category are listed:

- Innovators: venturesome;
- Early adopters: respectable;
- Early majority: deliberate;
- Late majority: sceptical; and
- Laggards: traditional.

Furthermore, past research shows many important differences between earlier (left side of the mean) and later adopters (right side of the mean) of innovations in three categories:(1) socioeconomic status, (2) personality variables, and (3) communication behaviour. In the table below, these differences are substantiated (Rogers, 1983).

Socio-economic characteristics	*The relatively earlier adopters have:*
These characteristics of adopter categories indicate generally that earlier adopters have higher socio-economic status than later adopters.	more years of education;
	are more likely to be literate;
	have higher social status;
	a greater degree of upward social mobility;
	larger-sized units, like farms, companies, and so on;
	a commercial rather than a subsistence economic orientation;
	a more favourable attitude toward credit;
	and more specialised operations.
Personality variables	*Earlier adopters have:*
	greater empathy;
	less dogmatism;
	a greater ability to deal with abstractions;
	greater rationality;
	greater intelligence;
	a more favourable attitude toward change;
	a greater ability to cope with uncertainty and risk;
	a more favourable attitude toward education;
	a more favourable attitude toward science;
	and less fatalism;

	higher achievement motivation;
	higher aspirations for education, occupations, and so on.
Communication behaviour	*Earlier adopters have:*
	more social participation;
	are more highly interconnected in the social system;
	are more cosmopolite;
	have more change agent contact;
	greater exposure to mass-media channels;
	greater exposure to interpersonal communication channels;
	engage in more active information seeking;
	have greater knowledge of innovations;
	a higher degree of opinion leadership;
	and are more likely to belong to highly interconnected systems.

Reflecting on the Technology Adoption Life Cycle by Moore (1991), it shows that technology is absorbed by the five types of consumers in the standard deviation, corresponding to the psychological and social profiles of the different types of consumers. For example, both early adopters and innovators would buy into new product concepts relatively early in their life cycle, but unlike innovators, early adopters are not technologists. Rather, early adopters are firms or people who find it easy to imagine, understand and appreciate the benefits of a new technology, and to relate these potential benefits to their other concerns. Also, early adopters do not necessarily rely on successful references in making their buying decision. Rather, they rely on their own intuition and vision. Early adopters are key to opening up any high-tech market segment (Moore, 1991).

2.6 Construction innovation processes

Winch (1998) identified the construction industry as being a complex system industry (Winch, 1998). The model of the complex systems industry developed by Miller et al. (1955) defines two systems integrators: principal architect/engineer and the principal contractor. Also, case studies by Nam and Tatum (1997) show that the role of the principal architect/engineer and principal contractor is central in all innovations (Nam en Tatum, 1997). The construction industry has, thus, two systems integrators. One at the design stage and one at the construction stage (Winch, 1998). The figure below shows the complex systems industry being applied to construction.

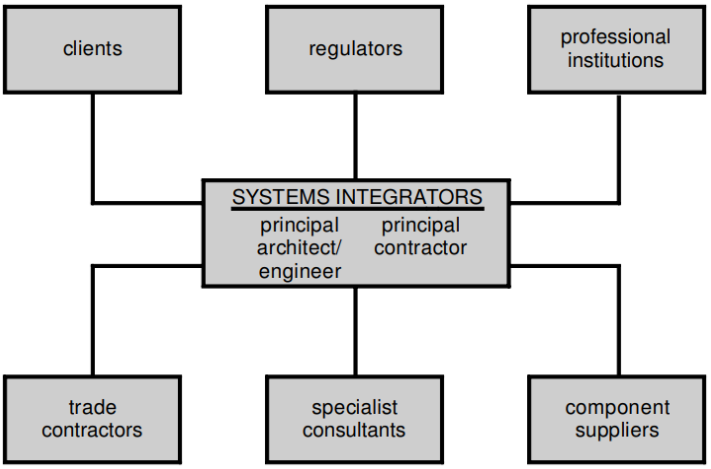


Figure 06: Construction as a complex systems industry (adapted from Miller et al., 1995) (Winch, 1998)

In his paper, Winch (1998) also discussed the very slow innovation in the construction industry due to the shared role of system integrator as explained above and the fragmentation of professional bodies in construction with as result the weakened ability to act as allies as they typically threaten the interest of competitors. Moreover, with the construction industry, in common with other complex system industries, as being a project-oriented industry, the figure below illustrates which four processes have to be managed for successful innovation in construction (Winch, 1998).

What is of great importance, is that innovations in construction, unlike many other industries, are typically not implemented in the firm itself. Rather, innovations are implemented on the projects in which the firm participates. As a result, innovations that are adopted by firms, have to be implemented on projects. Consequently, because of the collaborative nature of projects with other firms, most innovations in construction have to be developed with multiple actors within the project coalition. Winch (1998) states that “the individual's ability to do this will be strongly influenced by its role within the industry” (Winch, 1998. p.273). In the model, two moments can be differentiated: a top-down moment of adoption/implementation and a bottom-up moment of problem solving/learning (Winch, 1998).

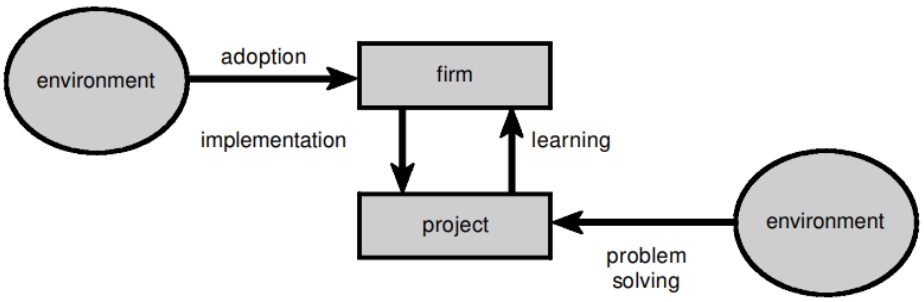


Figure 07: A model of construction innovation process (Winch, 1998)

2.7 Defining the target group

Theory around innovation adoption and the categorization of adopters is analysed. Rogers (1983) defines innovation as “an idea, practice, or object perceived as new by an individual or other unit of adoption”. Research shows that individuals evaluate an innovation through the subjective evaluations of near-peers who have adopted the innovation, rather than on the basis of scientific research by experts (Rogers, 1983). This could lead to an impasse when reflecting this finding to the acknowledgement by Cox et al. (2011) that with any new and innovative phenomenon, there will always exist the issue of ‘who jumps first’. Cox et al. (2011) states that eventually one party has to be willing to openly share information and encourage others to adopt a similar mutually agreeable exchange. Also Winch (1998) states that this competing nature and fragmentation of actors in the construction industry hinders innovation.

However, when looking at the Dutch industrialised timber construction industry, a trend can be noticed when looking at the investments made by major general contractors in production facilities for industrialised timber constructions. Among others, Van Wijnen, Plegt-Vos, Royal BAM Group, Janssen Bouw and Heijmans already developed or acquired such a ‘housing factory’. Next to these contracting firms, also multiple independent (not bound to one single contractor) housing factories have been put up, such as Barli, De Groot Vroomshoop and Homes Factory. These facilities produce industrialised timber constructions on the basis of orders by multiple firms aiming to optimise its production capacity in the near future.

After analysing the timber construction adoption in construction, the culture of the industry, theories around adopter categorization, the technology adoption life cycle and construction innovation processes it can be stated that these first steps on the Dutch industrialised timber construction market are of venturesome nature and thus these firms can be categorised as innovators. Taking into account the important role of principal contractors when it comes to innovations in the construction industry as found by Nam and Tatum (1997), this would seem an interesting target group to do specific research on. Especially in situations where these contractors should collaborate with other actors in a project to overcome the identified challenges when it comes to collaboration partnerships (Gosselin et al. 2016) and to deal with the competitive nature in construction projects (Winch, 1998), research could contribute to existing literature.

These observations of previous studies have resulted in this research focusing on ‘next adopters’. These next adopters are main contractors that do not have the capacity/volume or interest to invest in an industrialised production facility for timber constructions themselve, but participate in the early adoption of industrialised timber constructions by collaborating with other actors such as the ‘independent’ housing factories as mentioned above. Consequently, these contractors have to cope with collaboration partnerships with developers, architects and engineers in the industrialised timber construction industry which is expected to bring extra complexity to the innovation adoption.

2.8 Strategic niche management

Strategic Niche Management (SNM), originated in the Netherlands, is a theoretical framework that can be used to manage technological innovations within so-called niches. SNM is based on a multi-level perspective of socio-technical regimes within a changing landscape and influenced by emerging niches (Loorbach & van Raak, 2006). Schot and Geels (2008) define niches as spaces in which radical innovations are tried out, varied and developed further, while they are sheltered from the mainstream competition (Schot & Geels, 2008). The creation of niches is related to several success factors. Mlecnik (2014) summarises some of these success factors found in SNM literature: vision formation, learning and network composition and formation (Mlecnik, 2014).

The multi-level perspective distinguishes three analytical levels. Niches form the micro-level where radical novelties emerge. The socio-technical regime forms the meso-level, which accounts for the stability of existing large-scale systems. The macro-level is formed by the socio-technical landscape, an exogenous environment beyond the direct influence of niche and regime actors (Schot & Geels, 2008). Niche actors hope that novelties will eventually be used in the regime or even replace it. This is not easy, because the existing regime is stabilised and entrenched in many ways (lock-in). The core notion of the multi-level perspective is that transitions come about through interactions between processes at different levels: (a) niche innovations build up internal momentum, (b) changes at the landscape level create pressure on the regime, (c) destabilisation of the regime creates windows of opportunity for niche innovations (Schot & Geels, 2008). Figure 08 visualises this multi-level perspective.

When these theories are reflected in the context of this research, the multi-level perspective can be recognized one-to-one in the adoption of industrialised timber construction. Translated to the construction industry, the three levels can be seen as the Dutch built environment with its national and regional regulations influenced by international agreements (macro), stakeholders in the construction industry such as developers, architects, engineers, contractors -as well as the next-adopters- and suppliers (meso) and finally, initiators, engineers and designers of the innovation (micro). SNM theory, in particular the success factors, can provide guidance to interpret the way to adoption.

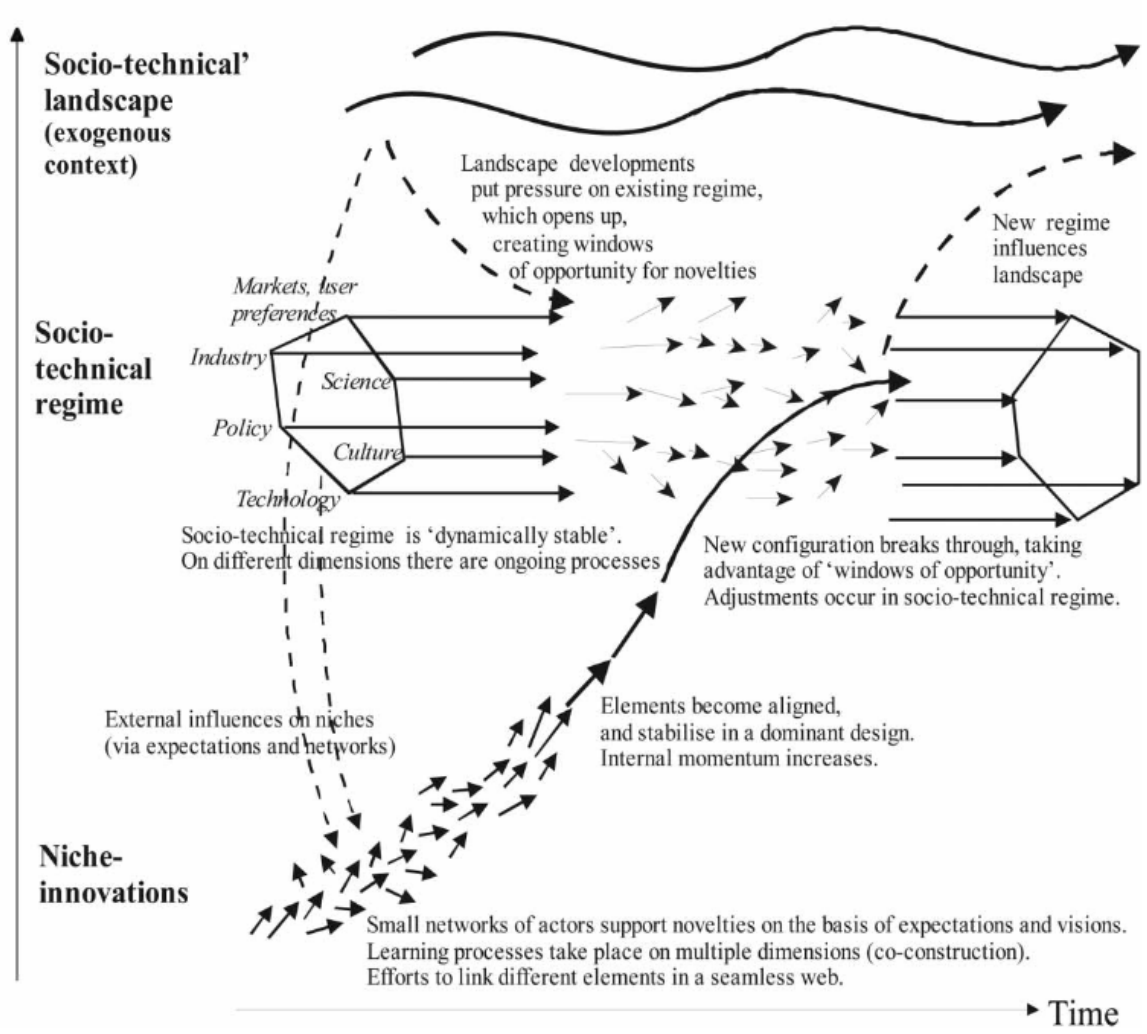


Figure 08: Multi-level perspective on transitions (Geels & Schot, 2008)

2.9 Absorptive capacity

Cohen and Levinthal (1990) define absorptive capacity as the ability to recognize the value of new information, assimilate it, and apply it to commercial ends (Cohen & Levinthal, 1990). Gluch et al. (2009) used the concept of absorptive capacity to create a model for green innovation and performance in the construction industry. In their paper, they state that both internal knowledge management processes as well as external knowledge exchange is important when investigating green innovation and performance in companies. Absorptive capacity is suggested as a concept that links these internal and external knowledge generation (Gluch, Gustafsson & Thuvander, 2009).

A company's potential absorptive capacity (PACAP) is influenced by external knowledge sources and past experiences (Gluch, Gustafsson & Thuvander, 2009). Building on the model of absorptive capacity by Zahra and George (2002), Gluch et al. (2009) proposed a revised model to indicate mechanisms behind green innovation and performance in the construction industry. The model can be seen below in figure 09.

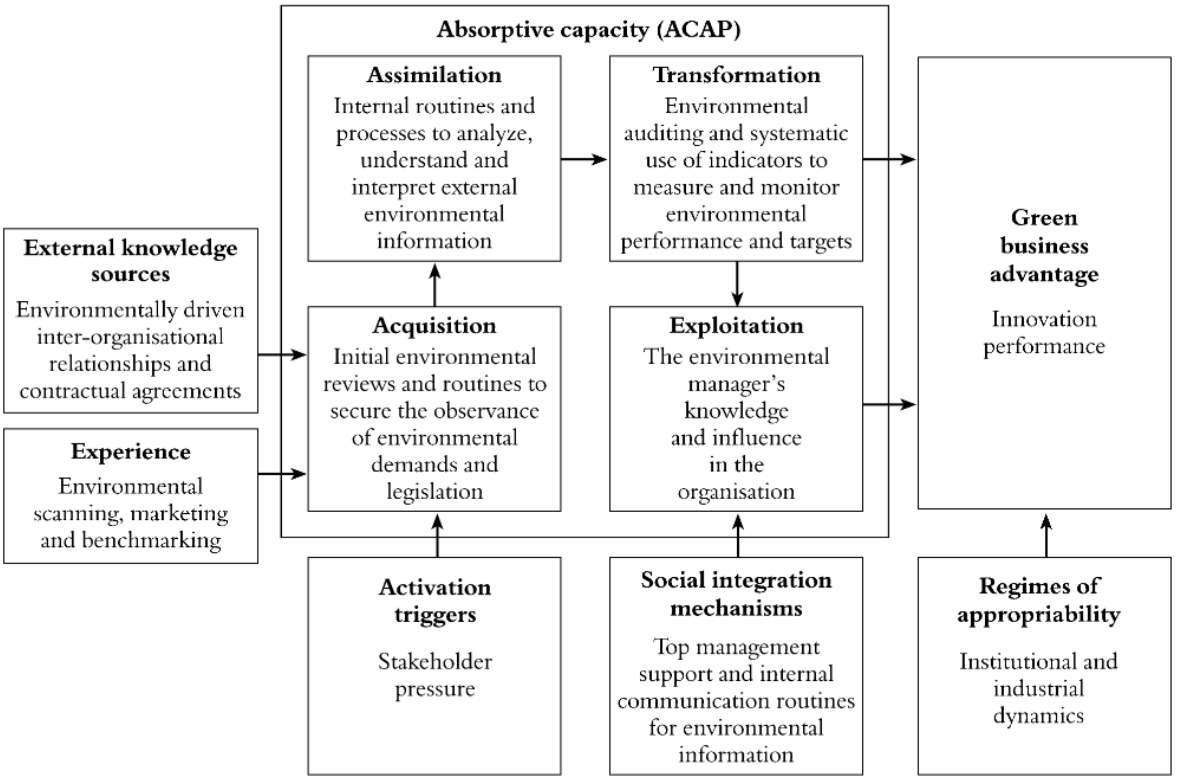


Figure 09: The green ACAP model—mechanisms behind green innovation and performance in the construction industry (Gluch, Gustafsson & Thuvander, 2009)

Central in the figure, assimilation, transformation, acquisition and exploitation are boxed within the absorptive capacity framework. Acquisition is directly predicted by external knowledge sources, experience and activation triggers, while exploitation is influenced by social integration mechanisms. The identified four parts of the ACAP construct all have relations between each other. Acquisition is found to be a predictor of assimilation, which in turn is a predictor for the transformation process, followed by exploitation. To explain parts of the variance of a company's green business advantage, acquisition, assimilation and transformation can be used. Therefore, properly working acquisition processes can be seen as a knowledge gate through which external influences and inspiration travel. The green ACAP can serve as a framework for focused efforts by actors within the construction industry (Gluch, Gustafsson & Thuvander, 2009).

2.10 Attributes of innovation

To find a universal way for describing attributes of innovations in a standard classification scheme, Rogers (1983) selected five different attributes, based on past writings and research. Each of the attributes is somewhat empirically interrelated with the other four. Conceptually they are different. The aim is to be able to predict a certain rate of adoption, without having to study each innovation as a special case.The five attributes of innovations are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability (Rogers, 1983). Below, each of the attributes will be explained in more detail.

- Relative advantage is related to the degree someone perceives a certain innovation as being better than the idea it should replace. If an innovation has the relative advantage, this would have a positive effect on its rate of adoption.

- Compatibility is related to the extent to which an innovation is recogniseable for potential adopters. In case the innovation is consistent with existing values, past experiences and needs of potential adopters, this would have a positive effect on the rate of adoption.

- Complexity is related to the perception of difficulty of an innovation. For example, if an innovation is perceived as very difficult to understand and use, this would have a negative effect on the rate of adoption.

- Trialability is related to the possibility of learning to cope with the innovation. If there is a possibility to experiment with the innovation, this would have a positive effect on the rate of adoption.

- Observability is related to the degree that potential adopters can display or show off the results of using the innovation to others. The more possibilities for making the results visible to others, the more likely it is that an innovation will be adopted.

3. Research methodology

3.1 Introduction

This chapter discusses how the research has come about and tries to answer the following two main questions: How was the data collected or generated? and How was it analysed? In short, the study uses semi-structured interviews to collect data. The data is of cross-sectional nature because it has captured a picture of aspects of organisations. To analyse the qualitative data, the study first reduces the data by using open coding techniques. As an integral part of the data analysis the reduced data will be classified by creating categories, assigning categories to the data and splitting and splicing categories (Blaikie and Priest, 2019).

Section 3.3.3 elaborates on the data collection method and section 3.3.5 clarifies the way of analysing the data. The section below first shows the conceptual model with the theoretical basis from chapter 2 as its foundation. After presenting the research process, the chapter will conclude by explaining the verification methods, data plan and ethical considerations.

3.2 Conceptual research model

The research is based on two main constructs: (1) strategies for next adopters and (2) pathways for adoption. The conceptual model pictures these two main concepts and how the two concepts together form the structure of the data collection. Concept one reflects theories around strategic niche management, absorptive capacity and attributes of innovation. Concepts two reflect theories around typologies of pathways and adoption pathways. These two concepts, together with the data obtained from the interviews, form the basis to answer the main question: What are pathways for next adopters to adopt industrialised timber construction in Dutch practice? Also, the preliminary results that are concluded after executing the interviews are reflected back to the theory that formed the basis for the interview questions. In the figure below this structure can be seen in the conceptual model.

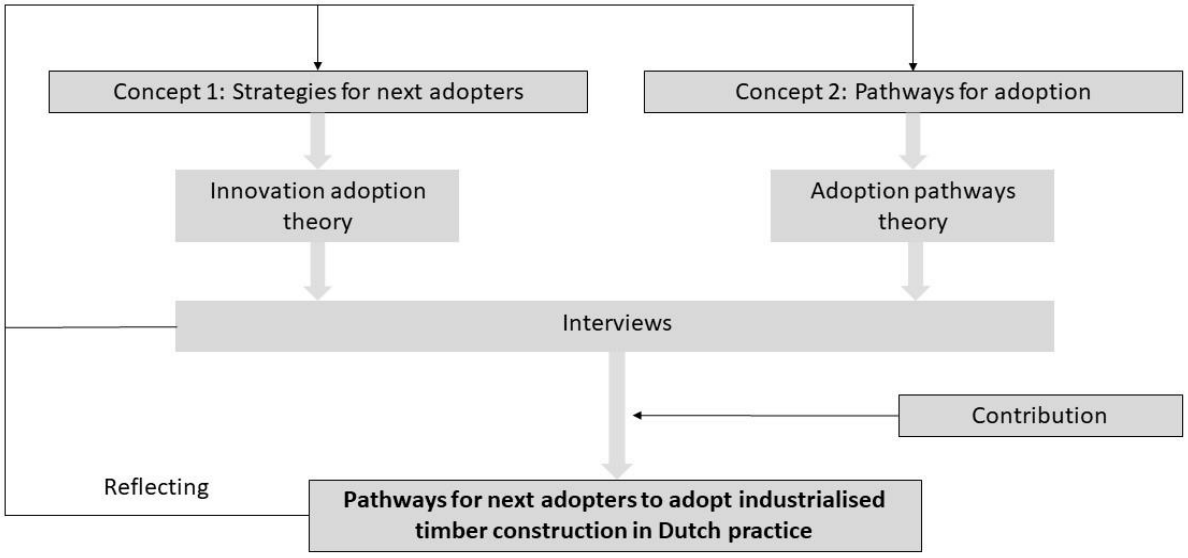


Figure 10: Conceptual model

3.3 Research method

3.3.1 Objectives and logic of inquiry

The gap that is identified from literature lies between what already is known in principle, but not in practice when it comes to adopting industrialised timber in the Dutch construction sector. Theories around absorptive capacity, strategic niche management and innovation adoption are extensive, but do not touch upon adopting industrialised timber in practice. The bridge between the theories mentioned above and practice in the Dutch construction sector is made in this research. Exploratory interviews that were conducted at the very beginning of this research, underline the relevance and demand for research on adoption pathways for industrialised timber in the Dutch construction sector.

To specify the logic of inquiry for this research, the research questions and conceptual framework can be analysed. All questions in this research are so-called ‘what’ or ‘how’ questions. ‘What’ questions require a descriptive answer since they are directed towards discovering and describing the characteristics of, and regularities in, some social phenomenon (Blaikie & Priest, 2019). In other words, one needs to understand what is going on, before it can be explained. ‘How’ questions are often answered in a more explanatory way. This method is used in this research to analyse pathways. When looking at the research purpose, next to the researcher’s personal motives and goals for undertaking the research, the research focuses on exploring theories to attempt to develop an initial description or, possibly, an understanding of some phenomenon. Consequently, it tries to explain elements, factors or mechanisms that are responsible for producing the state of or regularities in this phenomenon (Blaikie & Priest, 2019).

When exploring and describing an understanding of some phenomenon, inductive logic suits this approach best. First data is collected and descriptions are produced. As a third step, ‘what’ questions can be answered. However, in this research also an explanation in a certain

context is made. This indicates the use of retroductive logic. After the relevant data on a regularity is identified and documented, this is linked to a context and possible mechanisms and finally it can be concluded which mechanism(s) provide(s) the best explanation in context (Blaikie & Priest, 2019).

Before the researcher can start describing characteristics and regularities related to industrialised timber in the Dutch context, the researcher's understanding of these characteristics and regularities has to be improved. This is done by reviewing literature and exploratory interviews with practitioners. The exploratory interviews give the researcher a better understanding of the theories from literature in relation to Dutch practice. Finally, to be able to conclude which mechanism(s) provide(s) best explanation in the Dutch construction context, semi-structured interviews are used to come to an explanation.

In the figure below, the objectives have been specified for each of the research questions.

	Objective	Question
Main question	To explain what pathway(s) provide(s) the best explanation in context	What are pathways for next adopters to adopt industrialised timber construction in Dutch practice?
Sub-question 1	To review the literature to identify the characteristics of next adopters	What are the characteristics of next adopters in industrialised timber construction?
Sub-question 2	To analyse adoption pathways	How can adoption pathways be analysed?
Sub-question 3	To describe factors, drivers and barriers in the adoption process	What are factors, drivers and barriers for next adopters to adopt industrialised timber construction and how can the barriers be overcome?
Sub-question 4	To describe typologies of pathways	What are typologies of pathways that can be used to put adoption of industrialised timber construction in practice?

Figure 11: Objectives per research question

3.3.2 Type of data

The type of data produced by this research will be of qualitative nature, because my questions will mainly be based on experiences. When exploring how innovation adoption proceeds at a contractor firm, the data can hardly be expressed in numbers. Therefore, the outcome of the inductive interviews will be processed as qualitative data. Also, the research will be exploratory since the trend of industrialised timber construction adoption among main contractors is only a very recent phenomenon in the Dutch construction industry.

Data obtained by interviews can be categorised as primary data. Primary data contains all forms of original information that is collected to answer a research question through, for example surveys, observations, interviews and experiments. On the other hand, secondary data is data that has already been collected by other researchers. The latter will be used to answer part of the sub-questions. By doing a literature study on the specific questions at hand, trends can be identified and evaluated.

3.3.3 Data collection/interview protocol

Literature review

A rather extensive literature review will be done to answer (part of) the sub-questions. By means of this secondary data, especially analysing change and exploring key factors could contribute to answering sub-questions. Also, typologies of pathways can be identified by already existing data, which afterwards can be evaluated during the interviews. In this way, different methods will be combined in a mixed method.

Interviews

The semi-structured interviews will be a combination of closed and open coding. Based on literature, closed codes can be defined to form a layout in the interview protocol. During the interviews also new data can emerge, which then will be assigned to a new code: inductive (open) coding. Instead of starting from a theory and working towards a question (deductive), open coding will cause a reversed process, where the base point is a question after which a new theory can be composed.

Deductive interviews make use of a clear structure or predetermined framework to analyse the data based on theories and then use these to analyse the interview transcripts. This way of working is being used in situations where probable participant responses are already identified. Downsides of this approach are the inflexibility and potential bias in the analysis as the coding framework has been composed beforehand. This can also limit the theme and theory development (Burnerd et al., 2008).

Inductive interviews make use of very little or even no predetermined theory, structures or frameworks. The actual data itself is used to derive the structure of the analysis. This approach is best applicable in situations where little or nothing is known about the study phenomenon. A downside of this method is the time needed to make the analysis (Burnerd et al., 2008). Inductive analysis is the most common approach used to analyse qualitative data and is, therefore, the focus of this paper.

Burnard et al. (2008) describes the process of analysing qualitative data in nine steps:

1. Conducting interviews
2. Transcribing interviews
3. Make notes of short phrases of words
4. Collect short phrases and words and cross out duplications
5. Look for overlapping or crossing categories
6. Reduce categories to a maximum of 12
7. Allocate a colour to each category and mark the transcribed text with the colours
8. Cut out all sections of data and group per colour
9. Respondent validation (member checking)

In the figure below, these different steps are visualised.

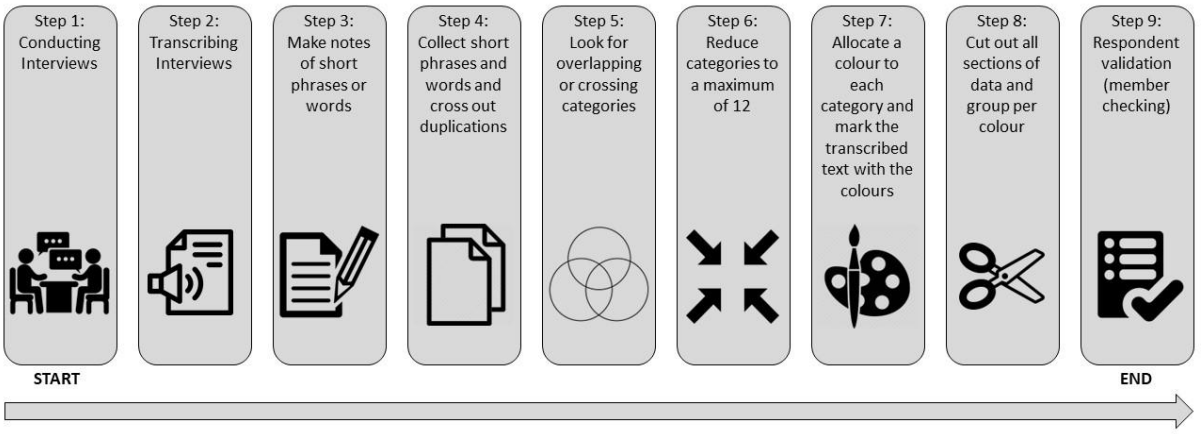


Figure 12: Stages in qualitative research

Criteria for selecting interviewees/case:

- Industrialised timber construction housing projects
- Have not adopted industrialised timber constructions yet
- Have the ambition to adopt industrialised timber constructions on short term or are in the process of adopting the innovation
- Firms without an own industrialised timber production facility

The unit of analysis:

- A selected firm, preferably with multiple currently running industrialised timber projects at the moment in which they adopt industrialised timber construction for the first time
- Between a total of 10-15 interviews within this firm on different levels and functions in the organisation

From what actors do I want to get information and what do I want to know from them?

- Managers of the firm to ask them about the decision to adopt industrialised timber construction and the decision making process (motivations) behind it > adopting process
- How does the firm adopt industrialised timber construction projects and how does this changes their working process/collaboration partnerships
- Actors within a project team inside the construction firm such as general managers, project managers, planners, calculators, foreman > implementation of the innovation

3.3.4 Data analysis

The interviews will preferably be held online with the aim to record the session. If the interview has to be done physically, also a recording has to be made at all times. On the basis of this recording, interview transcripts will be made. These will describe the information, but they do not provide explanations. Eventually the researcher has to make

sense of the data collected. This will be done according to the steps described above and by the means of software such as Atlas.ti.

Because of the qualitative nature of this research, it is possible to start analysing data during or immediately after the first data is collected. These first analyses may inform subsequent data collection and may be a reason to slightly modify interviews afterwards. Also, for example interview schedules may be changed in the light of emerging findings where additional clarification may be required.

The Gioia Methodology

To be able to meet a certain degree of rigorous standard of trustworthiness in this qualitative research, the data is analysed by following the Gioia Methodology. This systematic approach guides the researcher towards the development of new concepts and a structured way of presenting its findings. The Gioia Methodology is a well known and highly valued method in the domain of qualitative research. The origins of this approach date from 1991, when Gioia and Chittipeddi made an attempt to publish their paper. The reviewers of the journal to which the paper was sent to, were critical of the presentation of the data. Gioia and Chittipeddi were challenged to demonstrate the basis for their conclusions. The researchers then worked on a presentation to convince that they had not just cherry-picked the quotes and put a sexy label on it, but that a lot of care was taken in the data acquisition and the way the data was analysed. The researchers found a resolution in proposing an approach that allowed for a systemic presentation of both a 1st order analysis and a 2nd order analysis. These two orders together allowed for a qualitative rigorous demonstration of the links between data and the induction of this new concept, sense giving, but also allowed for the kind of insight that is the hallmark of high-quality qualitative research (Gioia et al. 2012). Since then, the approach has continued to prove its usefulness for researchers in conducting qualitative research.

The most significant data source from which data is employed is the semi-structured interview. This style of research is also “get in there and get your hands dirty” research. During the interviews the interviewer has to pay careful attention to what the informant is telling and conscientiously has to try to use their vocabulary to help understand their lived experience. The downside of this kind of interview is, among others, the risk of “going native”. In other words, being too close and essentially adopting the informant’s view and thereby, losing the higher-level perspective. During the interviews, special attention is paid to this phenomenon with the aim to safeguard the overall perspective and keep a certain degree of distance between the interviewer and the informant.

3.3.5 Verification

To verify the data obtained from the interviews, peer reviewing whereby another researcher will analyse the data independently is not realistic compared to the timeframe in which the research is done. Another method is to return the study to the participants (interviewees) and to ask them to validate the analysis. This can be done on an individual level by asking them to read through their interview transcripts and/or data analysis for them to validate, or on a group level by means of focus group workshops at the final stage of the process. Also a combination of the two can be chosen.

During this research, the available time is a restriction when it comes to validating the interviewees. This will be influenced by the number of interviews conducted and the time needed to analyse its results. Therefore, at a later stage during the research (for example halfway during the interview period) a final decision will be made about what validation method(s) is going to be used. Because some respondents may also want to modify their opinions, some time after the validation period should be reserved for this purpose.

3.3.6 Ethical considerations

Contribution to the research will solely be based on voluntary principles. No rewardings will be handed to the interviewees or other participants in this study. Also, the data obtained will be fully anonymised with the aim of getting sincere and free speech answers that are unbiased. Next to this, full transparency on the research method and steps in the research process will be given to enable validation by other researchers after the research is finished.

3.4 Research output

The goal of this research is to develop pathways for next adopters to adopt industrialised timber construction in Dutch practice.

Deliverables
Besides just the final thesis report itself, deliverables contain amongst others a coherent literature review on the used constructs and the results of analysing the data and the outcomes of the verification by the interviewees and the focus group.

Audience
The knowledge produced by this research is intended for all parties who work in or are related in any way to the Dutch construction sector, especially when it comes to industrialised timber construction processes. The content of the research can provide pathways for contractors who are thinking about, or are adopting this innovation in their organisation. Also, the research could lead to new input which then can provide a new starting point for further research which goes beyond the scope of this research.

Personal study targets
During this study I would like to gain more insight in the industrialised timber construction industry in the Dutch construction sector. Personally, I am very much interested in the topic and would like to get to know more about it and to specialise myself into a specific workfield to give input in my future professional career. Also the focus on analysing the process of innovation adoption at a general contractor seems very interesting to me.

I also want to use the coming period to increase my personal skills at critical thinking, problem solving in complex situations and interviewing. As such, I am highly motivated to deliver a high quality thesis with substantiated results that are applicable in Dutch practice. Eventually, I strive to be able to look back on the research period with pride and a feeling of fulfilment. During my P5 presentation I would like to invite some family and relatives to officially finalise the great studying period at the TU Delft.

4. Research findings

4.1 Introduction

In this section the main findings of the data collection and analysis will be reported. All relevant results will be reported in a concise and objective manner. The results will be structured around key themes, expressed in sub-questions. The four sub-questions in this research are listed below, and together form the basis of the answer to the main research question. Also some quotations of the informants will be used to underline relevant information or to clarify and support tables and sub-conclusions.

The sub-questions in this research are the following:

- What are the characteristics of next adopters in industrialised timber construction?
- How can adoption pathways be analysed?
- What are factors, drivers and barriers for next adopters to adopt industrialised timber construction and how can the barriers be overcome?
- What are typologies of pathways that can be used to put adoption of industrialised timber construction in practice?

The sub-questions will help answering the main research question, which is:

What are pathways for next adopters to adopt industrialised timber construction in Dutch practice?

4.2 The characteristics of next adopters

4.2.1 Introduction

In the literature review, already a good understanding of characteristics of early adopters in innovation processes was reached. However, to focus on next adopters in industrialised timber construction, a more specific understanding of their characteristics needs to be obtained. This is being done by reviewing literature and further explored through interviews.

4.2.2 Next adopters

Next adopters are defined in this research as main contractors that do not have the capacity, volume or interest to invest in an industrialised production facility for timber construction themselves, but participate in the early adoption of industrialised timber constructions by collaborating with other actors such as the ‘independent’ housing factories as described in the literature review. As a result, these contractors are bound by collaborations with other stakeholders in the process such as developers, architects, engineers and other co-makers.

From the interviews, four themes to identify next adopters appear to be leading when organisations or individuals make their decision to adopt: (1) characteristics of the decision maker, (2) motivation of the decision maker, (3) supply based motivation of the organisation and (4) demand based motivation of the organisation. Related to organisations who have the intrinsic motivation to start building with industrialised timber construction (supply based), aspects like the current sustainability measures, motivation to start something new and their attitude towards bio-based materials are important. On the other hand, organisations who are labelled ‘demand based’ pay more attention to following the market and react to innovations happening in the market in a ‘trial and error’ manner. In the tables below, the data analysis from the interviews can be seen.

4.2.3 Individual characteristics and motivations

Table 01 shows characteristics and motivations from individuals that are drawn from the interviews. The quotes in the table are a mix between stakeholders in all three cases. All informants are very conscious of how their work relates to sustainability. And for some informants, in their private lives, they are also busy making their lifestyle more sustainable and consciously dealing with nature. Next to that, also an 'open attitude' is mentioned. One has to be eager to learn something new and has to be curious to how new, unfamiliar things work.

Table 01 – Identifying next adopters, individual characteristics and motivations

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"… the operational director is largely vegetarian, our head of project preparation is vegan and that is also part of our DNA."	Sustainable characteristic of decision maker	Characteristics of the decision maker	Identifying next adopters
"... in 20 years when my children ask the question: 'But Dad, it all went wrong, what did you do?' I'm already working on what answer I'm going to give them. And I think this could be an answer: we focused on timber construction and I may have made a small difference with that."	Motive for doing better		
"I am a strong proponent of making construction more sustainable …"	Attitude towards sustainability		
"... you also have to be eager to learn. You have to be open like gosh, what does this all involve?"	Open attitude towards learning the ins-and-outs		
"I myself graduated in sustainable real estate management in 2011, so in that sense I was interested in sustainability. I also find circular construction very interesting, so I dive into it. That's why I also see it as a nice and interesting chance to learn all this."	Motivation to adopt the innovation	Motivation of the decision maker	
"...everything Paul is doing, what I'm doing, it's about affordability and health. Those are actually two important things. And not just today, also tomorrow and in 50 years time..."	Intrinsic motivation of the decision maker		

4.2.4 Supply based motivation of the organisation

In table 02 the motivation of supply driven responses are analysed. Some of the informants described their experience of a shift happening within their organisation towards a more sustainable way of working. Also the awareness of the CO2 emissions that the building industry produces has triggered the organisations to start working with industrialised timber. And not only the building material timber is mentioned to be a part of the solution. Also other bio-based building materials like bamboo are mentioned in their search for more sustainable materials.

Table 02 – Identifying next adopters, supply based motivation of organization

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... within the company we do make that move and we do that because we think it is very important for the world, ..."	Characteristics of the organization	Supply based motivation of organization	Identifying next adopters
"where, based on our own ambition, we are increasingly aware of the footprint that we all occupy and therefore also our projects."	Consciously dealing with CO2-emmisions		
"... we have quite a lot of electric cars, we have a roof-flax insulation power, we have set up a green branch. So there are quite a lot of things we are doing to go in a sustainable direction and I see this as one of those next steps to go even more in that direction."	Current sustainability measures within the organization		
"Being healthy and happy. That is what we are here on earth for. So in this company we try to create that environment in which people are happy and nature has a place and where at the same time clients receive a product that gives them best value. So a very good value proposition."	Motivation of the organization to start working with industrialized timber		
"...we are fans of biobased products anyway. So that could be the paintwork, that could be the flax in the roof, that could be bamboo. Bio-based appeals enormously, for several reasons: 1) it generally comes closer, so the impact is often very low, 2) also the idea that you can generate something from nature and that you can apply it again while it also grows elsewhere. In my opinion, it is the most convincing and direct form of sustainability."	Attitude towards bio-based materials		

4.2.5 Demand based motivation of the organisation

The final and third table that is used to identify next adopters focuses on the demand driven quotes. In contrast to the previous table, the quotes below show a more passive and reactive way of adopting the innovation. What can be noted is that the willingness to innovate in this category of informants is driven from a service providing point of view. Because the market demands a more sustainable way of building, this firm is willing to innovate and provide this service. The firm is not adopting a new innovative construction type because it's their own ambition, but because it is a reactions towards a question from the demand side.

Table 03 – Identifying next adopters, demand based motivation of organization

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"We are a service provider. There are construction companies that are very excited about this, that are convinced of their own right to exist. But we are simply the service provider and the client has a question and we work it out further. Ultimately, we realize the product that the customer asks. That's how I stand in it. -/- ... in the end I just want to earn money and it would be nice if that could be done with sustainable solutions, but if the market is not yet ready for that at that time, or it wants that If not, then just building with concrete is no problem either."	Following the market demand to define construction methods	Demand based motivation of organization	Identifying next adopters
"...as a builder we would like to follow the market. We don't see ourselves, we are too small for that, as a real innovative party." / "We are just very 'down to Earth': we chose this and then we find out how it works."	Reacting to innovations happening in the market, trial and error attitude		
"Partly because we are a family business, we never like very large reports and visions. You just try to look at the market in an enterprising way and respond to it and thus be interesting as a party."	Organization as family business		

4.3 Analysing adoption pathways

4.3.1 Introduction

When analysing adoption pathways, existing literature has to be explored to find patterns in adoption trajectories. In this chapter, different models are analysed and compared to be able to find the common steps in the process of an adoption pathway. This analysis can then be used to compare the new data from this research to existing studies and findings. This chapter aims at answering the following question: How can adoption pathways be analysed?

4.3.2 Comparing innovation adoption pathways

Rogers (1995) writes that adoption refers to the decision of any individual or organisation to make use of an innovation, and has defined innovation adoption as a decision to make complete use of an innovation as the best course of action available, and correspondingly, rejection as a decision not to adopt an innovation. When looking at organisational adoption trajectories in literature, a differentiation can be made between innovation adoption at the organisational level and innovation adoption by individuals within an organisation. Organisational adoption is related to the decisions made at both levels (Frambach & Schillewaert, 2002). When looking at both individual and organisational innovation-decisions, 4 types of decisions can be distinguished (Rogers, 1995):

1. Optional innovation-decisions, choices to adopt or reject an innovation that are made by an individual independent of the decisions of other members of a system.
2. Collective innovation-decisions, choices to adopt or reject an innovation that are made by consensus among the members of a system.
3. Authority innovation-decisions, choices to adopt or reject an innovation that are made by a relatively few individuals in a system who possess power, status, or technical expertise.
4. Contingent innovation-decisions, choices to adopt or reject that can be made only after a prior innovation-decision.

Frambach and Schillewaert (2002) also describe different types of innovation adoption: intra-organisational acceptance and contingent innovation decisions or “forced adoption”. Intra-organisation acceptance corresponds to optional- and collective innovation-decisions whereas forced adoption corresponds to authority- and contingent innovation-decisions.

In the next paragraphs, some frameworks of individual adoption as well as on the organisational level will be analysed. These frameworks will later function as a basis for the innovation adoption pathways in this research.

Firstly, Rogers (1995) describes that the innovation-decision process consists of 5 steps: knowledge, persuasion, decision, implementation and confirmation. These 5 steps are found to be the series of actions and choices over time, which an individual goes through when evaluating a new idea and when deciding whether or not to adopt. The 5 sequential stages can be briefly explained as follows:

1. Knowledge about the innovation is gained at the moment the individual is introduced to the existence of the innovation. A first understanding of how it functions is obtained.
2. Persuasion is related to forming an attitude towards innovation by the individual. This can both be favourable or unfavourable.
3. A decision is made when an individual makes a choice to adopt or reject the innovation.
4. Implementation occurs when an individual puts an innovation into use.
5. Confirmation happens when an innovation-decision is reconsidered because of new insights, the already made decision can be reversed or strengthened.

Later, Edelmann (2005) continues with this theory and adds that every step of the method involves gathering, processing and incorporating new experiences and information. In the figure below, the 5 steps are shown together with the influence of communication channels and the input of the characteristics of both the decision-maker and the innovation. A communication channel is described by Rogers (1995) as 'the means by which a message gets from a source to a receiver'. Two types of communication channels are categorised: interpersonal or mass media in nature, and as originating from either localite or cosmopolite sources.

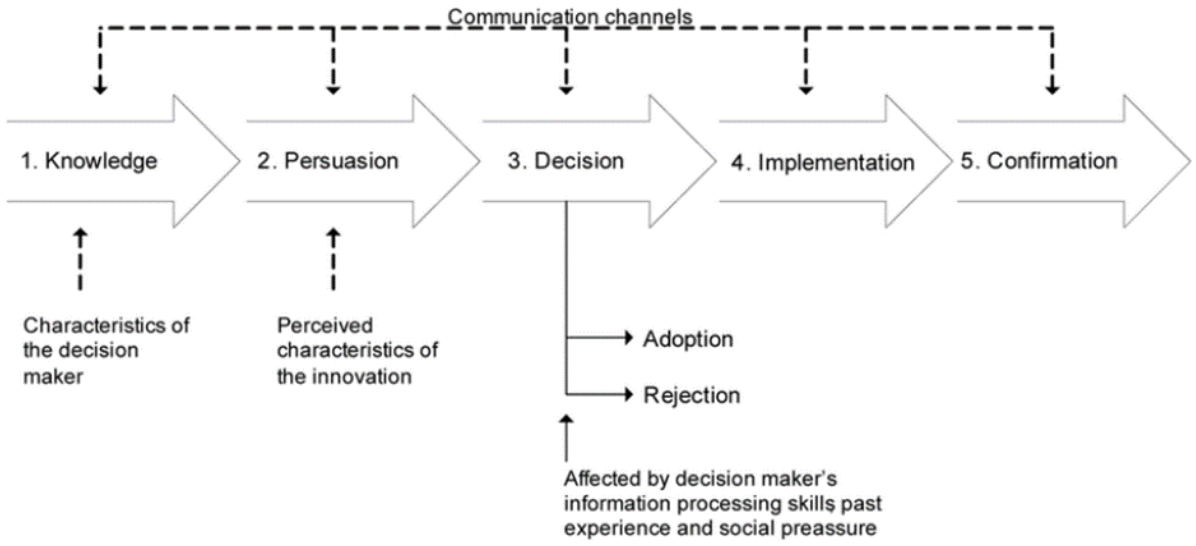


Figure 15: Stages in the innovation adoption decision process (Edelmann, 2005 - modified from Rogers, 1995)

4.3.3 Individual innovation acceptance

Frambach en Schillewaert (2002) also describes a general framework for individual innovation acceptance in organisations. As can be seen in the figure below, they have identified factors that explain individual adoption and their interrelations. Also, the oval in the left upper corner indicates an input from organisational innovation adoption. This is due to the contingent nature of innovation decisions in an organisation where individuals are dependent on the innovation decision made by the organisation as a whole. Central in this figure is positioned the attitude towards the innovation based on beliefs and affects. Attitudes can change and be influenced and there is evidence that a person's attitudes mediate the influence of external variables and stimuli (Frambach en Schillewaert, 2002).

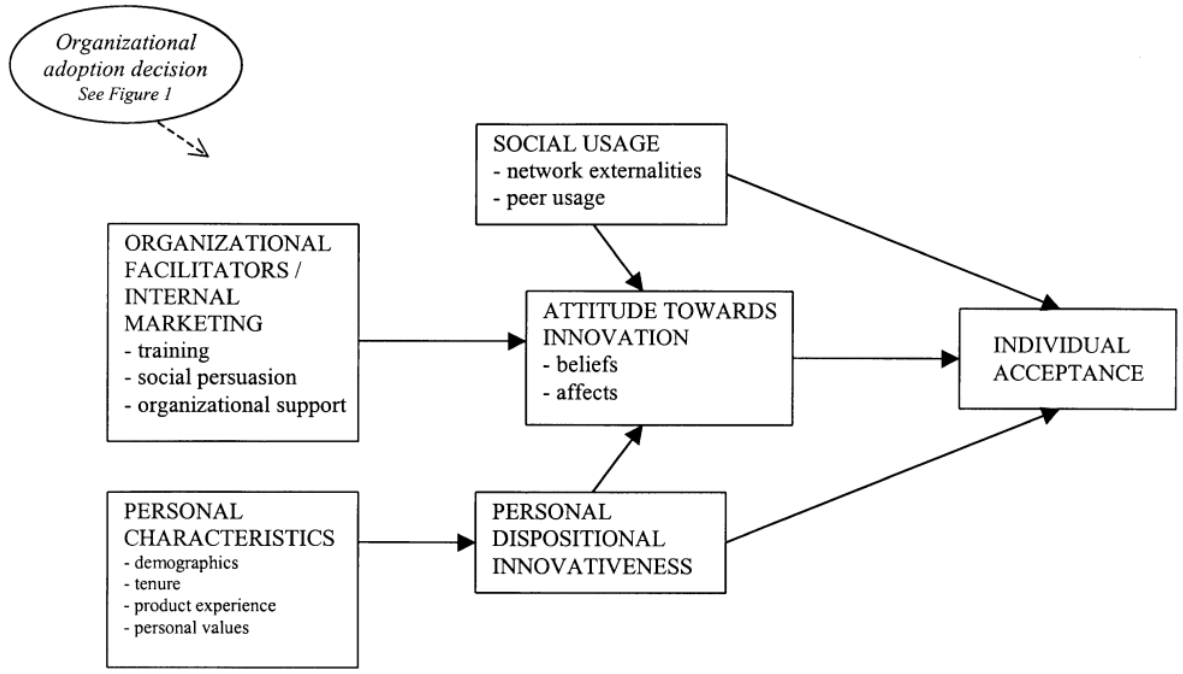


Figure 16: A conceptual framework of individual innovation acceptance in organisations (Frambach en Schillewaert, 2002)

4.3.4 Organisational innovation adoption

Before an individual within has the opportunity to innovate, also the organisation as a whole needs to adopt such an innovation. In the figure below, organisational innovation adoption is depicted. The same five stages in the innovation adoption decision process from figure 15 can be recognised on the right hand side of the figure. The external input, influencing the adoption decision consist of perceived innovation characteristics, adopter characteristics and environmental influences. This input can be recognised from the data collection in this research, wherein the informants were specifically asked about these topics.

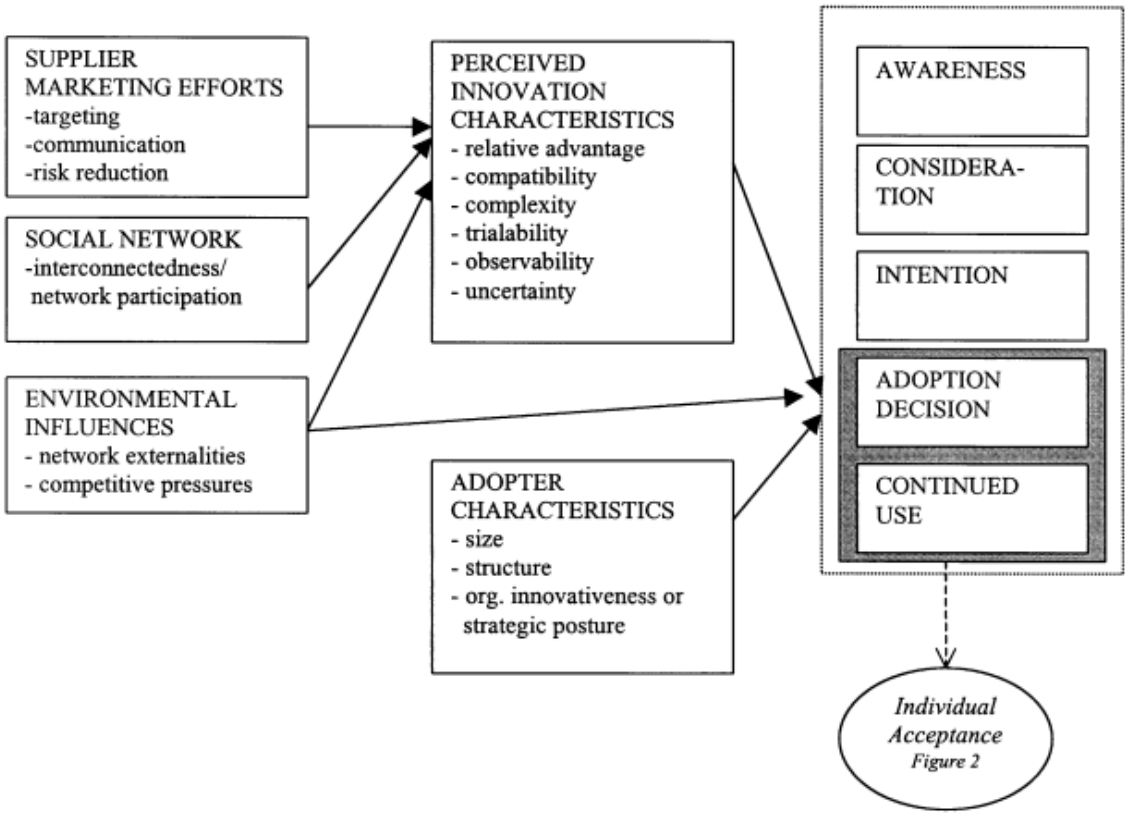


Figure 17: A conceptual framework of organisational innovation adoption (Frambach en Schillewaert, 2002)

4.4 Factors, drivers and barriers to adopt

4.4.1 Introduction

From the analysis of the data, factors, drivers and barriers can be recognised that prove to be critical in the adoption process. This data is analysed using the Gioia method and therefore, aggregate dimensions are the result of analysing the raw data, from first to second order codes and themes. Making this analysis is used to get an understanding of the critical factors, drivers and barriers for next adopters to adopt industrialised timber construction.

In the tables below, the analysis of the data is shown in a transparent way. In the first column the raw data is shown using quotes from the informants. In the next steps, these quotes are abstracted to 1st order codes and 2nd order themes. In the last column, aggregate dimensions are shown as the final category and most abstract form.

Context of adopting

Table 04 – Context of adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"I wouldn't do such a project too far away, for example, I would like to be close by. The first project we do is also a fifteen minute drive away. You have to be able to go there often to be on top of it. For me well, especially when you start."	Travel distance to project location	Location specific conditions	Context of adopting
"...it has not been the case in this project that wood was an obligation, a condition or a starting point. But from the location where this project has meanwhile been realized, the nature of the place and the opportunities that were present at the location were the reason to set up the design, the structure and the vision of the design."	Influence of the place and opportunities to vision and design		
"... health has indeed been an important issue. I think that this place was really seen by the municipality of Eindhoven as a place where something special had to happen."	Demand at the location from the municipality	External stimuli for adopting	
"... the innovative product is then always more expensive and with many more risks. A big advantage that we have had here and it has made possible in part, is that the Municipality wanted to think along with how do I make such an innovation feasible? And then you also come to the land value policy.."	Helpful policy of the municipality		
"If the municipality had gone for maximum yield, you would have had a completely different plan. So if the municipality has a different ambition or interest, you won't get the innovation done at all."	Importance of willingness of the municipality		

Role of the network/partners in the adoption process

Table 05 – Role of network/partners in the adoption process

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"So you actually need more parties that are open to it and that you feel that too. Who don't just sit like 'it's all difficult and complicated' but mainly say 'interesting, who knows it's an option for the future, I'll try it', that kind of attitude."	Mindset of partners in the adoption process	Characteristics of project partners	Role of network/partners in the adoption process
"...in addition, we looked very carefully to ensure that every consultant we involved in the project always brought a background and expertise in the field of timber construction."	Carefully selecting advisors with experience		
"... you also need a number of construction partners who say, okay, I've never done this before or not often or I don't know very well, but I'm going to do it, I think it's cool."	Venturous attitude of co-makers in the adoption process		
"... the foreign market knows very well how to build in timber and what problems you have to solve for this. So they only need a local party to translate that into Dutch legislation and regulations. You can also see that there is more and more supply and that it is getting closer to the Netherlands."	Cooperating with foreign parties	Foreign co-makers	
"Co-makers keep coming from abroad with the Dutch agencies are around them in the near future. That still remains the model we operate in..."	Also for coming projects, working together with foreign parties		
"... especially the manufacturers of CLT are not in the Netherlands. So they work with agencies from the country where it is produced, in order to be able to translate the product to the Dutch market and the applicable laws and regulations."	Finding a foreign co-maker/supplier		

Table 06 – Role of network/partners in the adoption process

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... that the clients have clearly stated that there is potential and that they would like to go in that direction with a number of projects. They are very important..."	Importance of interested client in the adoption process	Motivated client as key player in the adoption process	Role of network/partners in the adoption process
"... it is only a successful innovation, in my opinion, when a market party is willing to pay for it and in our case that means a client who wants a building made of a timber construction... "	Finding an interested client		
"You have to have a client who really wants it and not a client who says 'I have to do it from my supervisor' or something. You all have to want to go in that direction."	Importance of intrinsic motivation of client		
"... we got involved in the development through a relation of mine who had won this competition that we entered together. Well, in the application we indicated that we wanted to build in wood..."	Choosing for timber apart from client	Own initiative in tender from developer	

Table 07 – Learning processes

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... look for partners who have experience and conduct research throughout the process... "	Seeking knowledge at partners and research	Learning from project partners	Learning processes
"We went to a wood construction factory in Belgium to get a feeling of how they do it? I have to say, really building it with CLT, eh, that cross-layer wood that hasn't happened there yet, so that still remains a new aspect..."	Learning from timber supplier		
"In addition, we pick up a lot from the developers themselves, who can contribute a lot from their experience and you can learn from that or start the discussion about it. That helps."	Learning from project partners' experience		
"... we have been looking at other timber construction projects. How is it done there and how are things going there? Who all walks around and how do they handle things? So we did observe that. In that sense, we have been lucky that a project was being carried out in timber construction nearby and we were able to keep an eye on it from a short distance."	Learning from other local project	Learning from observability other projects	
"... we went to look at other projects, projects that have already been realized and that have already been taken into use."	Learning from realised projects by others		

Learning processes

Table 08 – Learning processes

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"..., so there wasn't really a very deep strategy behind it or anything. Just learning by doing."	Learning by doing	Starting without practise	Learning processes
"So no, we didn't really look at reference projects. We just got to work ourselves."	Trial and error method		
"We created a sub-pilot within this pilot project: 2 of a total of 56 homes. With two goals: (1) with two homes, we wanted to see if what we had come up with on paper would also work in practice. So we used those two sub-pilot homes to learn from and implement points we found for improvement on the other 54 homes, and two (2), we were able to have a trial home so that we could show the buyers what kind of house you can actually expect upon completion and what you can do with it afterwards. So it became a kind of huge showroom of what potential such a timber house would have."	Learning from (sub-)pilot project	Searching for trialability measures	
" I don't think we will encounter major surprises from the mock-up. You can even check that in the factory whether they meet our expectations. I think, especially when it comes to placing, connecting and finishing, you will occasionally think of: 'I didn't see this coming', 'I didn't expect this', 'an extra measure needs to be taken here, for example, to ensure safety'. Or: 'gosh, there's a part that needs to be finished and we didn't foresee that'. I think that will happen sooner."	Using a mock-up to learn from		

Challenges when adopting

Table 09 – Challenges when adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... you can of course really want something, but you also have to be given the opportunity to do it. That is the biggest barrier to eventually applying an innovation."	The need for an opportunity to apply innovation	Finding a suitable opportunity and conditions to start	Challenges when adopting
"... at that time the market was very stable in terms of pricing and things like that. And we had some room in the budgets, so there was some leeway there to deal with unforeseen issues. In addition, you build in Amsterdam, as a result, you simply have higher yields than building somewhere in the east of the Netherlands... "	The perfect opportunity and conditions for innovating		
"... in engineering, of course, we had to pay a lot of tuition. -/- ...it has been quite a quest, of course you don't think about it all in the beginning. During the project it proves to be really pioneering in that respect, in my opinion."	Unforeseen challenges in the engineering phase	New technical challenges when working with new construction method	
"...but if, when you want to apply for a permit, you need to be able to hand over all kinds of certificates and provide proof that sound, fire resistance, etc. all meet the standard. And you suddenly can't pull those certificates out of the closet, because we don't have that yet, so then you notice that you are really doing something new."	Practical permit challenges when building with a new material		
"... and the moment you start stacking, because that's actually what we're going to do. Yes, then the connections suddenly become very important. And those connections are very new."	Complexity when being introduced to new connections		

Table 10 – Challenges when adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"...look for parties that also bring a lot of experience with them. That is important in the choices you make for the selection of subcontractors and suppliers for your project. And it is also very important how you manage the authorities properly. That sounds crazy, but you just have to do it with well-equipped parties, that gives confidence. And they also have to guide the testing authorities properly in the implementation, because these types of projects are really looked at through a magnifying glass."	Benefits of contracting experienced project partners	Contracting co-makers with relevant experience	Challenges when adopting
"... you literally have to rethink a lot of things. Throughout the chain there are a kind of obvious things about how we build traditionally and everyone understands that. That is very different with building in timber. So every link, so to speak, can be a weak link, you have to be very careful to prevent that."	Rethinking traditionally obvious things throughout the building chain		
"... those foreign parties have knowledge and experience of building in timber, but not for a project of this scale in this type of housing on the Dutch market and within Dutch law and regulations. That was new to everyone. They also had to feel like going on that adventure together, of course."	Foreign partners did not have accurate knowledge in the Dutch context	Barriers of working with foreign co-makers	
"The co-maker that comes from Belgium, which is also the French-speaking part of Belgium. Things just get lost in translation, literally. We see that as a risk."	Information loss when working with foreign co-makers		

Risk management

Table 11 – Risk management

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"...because of that split in the contract we are now not bothered by very big risks. And as a result we just have to manage the cash flows around the work we do and the developer has the cash flows around the units they organize and has to coordinate that with the supplier."	Financial risk mitigation	Contractual risks	Risk management
"... so you talk to both the client and the supplier, and discuss what is possible, and you share that with each other. And that has everything to do with risks. So the client does not want to run the risk that he already has paid while he only gets half- or ultimately- doesn't get the right product. And at a certain point the factory doesn't want to pre-finance everything and they also want to get paid once."	Risks between supplier and client		
"... clients all say that they would like to have the contractual responsibility with 1 party. And for the time being we are a bit more careful with that. So we are looking for a contractual form in which we take the risks that we can bear and oversee. "	Contract related risks and responsibilities	System risks	
"...and what I look out for is systemic risk. So if I have 3 projects with the same units and the same supplier and that supplier stops and it would go wrong in 3 places because there is a systemic risk, that could have major consequences. -/- So you have to look very carefully at how you make that risk manageable."	System risks related to scale		

Table 12 – Risk management

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... I think the most complicated thing is affordability. And then in a time when construction prices are rising so fast, this is being put under so much pressure..."	Financial challenges	Affordability	Risk management
"... we just don't have enough insight into that yet, what the risks are with regard to what comes out of the factory."	Expected risks related to industrialised produced timber elements	Producing in the factory	
"... what you don't want is that people who will soon be living there, whether buyers or tenants, become try-outs. Every form of innovation carries the risk of doing something new. That's quite exciting and if it doesn't work later what then. And you always look for the comfort and certainty towards your future residents, buyers, tenants that they can just live comfortably."	Safeguarding the end-goal when trying something new	Unknown results	
"...it's just a matter of deepening with good advisors to arrive at a good product."	Finding comfort at experienced co-makers		
"... it is immediately checked off. Great, we can do this. What else can we do? And, that's quite a dangerous one, because I see that in my team too, what else can we do? Then you forget just that you have to go through that process of innovation again. And that you actually need a few years of preparation to make it succeed."	Being careful with getting used to the success	Overconfidence	

Success factors when adopting

Table 13 – Success factors when adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"...I think above all that people should be curious and critical. Those are the two things you need. -/-And then you learn to go through the project itself, so to speak, and to touch every part, that's where you learn."	Importance of being curious and critical	Essential mindset of the (people in) the organization	Success factors when adopting
"A contractor must be intrinsically motivated, because otherwise it doesn't make much sense I think or it will be very difficult to make a success of it. -/- ...there is a lot of uncertainty surrounding that process, you have to embrace that and dare to step in."	Need for strong motivation to start With the innovation as organization		
"... you choose a path and when you make that choice then you have to go for it for the full 100% and not just for 50%, because then it will not work out."	Willingness to give all your effort to make the innovation succeed		
"Your own people, to what extent they embrace this is very important. So they say 'we don't understand this' or 'we don't feel like doing this' or 'we've never done this', so there has to be sufficient capacity or the desire to get this done."	Importance of enthusiastic employees in the adoption process	Getting your employees motivated and in the same direction	
"And I think that our interest for now mainly lies internally and that we get things very well organized. That all our employees who are involved are also very proud of it and happy with it."	Organizing the internal team structure		

Table 14 – Success factors when adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... as a developer and builder, we have also done that by not pursuing a maximum return on this project, but the goal, i.e. stating that the innovation had to succeed. With the willingness to settle for less."	Setting priorities in favour of the innovation	Choosing for quality instead of profit	Success factors when adopting
"...we see the long-term trend that we like to get into early on and not one of the last. And I think that keeps the business healthy. So it's not directly about just returns, because I think with all the risks associated with it and that the return is very disappointing."	Steering towards a healthy business		
"We already lift complete front and rear facades in flats and we have also done new constructions where we erect a steel frame and then put the entire facade against it. They then come out of the factory one after the other and then you go up very quickly."	Experience with prefabricated façade elements and steel constructions	Using past experiences	
"... in all types of projects that come along, we have built in different ways and have even built a school in timber, so we do have experience with building in timber and also in variants such as HSB. However, this project in CLT was new. We do take the technical experience with timber with us."	Experience with variants of timber constructions		
"We have done a lot of timber frame constructions, and also built a lot with facade-filling elements. We are also used to work with prefab steel constructions. So we were familiar with that, but not yet with timber constructions in this form"	Experience with timber framing and prefabricated façade elements		

Advantages when adopting

Table 15 – Advantages when adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"This project has now been nominated for the 2022 timber construction prize and we are very proud of that. I can't put an amount on that. -/- ... in fact just that the team is proud to have built it and that is also a return. No, I can't express it in euros, but I think it is invaluable, so the project is a great success in that respect -/- ... fortunately I have often met enthusiastic residents, but these people are the superlative."	Making the team and buyers proud and happy	Making all stakeholders proud of contributing in the innovation	Advantages when adopting
"... everyone who worked on it, all the subcontractors who have been there. Everyone is very proud."	Proud project partners after delivering project		
"It is very tangible. That is very practical, tangible as an innovation. I think that has also been one of the successes."	Tangible innovation leads to enthusiasm	Factors that make adopting easier	
"... for an average technician it is an interesting innovation, it is a bit sexier than other technical developments... -/- wood yes, everyone benefits from that. That makes it easy for us and people thought it's also nice to work on this innovation up to and including the employees on site. It even smells good, they said."	Employees getting enthusiastic about timber construction		
"... that's very cool if you manage to do that and it is such a large share in the impact you can make, it is of course relatively easy to get people on board. Because you can explain it and enthuse."	Making sustainable impact and enthuse		

Table 16 – Advantages when adopting

Raw data	1st order codes	2nd order themes	Aggregate dimensions
"... the Architect did say, well, then you have to have experience with wood construction, otherwise you really won't be selected by that client. Look, then it will be interesting, because then you can of course have a relevant reference project. And in that sense it is very useful from a commercial point of view."	Choosing for timber because of its benefit in tenders	(direct) Commercial benefits	Advantages when adopting
"... and then it also plays a commercial role. How can I convince the jury that this is better than what the competitor offers? Triggered by the fact that you will be assessed on sustainability. - ... you start looking for something to make a difference."	Convincing juries with the sustainable impact of timber construction		
"... we have realized that the market is changing and that the demand may be changing. And then you better sit in the front and know what's going on..."	Wanting to be involved early to have a good position in the new market	(indirect) Market position benefits	
"We now notice that in the entire process in which we are working, with our co-maker, you simply learn a lot about timber construction and the process. We didn't learn it in 2 days. That means that if another organization suddenly has to switch, we simply have a head start ..."	Be ahead of competitors in terms of knowledge and experience		
"There are actually two more reasons why we invested in this innovation: ... the first movers advantage that we as a developing construction company have gained on this project now offers us many opportunities -/- ... Secondly, we are also in a 'war for talent'. Many graduate students look at us as an interesting employer."	The first movers' advantage and positioning as interesting employer		

4.5 Pathways for adoption

4.5.1 Introduction

To be able to recognise certain typologies of pathways in practice, the three different case studies are analysed and consequently, pathways are described. For each of the organisations, a short description of the context is formulated to give an impression of the type of firm. Also their pathway to put industrialised timber construction into practice is described shortly and depicted in a diagram. This chapter aims at formulating an answer to the following question: What are typologies of pathways that can be used to put adoption of industrialised timber construction in practice?

4.5.2 Case 1

The first organisation that has been studied is a contractor from Noord-Holland. The firm has around 125 employees and had a 75 million turnover in the past year. The contractor is specialised in building educational buildings, housing and care facilities. These can be newly built projects but also renovation and transformation projects. Core values at this firm are reliability, quality and commitment. Their strategy to follow-up on these values is paying attention to people, embracing the power of new technology and showing respect and appreciation for nature. More specifically, projects are being taken care of from start to finish, residents and users are worked with carefully and the people feel a great responsibility for preserving the earth.

The process for this contractor started with an ‘interesting move’ from an employee, who switched from working for a corporation to working for an industrialised timber developing party. This person was part of the professional network of the director of the contractor, who got special attention for his career switch. Motivated by curiosity and a genuine interest in timber constructions, the director scheduled a meeting with this developing party to get to know each other. From this first orienting meeting, already the willingness to realise a project together in the future was expressed. Actually, there were already 3 projects ready to be developed and for which this developing party still needed a contractor. When the contractor indicated that they were interested in realising these projects, follow-up steps were quickly taken to shape the process.

It helped the speed of the process very much, that there already was a project in which the client and developer/Architect agreed upon building it in industrialised timber. Another important aspect was the experience of the developing party. This experience from realised projects was an important source of knowledge for the contractor.

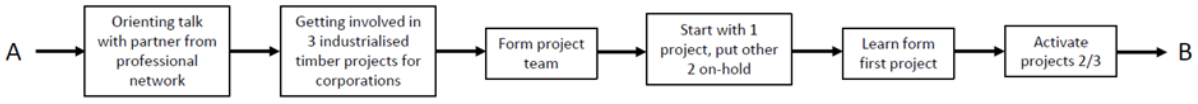


Figure 18: Pathway diagram case 1

Important in the initiating process was the trust and reliability of the participating parties. The director found a similar interest in the intrinsic motivation of all of the stakeholders and found comfort in the shared goal of realising a better project and bringing the ambition of building with industrialised timber a step further. Along the process, these shared objectives turned out to be of great importance since many obstacles had to be overcome while many of those challenges did not result in any more profit. In other words, all parties had to bring in some 'learning budget' while holding on to the same shared end-goal.

One of the things that needed to change was the contract management for the project. Compared to a traditional project, a much larger upfront investment was now required to pre-finance all modular units with the timber construction supplier. And where in traditional projects this purchase-risk lies with the contractor, the latter now found it too risky to be fully accountable for this great risk. In collaboration, the parties involved decided that the purchase of the timber modules would be the responsibility of the client and developer. The rest of the costs for building the construction would be the responsibility of the contractor.

Although all 3 projects were ready to be developed, the contractor chose to start with 1 and put the other 2 on-hold. This first project was seen as a learning project. Doing it this way, it was believed that some risks were spread and that the involved stakeholders could find their way into the process of realising an industrialised timber project.

The supply based pathway

When reflecting upon the five typical steps in the innovation adoption process, the figure below can be drawn from the innovation pathway as described above. This pathway can be described best as the 'supply based pathway'. The organisation already had a very positive attitude towards the innovation which led to a situation wherein the firm itself was seeking to innovate. The combination of an innovation seeking mindset and the strong intrinsic motivation of the decision maker made the organisation also willing to take some more risks.

4.5.3 Case 2

The second organisation that has been studied is a contractor from Gelderland. It has a size of around 140 employees and turned over 135 million euros last year. The main focus of this contractor is building in the sectors of housing, food, hightech, health, energy & environmental technology, care & wellbeing, education and sports & culture. On the website they state that they are sincerely involved and interested in their clients, cooperation partners and each other. What they do, they like to do well. Together with their construction partners. In a socially, ecologically and economically responsible manner. Understanding and mutual trust are important pillars in their vision. This company aims at creating something that is of lasting value.

For this case the municipality started by setting the requirements for this project with high aims when it comes to sustainability and quality of living. As a result, this contractor was stimulated to look for alternative ways of realising the project. They started looking into building with industrialised timber. At the same time, they were forming a project team with creative people around them which also stimulated thinking outside the box. Although there was almost no experience with industrialised timber in the Netherlands at the time (2018), everyone was excited to design the project this way.

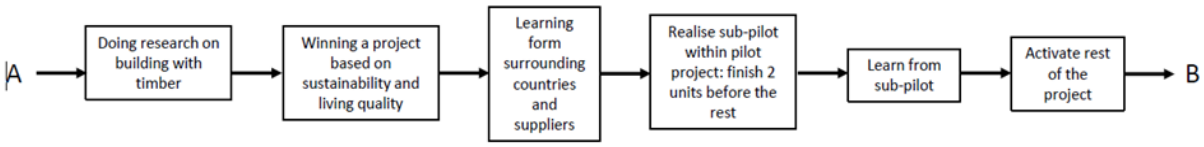


Figure 19: Pathway diagram case 2

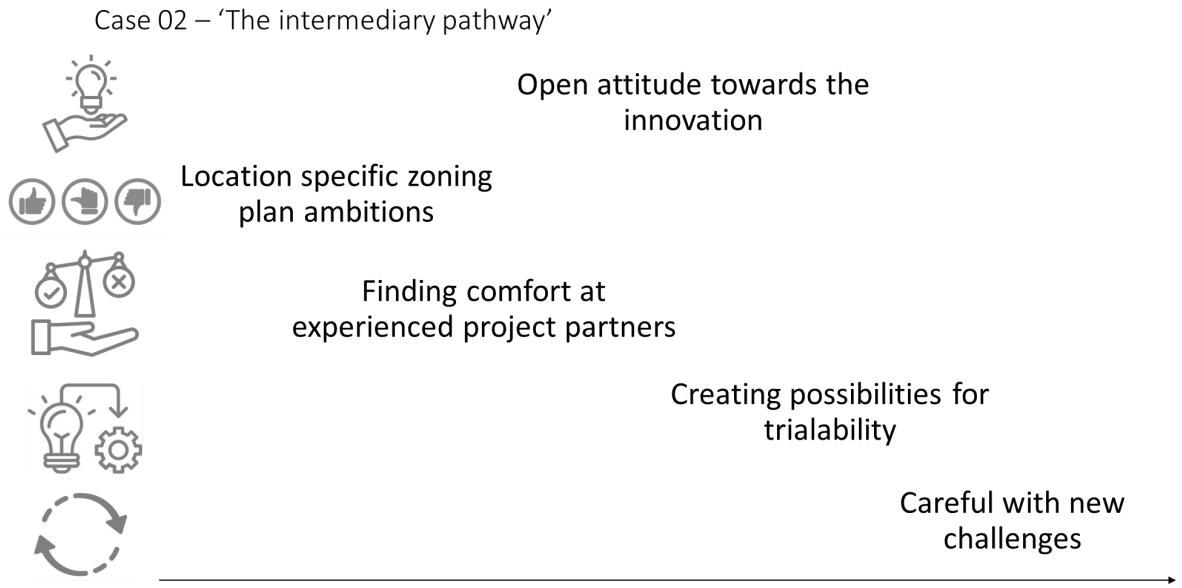
To find some comfort and to learn about building with industrialised timber, the contractor had to look in surrounding countries for experienced suppliers and builders. They found an experienced supplier in Germany and started working together.

What also was very important, was to be able to sell all the houses to be built since this was a private market housing project. At the time a lot of biases went around about living in a wooden house. In the process of finding a way to learn while at the same time convincing the potential buyers of the quality of wooden houses, they decided to forward 2 complete houses in the project schedule. This way, they were able to check if reality turned out the way they thought it would be and show the potential buyers the quality of the houses and take away the negative biases.

Another advantage for this contractor was that the developing party belongs to the same parent company, which makes the communication lines very short. Together they surrounded themselves with experienced advisors and engineers to help them realise the project.

The intermediary pathway

When looking at the five typical steps in the innovation process again, a difference can be noted from the previous pathway. What was critical in the adoption process in this second case, were the location specific zoning plan ambitions set by the municipality. Because of these predefined conditions to work with, the organisation came up with the idea to start building in industrialised timber construction. Because of the created context, originating from the local public entities, this pathway got the label ‘intermediary’. This pathway does not specifically fit into the demand- or supply driven, but is initiated by an intermediary institution. In this case the municipality.



4.5.4 Case 3

The third and final organisation that has been interviewed is a contractor from Overijssel. This organisation is a bit smaller than the two previously described organisations, but is a part of a bigger family business who is also active in other fields of expertise. The contracting part of the business employs around 50 people and has a turnover of 30 million euro in the last year. They have specialised themselves in commercial- and apartment buildings, retail and leisure, schools, distribution centres, offices, industrial halls, villas and monuments. One of their key values is thinking along with the client, being open, facilitating and acting fast. Characteristics of this firm are the enterprising and facilitating mindset. It is a family business that is open, thinks along, is decisive and can switch fast. Creativity and craftsmanship is what typically describes this family business in a nutshell.

The initiative for this company came about after a developer won a tender in which the ambitions were set on building with industrialised timber. Because of the already existing relation between the developer and the contractor, the latter was asked to realise the project. However, this contractor did not yet have relevant experience in this field of building. Consequently, wanting to realise this project could possibly bring many new challenges.

The enterprising mindset made the director of the firm decide to start with the project, although not having the experience in this field. The director believes in learning by doing and thus wanting to start without any practise. Experienced advisors and co-makers would help in the process and provide some comfort to deal with unexpected situations and/or setbacks.

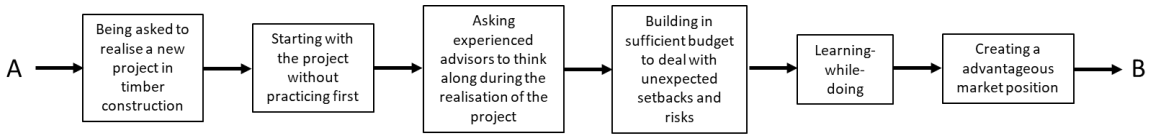


Figure 20: Pathway diagram case 3

The demand based pathway

When applying the five typical steps in the innovation adoption process, this case could be defined as the demand based pathway. In the figure below, a shift can be seen between the persuasion stage and the attitude and decision stage. Because of the ‘learning by doing’ mindset and the motivation to provide a service for the requested demand, there was no urge to be persuaded for the innovation or a need to be more familiar with the matter before making the decision to adopt.

Case 03 – ‘The demand based pathway’

Little motivation to increase sustainability

Providing a service, facilitating attitude

Demand for industrialised timber

Starting without practise, learning while doing

Making profit is important success factor

4.5.5 Cycle of innovation adoption in industrialised timber construction

The findings from the data analysis, together with analysing existing pathways formed a new model for adoption pathways when looking specifically at next adopters in the Dutch context. Below, a summary of the data analysis is shown in four summarising tables. Finally, all findings are brought together into a new cycle model which is the best representation of innovation adoption pathways for next adopters to adopt industrialised timber construction.

From the data analysis in this research, 8 aggregate dimensions can be identified that prove to be critical in the process of adopting industrialised timber construction. These dimensions are (1) identifying next adopters, (2) context of adopting, (3) role of network/partners in the adoption process, (4) learning processes, (5) challenges when adopting, (6) risk management, (7) critical success factors and finally, (8) advantages when adopting. Also, most striking findings from the interviews are pointed out in the analysis of the data such as the importance of the attitude of the adopter and the possibility to learn during the adoption process. Thereby, much of the analysed data corresponds with findings from previous studies.

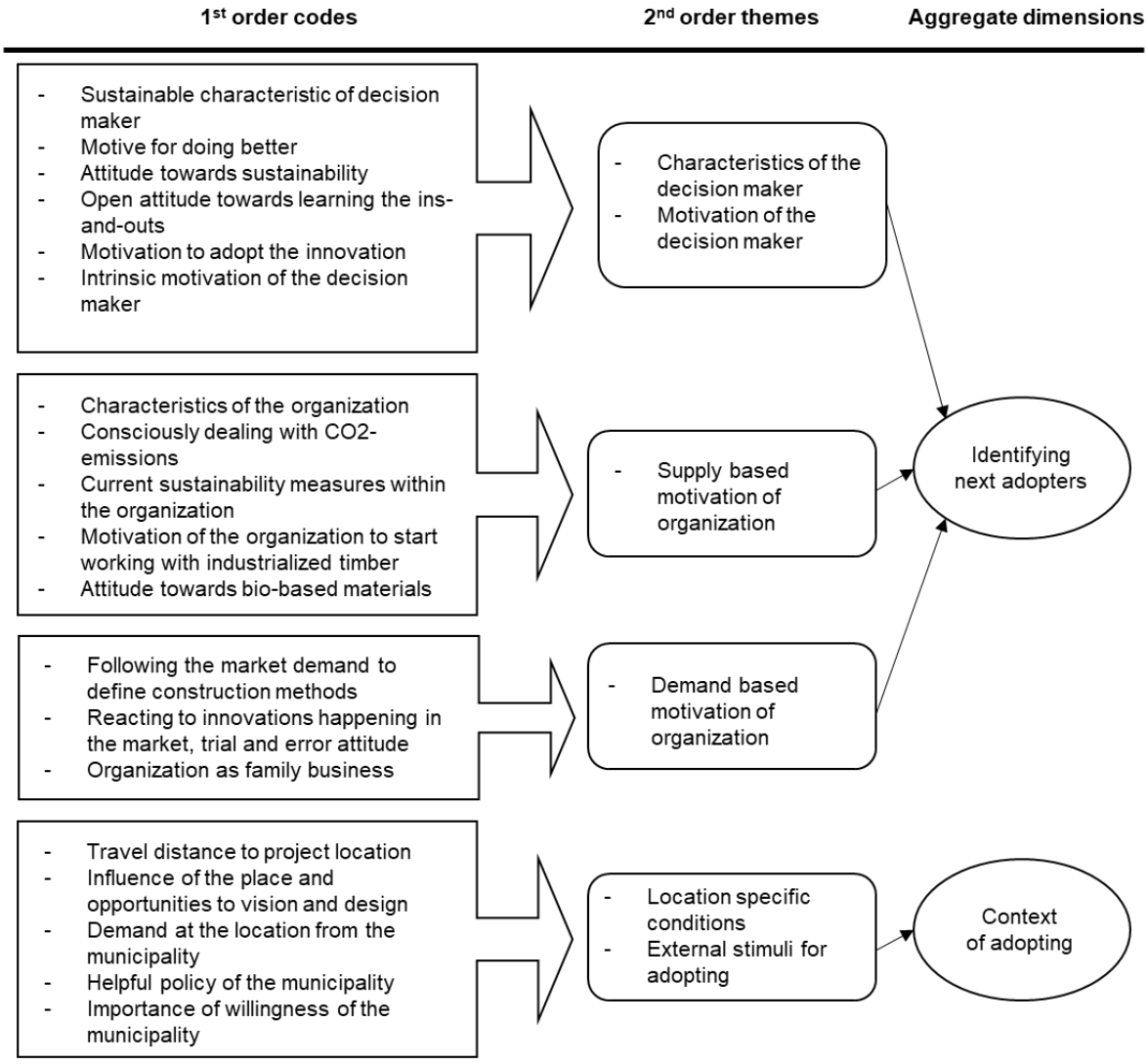


Figure 21: Data structure: identifying next adopters / context of adopting

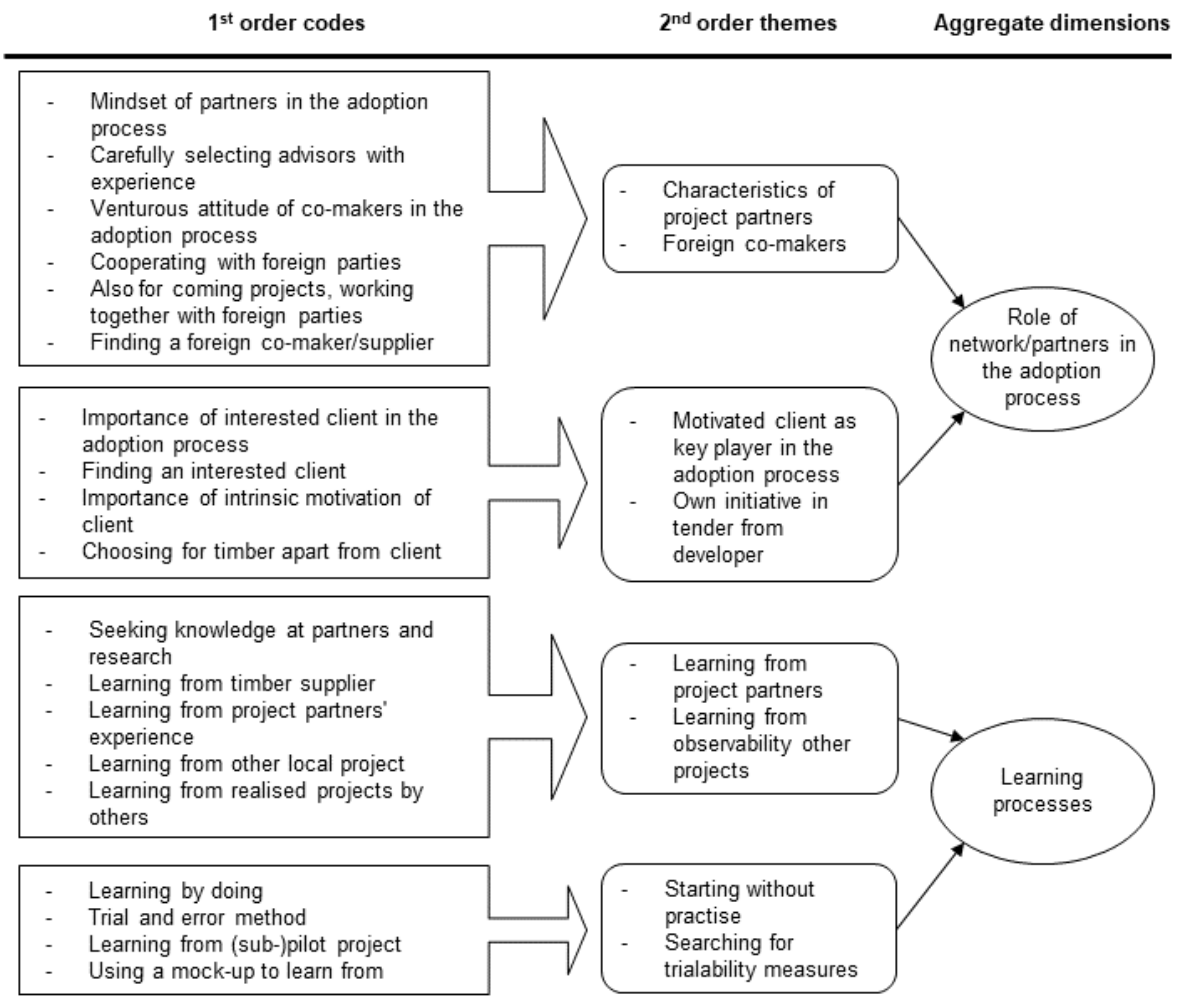


Figure 22: Data structure: Role of network/partners in the adoption process / Learning processes

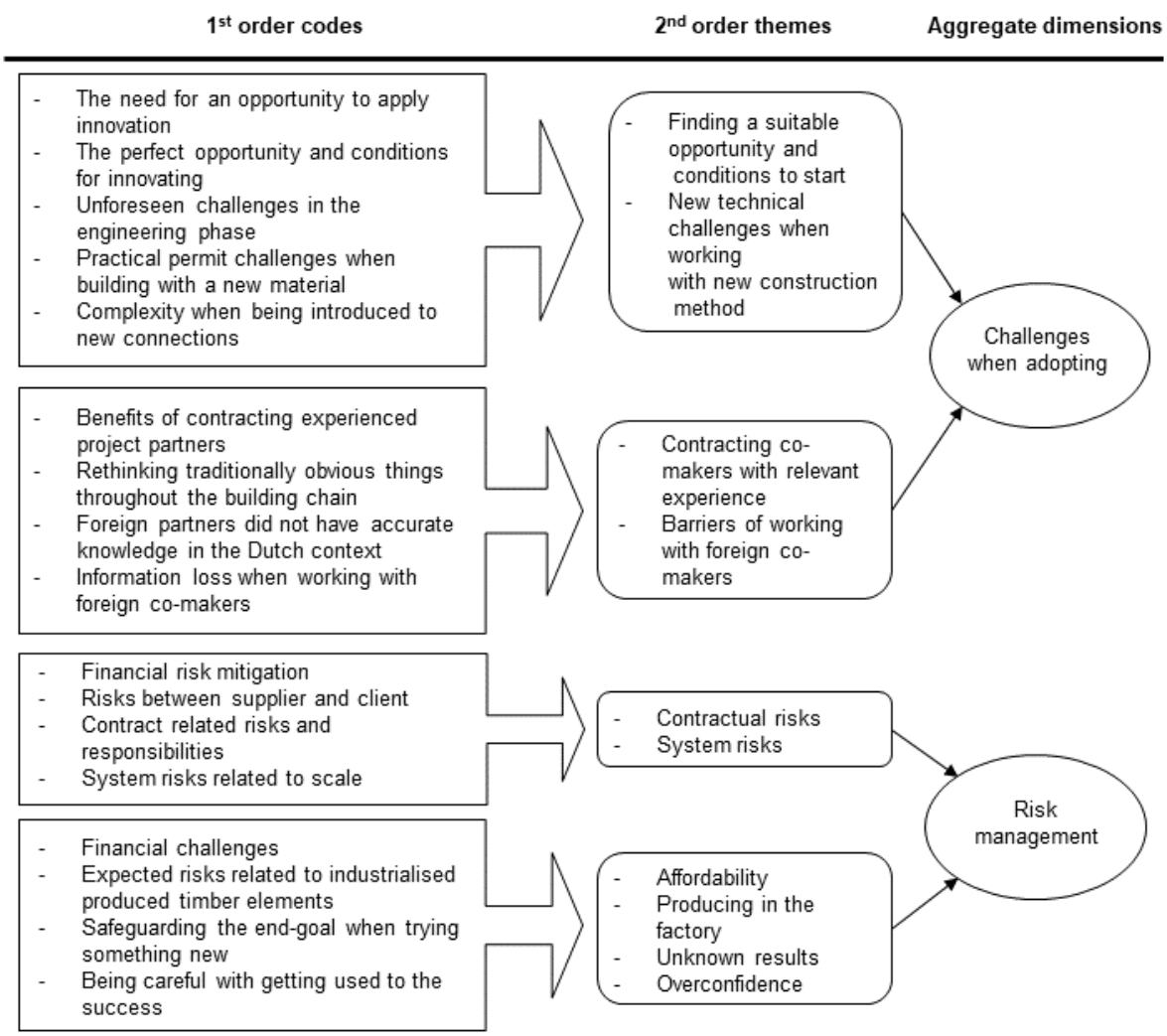


Figure 23: Data structure: Challenges when adopting / Risk management

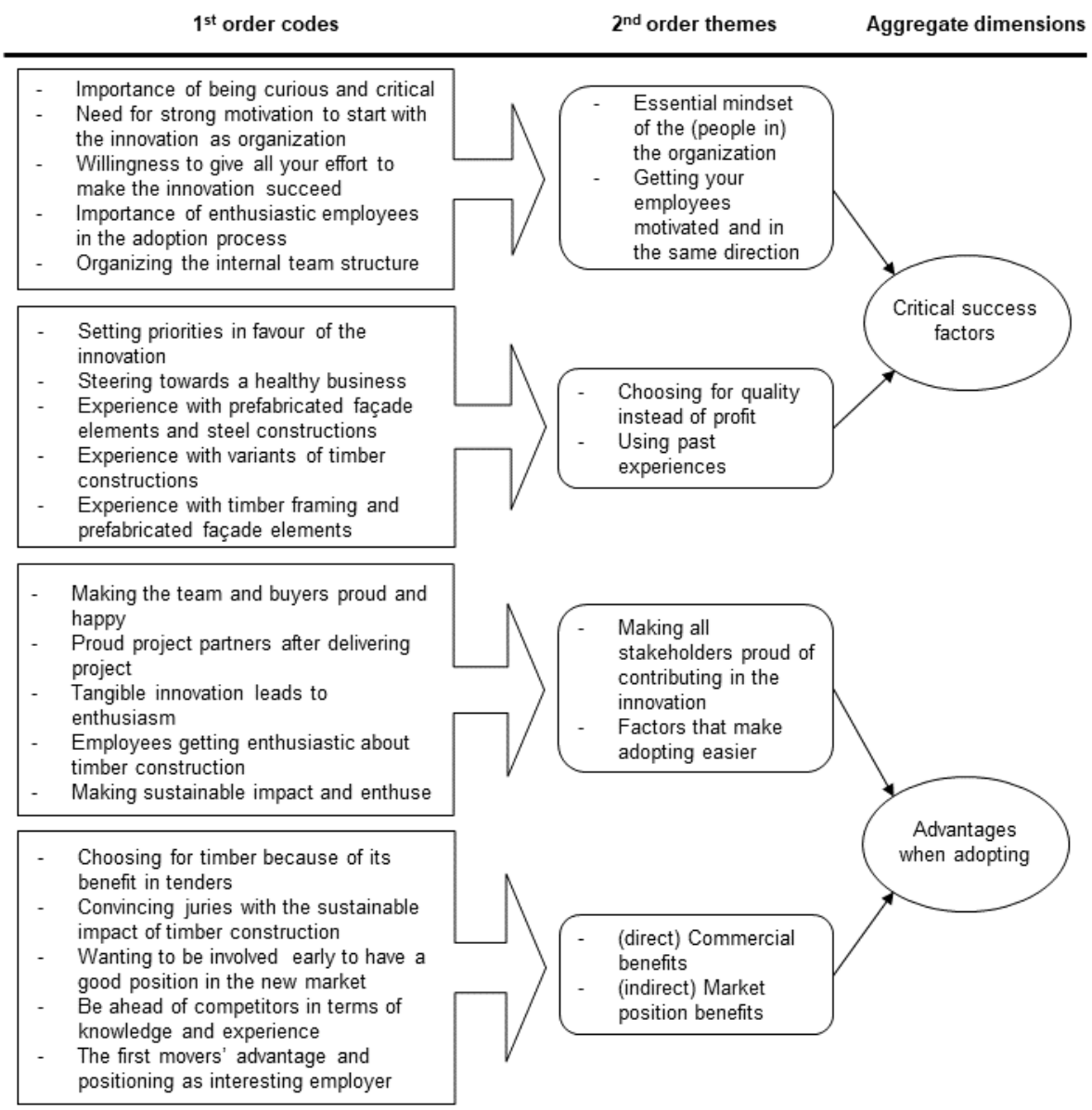


Figure 24: Data structure: critical success factors / Advantages when adopting

Model 'Cycle of innovation adoption in industrialised timber construction

The three different stories of the cases in this study show that the adoption process can not always be framed in the same linear steps that have been found in literature. Therefore, this research introduces the 'Cycle of innovation adoption in industrialised timber construction' model. In this model, the typical steps in the innovation adoption process are recognized, but they are placed in a circle and supplemented with the 8 aggregate dimensions found in the data analysis. These 8 dimensions show the different phases in which organisations can 'jump on' or 'jump off' the innovation adoption process.

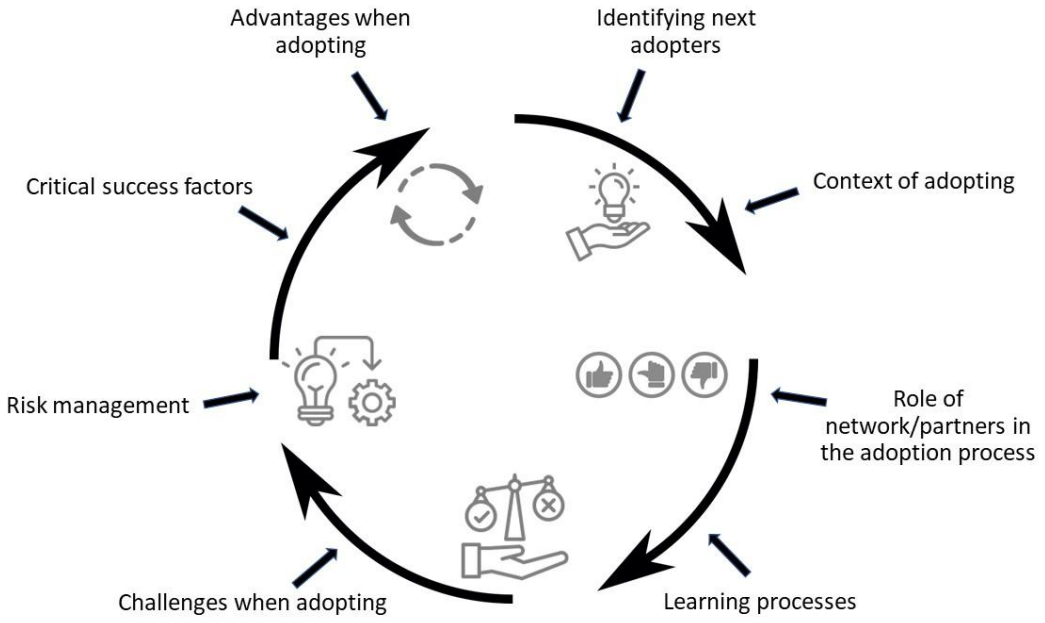


Figure 25: Cycle of innovation adoption in industrialised timber construction

5. Conclusion

5.1 Introduction

In this chapter it is attempted to formulate an answer to the main question. The main findings are formulated objectively and concisely. In the recommendations some concrete solutions to raised challenges are described and can be used at organisations to help find their way in adopting industrialised timber construction.

5.2 Answering the research question

In this research an attempt was made to find an answer to the main question of what are pathways for next adopters to adopt industrialised timber construction in Dutch practice?

Next adopters are defined in this research as main contractors that do not have the capacity, volume or interest to invest in an industrialised production facility for timber construction themselves, but participate in the early adoption of industrialised timber constructions by collaborating with other actors such as the ‘independent’ housing factories as described in the literature review. Thus, these contractors are bound by collaborations with other stakeholders in the process such as developers, architects, engineers and other co-makers. In the data analysis four themes appear to be leading when identifying these next adopters.

Adoption can be analysed from both the perspective of individuals as well as organisations. In this research, multiple different decision makers within three organisations are interviewed. From the data analysis in this research, 8 aggregate dimensions can be identified that prove to be critical in the process of adopting industrialised timber construction. These dimensions are (1) identifying next adopters, (2) context of adopting, (3) role of network/partners in the adoption process, (4) learning processes, (5) challenges when adopting, (6) risk management, (7) critical success factors and finally, (8) advantages when adopting. Also, most striking findings from the interviews are pointed out in the analysis of the data such as the importance of the attitude of the adopter and the possibility to learn during the adoption process. Thereby, much of the analysed data corresponds with findings from previous studies.

Between the different case studies, differences and similarities are described. As a result, three different pathways are identified and presented in this research. The three pathways differ per aggregate dimension, but also in timeframe and emphasis per stage.

For each of the case studies, their pathway of adopting is described using the above 8 dimensions. These pathways also have a relation to time and are based upon 5 stages in the innovation adoption process which are defined in previous studies and theories. These stages are: attitude, persuasion, decision, implementation and confirmation. However, these typical stages in the innovation adoption process have often been presented in a linear fashion, influenced by contextual input.

The three different stories of the cases in this study show that the adoption process can not always be framed in the same linear steps that have been found in literature. Therefore, this

research introduces the ‘Cycle of innovation adoption in industrialised timber construction’ model. In this model, the typical steps in the innovation adoption process are recognized, but they are placed in a circle and supplemented with the 8 aggregate dimensions found in the data analysis. These 8 dimensions show the different phases in which organisations can ‘jump on’ or ‘jump off’ the innovation adoption process.

The research thus showed that pathways for next adopters to adopt industrialised timber construction in a Dutch context can best be conceptualised by the cycle model of innovation adoption.

5.3 Recommendations

For organisations that can be identified as next adopters, this research introduces a cycle model of innovation adoption. Subsequently, organisations can use the model to recognise the five stages in an innovation adoption process and then define their specific steps to take. The model can provide structure in the process of adopting industrialised timber construction in Dutch practice and let organisations get a grip on its pathway.

It is important to notice that the starting point of a certain organisation in the innovation adoption process can differ from other organisations. For example, one organisation may start at the persuasion stage while another may start by making the decision immediately based on contextual factors. Also the follow-up steps in the process do not necessarily need to be in the same order as other next adopters. Organisations can ‘jump on’ or ‘jump off’ the cycle model of innovation adoption and in this way follow the continuous cycle according to their own preference.

6. Discussion and limitations

6.1 Introduction

In this chapter a reflection is made on the research method, data and conclusion. Also the position of the research in relation to society and academic debate is indicated. Furthermore, the discussions aim to compare the findings with previous studies and literature that formed the basis for this research.

6.2 Interpreting results

The research is based on two main constructs: (1) strategies for next adopters and (2) pathways for adoption. The first construct reflects on theories around strategic niche management, absorptive capacity and attributes of innovation. The second construct reflects theories around typologies of pathways and adoption pathways. These two constructs, together with the data obtained from the interviews, form the basis to answer the main question. It is thus of great importance to reflect upon these theories when interpreting the results.

From the data analysis in this research, 8 aggregate dimensions are identified that prove to be critical in the process of adopting industrialised timber construction. These dimensions are (1) identifying next adopters, (2) context of adopting, (3) role of network/partners in the adoption process, (4) learning processes, (5) challenges when adopting, (6) risk management, (7) critical success factors and finally, (8) advantages when adopting. Clear relations between literature and these findings can be recognised. In the paragraphs below some of these linkages will be elaborated.

Context of adopting in relation to Rogers' compatibility

Rogers (1998) describes compatibility as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters". The more compatible an innovation is, the more likely it is that an organisation will adopt an innovation. A big factor in this consideration is uncertainty. An idea that is more compatible is less uncertain to the potential adopter. An innovation can be compatible or incompatible on three different levels: (1) sociocultural values and beliefs, (2) previously introduced ideas or (3) with client needs for innovations (Rogers, 1998).

In the construction sector, values and beliefs are traditionally very rigid and hard to change. As already found in the literature review, past research (e.g. Gosselin et al. (2019)) indicates that a cultural mindset switch is needed if timber used as a structural material is to become more popular. From the interviews a switch in cultural mindset can clearly be recognised. Most informants are convinced that a future lies for the application of industrialised timber. This innovative mindset is best noticeable in the supply based pathway. Here the informants were really convinced of adopting the innovation from their own personal beliefs. On the other hand, the demand based pathway is less innovation seeking and adopts based on other drivers.

For example the existing values and past experiences of the informants were mentioned as critical factors in the decision to adopt. If the values and experiences of individuals are in line with the innovation, the adoption process will be more smoothly and implementation and confirmation of the innovation has a higher chance of succeeding.

From the data analysis the context of adopting appears to be an important factor in the innovation adoption process. In the data, both location specific conditions as well as external stimuli to adopt are identified. Examples can be the (travel) distance to a project location or the influence of the place on the decision to adopt. Also the identity of an organisation is mentioned as an important factor. Eventually the people within an organisation are the ones who need to accept the innovation decision to make it a success.

Looking to a broader context in relation to SNM

When looking at the multi-level perspective as described in the literature review, the micro-level is formed by so-called niches. Schot and Geels (2008) define niches as spaces in which radical innovations are tried out, varied and developed further, while they are sheltered from the mainstream competition. Success factors in the creation of niches are vision formation, learning and network composition and formation (Mlecnik, 2014). Niche actors aim for their ideas to break through in existing regimes. In the built environment this is not easy since the existing regime is often stabilised and locked-in. This also relates to the values and beliefs described by Rogers (1998) which traditionally tend to be very rigid and hard to change.

When not only looking at internal values and beliefs in the search for compatibility, also the context external of the organisation should be taken into account. Transitions come about through interactions between processes at the niche-, regime- and landscape level. Especially in the intermediary pathway the landscape level provided a certain pressure on the regime by setting a context specifically suitable for the use of industrialised timber construction. Another striking example, apart from the data collected in this research, is the ambition from the municipality of Amsterdam to build a new 700 house neighbourhood constructed from bio-based materials. As a result of the ‘Green Deal covenant Houtbouw MRA’ the municipality of Amsterdam now wants to follow through on her promise to build 20 percent of the newly built housing in a bio-based manner.

The pressure of this ambition on the existing regime demands for new ways of thinking and innovative construction principles. This destabilisation of the regime creates a window of opportunity for the niche innovation of industrialised timber construction to jump in this gap. The result is that organisations are forced to shift from traditional constructions to bio-based alternatives. This shift creates opportunities for next adopters to adopt industrialised timber construction.

Challenges of adopting in relation to Rogers’ complexity

Rogers (1998) describes the attribute of complexity as “the degree to which an innovation is perceived as relatively difficult to understand and to use”. Some of the informants in this research mentioned the challenge in the adoption process to understand the matter and deal with lacking in-house knowledge. In all three cases, external parties such as Architects, engineers and co-makers proved to be very important in creating an environment in which

the contractors would feel comfortable enough to work with the innovation. This process is also recognised in the risk management of the informants. Having experienced co-makers assigned to the project is seen as a very important factor.

These new partnerships would also come with new challenges such as language barriers and contractual agreements. The first new challenge is due to the issue that most experienced partners in the industrialised timber construction projects come from countries abroad. New contractual forms were introduced when suppliers of prefabricated timber elements were contracted.

Linear versus cycle framework
The linear models about innovation adoption processes found in literature are mostly restricted to separate stages in a particular order. The continuous cycle framework introduced in this research allows organisations to ‘jump on’ or ‘jump off’ different stages in the cycle. The cycle framework is a result of analysing the adoption processes of the three case studies in this research. For each of these cases a different order of steps in the adoption process could be identified. The existing steps in the innovation adoption process found in literature formed the basis for the model en also where recognised in the case studies. Additionally, eight aggregate dimensions are added to the model that prove to be critical in the process of adopting industrialised timber construction.

The organisations that are analysed in this research can be categorised in three different pathways: (1) the supply based pathway, (2) the intermediary pathway and (3) the demand based pathway. The existing linear models from literature with its restricted and separate stages do not allow for these pathways to fit. Therefore, the continuous cycle framework is introduced which is more flexible and therefore also applicable in different cases and situations.

New, different, unexpected and surprising findings
What was surprising to notice during the research were the major differences between the case studies. When reading about innovation adoption, one might get the impression that this is a rather linear process while following certain fixed steps. However, in practice innovation adoption pathways seem to follow a variety of possibilities, where the different stages from literature can be recognised but not in the same order. Also, the emphasis on a certain stage in the innovation adoption process can differ much from one organisation to another.

A recurring aspect in the process of adopting industrialised timber at the studied organisations is the importance of its professional network and co-makers.

6.3 Research limitations

A limitation of this research is that in the verification of the findings, no time can be incorporated for peer reviewing the result and analysis of the data. This could result in the lone researcher bias, which means that the data is interpreted in a subjective way and not interpreted by another independent researcher.

Reflection

In this reflection I would like to look back on the past months of working on this thesis towards the current moment. Specific emphasis will be placed on the choice of method (how?) and the argumentation (why?) which were defined for the P2 moment. Moreover, an attempt will be made to answer the above questions and to what extent it did or did not work.

Defining an interesting research topic

Already in the beginning of the year 2022, I became interested in the topic around timber constructions and was reading up on articles and books around the matter. This became more specific when I decided to go for this theme for my thesis. After reading more in-depth articles about recent developments related to industrialised constructions and the potential of some of the innovative ideas to solve several problems in the construction industry, I knew for sure that this was going to be the topic for my graduation research.

After following the course Leadership and Strategic Management by Paul Chan, I also became interested in the topics and theories around change and innovations. Together with the growing interest in industrialised timber constructions, this resulted in a summary proposal for my research. After a first round of feedback, I noticed that this subject is also relevant at the TU Delft as a research subject and that it has great potential to look into. Soon I had contact with Paul about becoming my first mentor and also Erwin Mlecnik showed that he was interested in my research proposal, right from the start. This resulted in a relatively fast registration of my first and second mentor, which was good to know so early in the process.

Another reason, besides being just interested, for Paul to become my first mentor, is that the subject around industrialised timber construction and the related process of adopting innovation is categorised under the graduation chair Design and Construction Management. This domain addresses questions related to process control in the development and realisation phases of the construction of buildings. Specifically, the building process innovation is mentioned as an area of attention. Among other things, improved cooperation between parties to the building process is critical for innovation and therefore an important topic within the chair.

Working towards the first official moment: P1

When starting the literature review process, I discussed with Paul how I could best process all the sources and information. This resulted in an Excel document in which I systematically documented titles, authors, dates, short summaries and other important aspects, with the aim of building a comprehensive summary of the read information. Soon a lot of information was documented in this file. Besides, I put together a file folder for hard copies of the most relevant and interesting papers. I did this because of my preference to read texts on paper instead of only in a digital way. Also, having a printed version of the text enabled me to be creative with colours and comments in a flexible way.

Towards my P1 period Paul guided me along some critical thinking steps to define a proper problem statement: What is the issue? What do we know about this issue? and What do we not know about this issue?. Answering these questions forced me to think about building up

the argument in a systematic way. The structure of thinking can still be noted in my report. Also the Research Methods course helped me with this process of building up an argument and to make a start on thinking about the possible research methods to find an answer to the related main question.

The main feedback I received after presenting my P1 report, was that the review of previous studies had to be elaborated in more depth and documented in a more structured report. The P1 report was more an ‘information dump’ instead of a structured way of building up research. Also, a deeper analysis of the proposed target group, next adopters, had to be done to explain the characteristics of these different actors and also pin down more specifically on how the categories related to the choice of key actor(s) involved in the study. For the P2 report I made sure to elaborate on these subjects.

Finally ‘getting my hands dirty’ in practice

After the P1 presentation, I felt the urge to present my ideas and thoughts about the research topic to practitioners in the construction industry. The main goal was to get feedback on the content and to be directed to the latest developments that are accurate for the sector. To follow up on this, I scheduled meetings with two market parties who are currently developing industrialised timber construction concepts. These are companies that initiated and engineered an innovative industrialised timber construction design and fully developed this over the past couple of years. One of them already realised a handful of projects in the last two years.

Perhaps the most important result of the conversations was the connection with a contractor. This contractor did not have any experience with industrialised timber constructions, but was just contracted for their first timber project. Therefore I thought it would be interesting to interview the people who are involved in this project and analyse the process and strategy this organisation follows. As the next step, I scheduled a meeting with the operational director to introduce my research and discuss whether the case would be usable. This conversation turned out very interesting, and they told me that I could speak to as many people as I would like about this new and exciting project.

Meanwhile speaking with practitioners for my research topic, I was also able to practise my interview skills during the RM2 course. In our group of 3, we all had to execute 1 interview and process the transcription following certain steps. For the processing of the data we had to use the Atlas-TI software. This practising round was very useful, and showed how the interviews should be done for our own research.

Next to speaking with practitioners, I also visited some industrialised timber related public events. For example, I visited a symposium called “The Wooden Age” (in Dutch: De Houten Eeuw) in Pakhuis de Zwijger in Amsterdam. During this afternoon, I listened to several speakers and talked with other interested people about the latest developments around industrialised timber. Again, this led to some useful contacts.

P2 in sight

Towards my P2 presentation, I mainly focussed on the formulation of my research questions, the research method, main objectives and my research plan. Also, I dived deeper into the

relevant literature and sharpened my know-how especially on the topics I received feedback on after the P1 presentation. Furthermore, I came up with a conceptual framework and first concept of an interview protocol. Lastly, I put together a plan for the rest of the research taking into account the P3, P4 and P5 dates.

In my P2 presentation I explained how I was planning to execute my research and why this would be the best way to do it. In short, the method I chose was doing interviews based on my findings in literature. I aimed for qualitative interviews with a semi-structured nature. With this form of interviewing, I could build up on literature related to my key concepts while at the same time have the opportunity to ask follow-up questions and have a more open conversation. Speaking in jargon, combining both inductive and deductive methods. In total, the aim was to interview around 10 people.

Data collection time

A couple of weeks later, I finished my first 2 interviews. Both at the first contractor. I got the opportunity to speak with the operational director and main director about their experiences thus far related to the adoption of industrialised timber constructions. I had two very interesting conversations which lasted around 60 minutes each. I got the chance to ask the questions I prepared and the interviewees also had their opportunity to bring up topics they found important by themselves. This combination resulted in 2 good first interviews, on which I can build and improve towards the next ones.

Besides that I learned a lot by myself while executing these first two interviews, I also received feedback on my interview protocol and questions from my two mentors. The main points of feedback were: use easier words in my translation from English to Dutch, search for quantitative aspects you can question the interviewee, focus more on relationships/key partnerships, make the list of questions shorter because of time limits, ask open-ended questions and thus allowing the interviewees to tell their story in an uninterrupted fashion, also ask about disadvantages and finally, justify the sampling strategy. With both my own experience from these first two interviews and the feedback I received, I feel ready for the interviews to come.

In the following weeks I conducted the rest of the interviews. The reviewed interview protocol proved to be very effective and the data proved to be very useful. Processing all the data was a pitfall. Beforehand I did not expect this part to be so much work. In total I conducted 8 interviews. 2 people from the first company, and from both the second and third company I spoke to 3 people. This resulted in 8 conversations from around 60 minutes that needed to be transcribed and analysed. To analyse the data in a structured manner, I used the Atlas-Ti software.

Balancing between working-, private- and study time

The period between the P2 and P3 presentation was mainly focused on executing the interviews and processing the data. During the summer holiday, which was also in this period, I shifted my focus from working on the thesis to working for the contractor I work for myself. Looking back, this was not the most thoughtful decision. As the P3 date became closer and closer, I felt that I was short on time and that I could barely present enough results during the P3 presentation. However, I still was convinced enough to make up the

lost time and be ready for the P4 moment in time. Because of my own confidence, I also convinced my mentors to let me pass the P3 moment with a happy face.

Soon after the P3 moment, somewhere at the beginning of November, I realised despite my efforts, that I would not make it on time to be ready for P4. Processing the data was much more work than I had thought in advance and at the same time I was very busy with my work at the contractor. In addition, during this period I bought a house with my brother, which also required a lot of my attention while writing the thesis. The combination of these factors of studying, working and my private situation, caused me to not produce enough work to be ready for the P4. One week before the P4 deadline I let Paul and Erwin know that it would be better to postpone the presentation and use the time as a feedback moment. Luckily, both Paul and Erwin understood my situation and agreed on taking a bit more time for the thesis.

New year, new study time

The next possibility to schedule a P4 moment was April the next year, so we did. This made it possible to spend up to twelve new weeks extra on writing the thesis. The first weeks of this period, I used to finalise the data analysis. Although I already had a good start, it did not work out the way I wanted it to work. I got stuck. The first steps in the analysis, transcribing and coding the interview data, was going well. But after that, it was hard for me to decide on the following steps to work towards a result. Paul helped me out by introducing the so-called ‘Gioia method’. This structured method of analysing qualitative data proved to be very helpful in this process.

Now I could finally finish the data analysis and come up with usable input for writing up the results and conclusions. Ultimately, the goal of the thesis is to come up with adoption pathways for next adopters in the Dutch industrialised timber construction sector. So I needed to combine all my findings so far into a strong and concise end of the research. I am confident that I got it done and that I am now ready for the period 4 presentation. My expectations of the P4 moment are that the results for now are sufficiënt, but that there is also room for improvement. The last 5 weeks between P4 and P5 can then be used to process this feedback and make the overall research stronger.

The final countdown

On Wednesday 8th of March I presented my findings in the P4 presentation. The presentation went very well and I could convince the committee of my research process and the results. However, the report still needed some work because it was lacking the discussion chapter and some figures needed more explanation. Luckily my mentors were confident enough to award the presentation with a ‘go’ so that I could finalise the last missing bit in the coming 5 weeks towards the P5 moment.

As said, the main point of critique was the missing discussion chapter. This chapter is important because it makes the researcher reflect on its conclusion in relation to the literature review. Questions to ask yourself are for example: What was surprising? What was new? Did you gain new, interesting insights? And How did the final results differ from your expectations and/or earlier findings in literature? To make sure that I would process this feedback well enough and that this chapter would be completed on time, we scheduled a ‘catch-up’ meeting in 2 weeks from the presentation. In this meeting I would need to present

my main points for the discussion and have the possibility to gain some last feedback before handing in the final report.

During the meeting we discussed the input for the discussion and some other points of attention. The mentors gave some extra feedback and suggestions so that I could finalise the discussion chapter and give the overall report a quality boost. Deepening the analysis of the findings could help make the research more valuable and therefore better. In the end it would be great to be able to end my studying career with a nice grade instead of barely making it with a grade that is just enough.

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